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Rapid implementation of research and innovation solutions to accelerate economic diversification in Central and East Africa

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MAIN REPORT

Rapid Implementation of Research and Innovation Solutions to Accelerate Diversification and Green Economic Complexity in Central and East Africa

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Abbreviations

AfDB	African Development Bank
CAR	Central African Republic
CASTEP	China-Africa Science and Technology Partnership Programme
DRC	Democratic Republic of the Congo
ECA	Economic Commission for Africa
GDP	Gross Domestic Product
GTAP	Global Trade Analysis Project
ICE	Intergovernmental Committee of Senior Officials and Experts
ICT	Information and Communication Technologies
OECD	Organization for Economic Cooperation and Development
PCT	Patent Cooperation Treaty
PDIDE	Industrialization and Economic Diversification Plan
R&D	Research and Development
RTA	Regional Trade Agreement
SDGs	Sustainable Development Goals
SMEs	Small and Medium sized Enterprises
STEM	Science, technology, engineering, and mathematics
TRIPS	Trade-Related Aspects of Intellectual Property Rights
USPTO	United States Patent and Trademark Office
WBES	World Bank Enterprise Surveys
WTO	World Trade Organisation

Executive Summary

This report examines the important role of innovation in the process of economic diversification and sustainable growth in Central and East Africa, focusing particularly on the challenges and opportunities linked to industrialisation and the adoption of green technology. This document aims to propose practical strategies to strengthen innovation ecosystems in these regions, with a view to accelerating their economic development through innovation and technology.

Background and Objectives

Central and East Africa is facing major challenges linked to excessive dependence on limited economic sectors, particularly raw materials.
To respond to these challenges, this report is mainly aimed at:

- Analysing the various innovation ecosystems present in these regions;
- Identifying the factors that promote or hinder innovation;
- Proposing practical solutions to speed up the implementation of effective innovation systems tailored to local conditions.

The report forms part of the discussions at the third joint session of the Intergovernmental Committee of Senior Officials and Experts (ICE) for Central and East Africa, to be held in Yaounde, Cameroon, in October 2024. The theme of this session, '**Rapid implementation of research and innovation solutions to accelerate diversification and green economic complexity**', portrays the urge to adop innovative solutions to transform local economies.

Methodology

The analysis is based on a rigorous, multidimensional approach, derived from:

- Practical case studies to assess the performance of innovation ecosystems;
- Benchmarking against global innovation models;
- Consultations with local stakeholders, including governments, private companies and research institutions;
- Dynamic monitoring of developments in innovation ecosystems over a one-year period.

Key results

1. **Importance of innovation for economic diversification**

Innovation is essential for reducing dependence on raw materials, strengthening resilience to economic shocks and improving the competitiveness of African economies. Innovation also makes it possible to improve productivity and move up global value chains.

2. **Innovation challenges and gaps**

The current state of innovation in Central and East Africa reveals a number of challenges, including low investment in research and development (R&D), inadequate digital infrastructure, and a lack of coordination between economic and institutional actors. Meanwhile, there are opportunities to bridge these gaps through proactive public policies and strategic partnerships.

3. **Role of cross-border patents**

Cross-border patents play a key role in disseminating technological innovations. The report highlights the evolution of patents in Africa, underlining the importance of improving intellectual property protection and promoting exchanges between African regions.

4. **Survival of innovative companies**

Companies that invest in innovation are more likely to prosper in the long term. Support ecosystems and appropriate funding mechanisms are therefore needed to enable businesses to reap the full benefits of innovation.

Main recommendations

To strengthen innovation ecosystems in Central and East Africa, the following recommendations are suggested:

1. **Strengthening R&D capacities**

Increase investment in scientific and technological research, and promote collaboration between local and international research institutions.

2. **Improving intellectual property protection**

Put in place effective regulations to protect innovations and encourage their commercialisation on the African market.

3. **Encouraging regional and international collaboration**

Encourage partnerships between African countries to develop regional innovation hubs and take advantage of regional synergies.

4. **Developing STEM skills**

Invest in education and training in science, technology, engineering and mathematics (STEM), to equip the younger generation with the skills needed to participate fully in the innovation economy.

5. **Creating an environment conducive to innovative entrepreneurship**

Put in place regulatory frameworks and incentives to support start-ups and innovative SMEs. This recommendation is a logical extension of the work undertaken as part of the development of the Master Plan for Industrialisation and Economic Diversification (PDIDE), which advocates for the establishment of a regional centre for incubating entrepreneurs through the promotion of entrepreneurship 4.0 to insert start-ups run by young people and women leaders into the value chains of Central and East Africa.

6. **Promoting the adoption of green technologies**

Encouraging the adoption and adaptation of environmentally-friendly technologies to support sustainable and inclusive growth.

1. Introduction

1.1 Strategic context

The Intergovernmental Committee of Senior Officials and Experts (CIE) is the supervisory body for the activities of the Sub-Regional Offices (SRO) of the United Nations Economic Commission for Africa (ECA). It is a forum for exchange between experts from member states, regional economic communities and their specialised institutions, the private sector, researchers, civil society and other technical and financial partners. The ICE meets annually to define and monitor the implementation of the work programme of the SRO and to discuss the main issues and challenges related to the economic and social development of each sub-region with a view to formulating appropriate recommendations to address these issues.

The ECA Sub-Regional Offices for Central and East Africa will organise for the third consecutive year their joint session of the ICE (ICE2024) to be held from 15 to 18 October 2024, in Yaounde in the Republic of Cameroon under the theme '***Implementing Rapid Research and Innovation Solutions to Accelerate Economic Diversification and Complexity in Central and East Africa'.***

The choice of this theme stems from the work of the previous joint session of ICE, held in Bujumbura, Burundi, from 26 to 29 September, during which the experts from Central and East Africa recommended that the ECA reflect on issues linked to research and innovation by extending their scope in the process of industrialisation and economic diversification in Central and East Africa.

While new-generation industrialisation and economic diversification through the development of a Manufacturing 4.0 (PDIDE) sector is essential for building more resilient economies and thus sustaining the long-term development of Central and East Africa, it is just as important to adopt a determined and proactive policy for the appropriation and dissemination of new technologies that are useful to the industrialisation process. Product manufacturing processes, or technologies, on which competitiveness depends, are constantly evolving. Industries must constantly benefit from technological and other innovations, or risk disappearing.

Sustainable Development Goal (SDG) 9 of the United Nations 2030 Agenda, which is to 'Build a resilient infrastructure, promote inclusive and sustainable industrialisation, and foster innovation', addresses three important aspects of sustainable development: infrastructure, industrialisation and innovation. SDG 9 is one of the most crucial goals for supporting Central and East Africa in their ambition for development and rapid transformation, through increased production capacity thanks in particular to innovation.

This theme also finds its justification in the declaration of the Heads of State and Government of the African Union who, at the end of their extraordinary summit in April 1980 in Lagos, Nigeria, committed themselves in the Lagos Plan of Action to the promotion of science, technology and innovation at the service of the continent's development. More recently, in June 2014, they renewed their commitment by adopting the Ten-Year Strategy for Science, Technology and Innovation for Africa (STIS-2024), essentially calling on member states to take action to accelerate the transition to economies driven by innovation.

1.2 General context

Economic development in Central and East Africa is at a critical juncture. Despite relatively high rates of economic growth in recent decades, these regions continue to face major structural challenges that hamper their economic transformation and sustainable development. Over-dependence on raw materials, weak economic diversification and a lack of technological innovation are factors limiting the ability of these regions to generate inclusive and resilient growth.

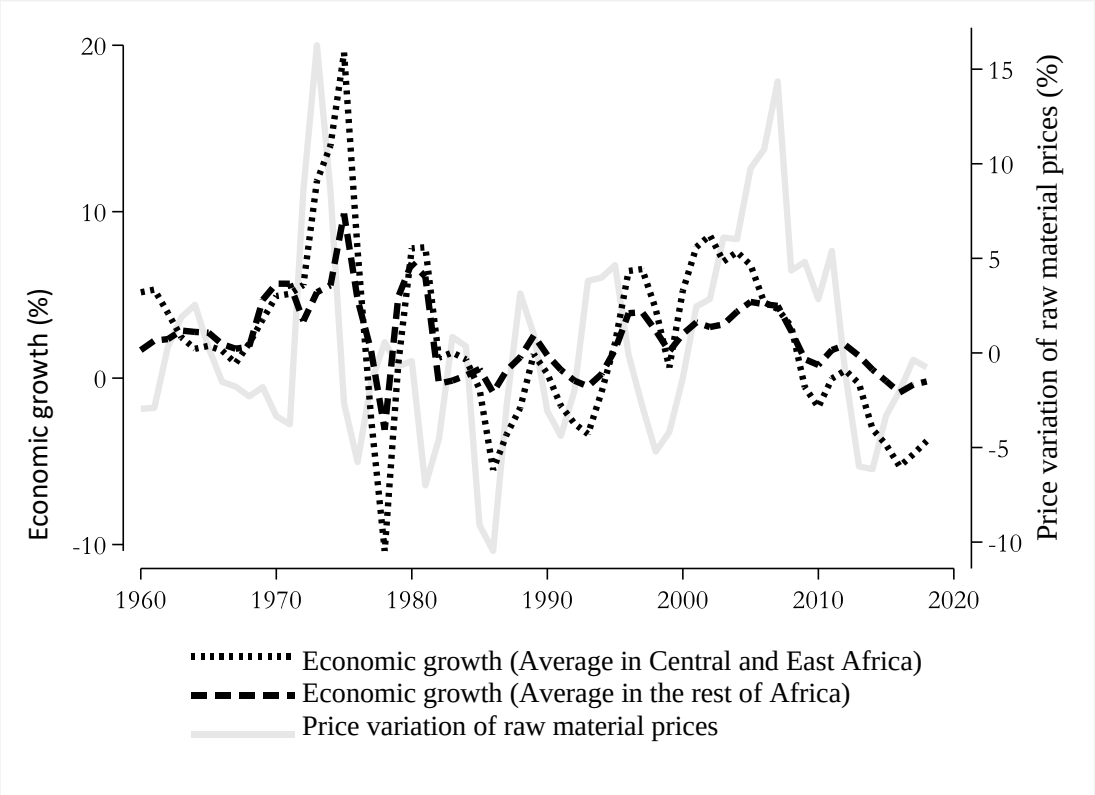
In this context, innovation and research are emerging as key levers for catalysing economic diversification and accelerating the transition to more complex and sustainable economies. However, the implementation of innovative solutions in Central and East Africa faces a number of obstacles, including inadequate infrastructure, low investment in research and development (R&D), and insufficient links between the academic world and the private sector.

1.2.1 Structural challenges and dependence on raw materials

One of the most striking economic features of Central and East Africa is their heavy dependence on raw materials exports. According to large number of literature, the most GDP growth in Africa is driven by price rise and increased demand for raw materials, as the economies of these countries are heavily dependent on the export of commodities. For example, Deaton (1999) has argued that rising prices contribute to economic development in Africa, because the economies of these countries do better when prices of raw materials rise than when they fall.

This dependence on raw materials represents major structural challenges for many Central and East African economies. It makes them vulnerable to price fluctuations on world markets, with a direct impact on their economic growth. Indeed, Graph 1-1 shows that growth is highly volatile, mainly due to dependence on fluctuations in the prices of raw materials. External challenges, such as the 1973 oil crisis and the 2008 financial crisis, have had a significant impact on growth. The 1973 oil crisis led to a sharp rise in raw materials prices (16.27%), which resulted in significant economic growth in East Central Africa (11.84%) and the other African regions (5.16%). However, the 2008 financial crisis had a negative impact on growth, particularly in Central and East Africa, where it fell from 4.15% in 2007 to 3.11% in 2008, then to -0.53% in 2009. In recent years, growth has slowed, with major declines in 2013 and 2014, due to the fall in raw materials prices, particularly oil. Central and East Africa have been particularly hard hit, with negative growth for several consecutive years (-3.07% in 2014, -4.00% in 2015, -5.30% in 2016). This underlines the importance of economic diversification in reducing vulnerability to raw materials price fluctuation.

Graphs-1.1: Economic growth and raw materials prices in Africa



Note: Data on economic growth and commodity prices are presented as three-year moving averages
Source: Authors' calculations based on data from the World Bank, World Development Indicators.

1.2.2 Productive capacity

The second determining factor is low productive capacity.[1]. First of all, it is clear that the aggregate productive capacity of Central and East African countries is significantly lower than that of benchmark countries such as the United States (69.24) and China (60.65). Most African countries in the region have scores below 40, with exceptions such as the Seychelles (51.58) and Djibouti (43.10). This significant disparity suggests a considerable gap in terms of capacity for economic and social transformation between these African regions and advanced or emerging economies. Analysis of data on the productive capacity of Central and East African countries reveals several key areas that require particular attention to promote economic diversification and innovation.

Information and Communication Technologies (ICTs) appear to be a vital area requiring urgent investment. Generally low ICT scores, with an average of around 27.5, indicate a strong need to improve digital infrastructure and technological skills training. The energy sector also presents significant challenges. Scores in this area vary widely, from 6.27 (Democratic Republic of the Congo) to 77.92 (Seychelles). This disparity highlights the significant

[1]UNCTAD has developed the Productive Capacity Index (PCI), a tool to measure the capacity of countries to achieve social and economic transformation, and also to monitor their progress towards sustainable development goals. The PCI is made up of eight indicators: natural capital, human capital, energy, institutions, structural change, information and communication technologies (ICTs), transport and the private sector (Table A1). It should be noted that the index rates productive capacity on a scale of 1 to 100. Thus, the analysis of the PCI and its indicators provides an overview of the progress made in each country, and also enables policies to be put in place to improve the worst-performing indicators.

challenges in terms of energy infrastructure in many countries in the region, which can hamper industrial and economic development. Human capital is another area requiring particular attention. Although scores range from 16.59 (Central African Republic) to 43.94 (Seychelles), many countries have relatively low human capital scores.

Institutions also play a fundamental role in creating an environment conducive to innovation and entrepreneurship. Scores range from 8.58 (Somalia) to 70.44 (Seychelles). Some countries, such as Rwanda (57.05), show significant progress in terms of governance and institutions, while others face major challenges in this area. The private sector and structural change are two other important areas to consider. Private sector scores are generally moderate, suggesting a need for policies to stimulate its development, given that a dynamic private sector is crucial for economic diversification and innovation. Similarly, structural change scores range from 10.43 (Chad) to 67.35 (Djibouti). This component reflects the capacity of countries to carry out economic transformations, and the varying scores indicate different levels of progress in this area. Finally, transport appears to be a critical area requiring improvement. Transport scores are highly likely to change, but generally low, ranging from 1.31 (Uganda) to 71.39 (Seychelles).

An analysis of the data on growth in productive capacity between 2021 and 2022 in Central and East Africa shows varying performances across sectors and countries (Table A2). In the energy sector, Burundi and Rwanda stand out with growth rates of 8.19% and 8.44% respectively, which are vital for economic diversification and industrial development. In terms of human capital, countries such as Somalia (4.36%), Central African Republic (3.92%) and Chad (3.60%) have made significant progress. In the ICTs field, Somalia (7.95%) and Central African Republic (4.19%) stood out, underlining the importance of these advances for innovation and global digital integration. Eritrea (3.32%) and Ethiopia (3.27%) performed well in strengthening institutions, which are essential for encouraging innovation and entrepreneurship. In terms of structural change, Seychelles (15.22%), Central African Republic (8.98%) and DRC (7.39%) showed significant growth, facilitating the transition to higher value-added activities. Finally, in the transport sector, Madagascar (3.31%) and Rwanda (2.71%) performed best, underlining the importance of infrastructure for trade and regional integration.

Table 1.1 Productive capacity in Central and East Africa

	Aggregate productive capacity	Energy	Human capital	ICT	Institutions	Natural capital	Private sector	Structural change	Transport
Angola	29.24	36.53	23.98	17.76	36.56	45.21	31.86	37.49	17:38
Burundi	24.82	8.78	28.72	14.94	25.30	69.80	35.79	22.74	26.56
Cameroon	26.77	27.53	29.62	32.19	31.35	38.63	33.20	42.50	5.87
Central African Republic	24.46	13:31	16:59	11.90	19.93	50.43	34.26	44.67	31.67
Chad	19:18	12:33	17.80	11.95	25.20	83.13	31.33	10:43	10:22
Comoros	37.03	44.62	32.87	24.99	31.32	49.91	46.88	23:34	56.45
Congo	28.47	22:45	26.81	19:32	27.58	44.34	32.21	36.14	26.09
Democratic Republic of the Congo	21.80	06:27	22:34	18.99	38.60	44.71	29.71	44.45	08:41
Djibouti	43.10	47.08	24.65	34.32	34.40	52.85	39.90	67.35	61.18
Equatorial Guinea	30.78	63.92	24.04	18:43	26.19	31.87	33.81	34.17	29.49

Eritrea	23.99	23.83	23:22	15:03	18:29	52.95	33.32	32.47	12:57
Ethiopia	30.54	21.74	27.22	21:07	35.38	46.38	37.66	38.69	25.39
Gabon	33.97	41.41	33.99	41.04	38.86	31.97	36.05	42.73	16:04
Kenya	37.79	30.59	35.16	35.93	43.42	44.13	44.24	49.03	25.92
Madagascar	28.98	23:41	26.99	18.91	37.28	57.52	28.20	38.51	17.88
Rwanda	37.12	25.39	37.31	28.06	57.05	51.38	40.28	45.40	25.27
São Tome - and - Principe	43.10	54.11	35.24	34.53	50.31	34.46	46.91	46.25	48.07
Seychelles	51.58	77.92	43.94	70.12	70.44	14:33	52.82	54.82	71.39
Somalia	21.86	19:26	19:10	19:30	08:58	62.32	27.99	33.64	14:59
South Sudan	23:30	31.57	22.62	09:47	10:30	51.31	20:53	32.85	36.00
Tanzania	31.86	22:13	27.81	29.93	43.93	43.51	39.81	43.20	17:54
Ouganda	21:39	15.93	27.19	21.97	41.12	54.46	34.30	45.69	01:31
Reference									
United States of America	69.24	78.07	81.61	79.23	79.56	26.69	90.69	94.90	57.27
China	60.65	69.74	63.94	66.16	50.81	39.83	81.22	98.97	38.17

Source: Authors' calculations based on UNCTAD data.

1.2.3 Emerging opportunities and dynamics

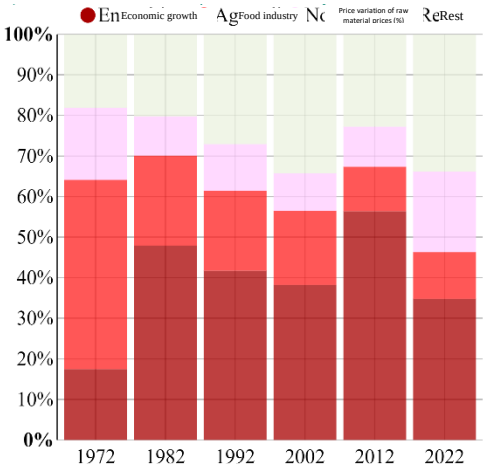
Trade dynamics in Sub-Saharan Africa, both intra- and extra-regional, have changed significantly between 1972 and 2022 (Chart 1-2). The data reveals key opportunities emerging from these trends, notably through the African Continental Free Trade Area (AfCFTA), which promises to reshape regional and global trade patterns. Indeed, the structure of intra-regional trade in Sub-Saharan Africa has diversified significantly, with marked growth in the energy, chemicals, steel and mechanical goods sectors, largely underpinned by industrialisation and infrastructure development. At the same time, extra-regional exports have also expanded, particularly in the energy, non-ferrous metals and agri-food sectors. These dynamics are set to change under the impetus of the AfCFTA, offering new opportunities to capture and amplify these trade flows.

Intra-regional trade offers opportunities for diversification. Intra-regional trade, historically dominated by energy products, has fluctuated between different sectors. For example, the energy sector grew strongly between 1972 and 2022, reflecting the growing importance of oil and gas in intra-African trade. Similarly, the chemicals sector has shown steady growth, underpinned by industrial demand for inputs such as fertilisers. These developments underline a growing opportunity for Sub-Saharan Africa to reduce its dependence on external markets for industrial and agricultural inputs. By removing tariff barriers and harmonising regulations between African countries, the AfCFTA is likely to accelerate intra-regional trade in these strategic sectors. The expected reduction in trade barriers will offer African countries the opportunity to consolidate their production capacities, particularly in the chemicals and steel sectors. The growth in mechanical goods trade, which increased gradually between 1972 and 2022, further underlines the potential of an enhanced industrial cooperation under the AfCFTA. The free movement of goods and services, combined with targeted investment, could transform regional value chains in the machinery and manufacturing sectors.

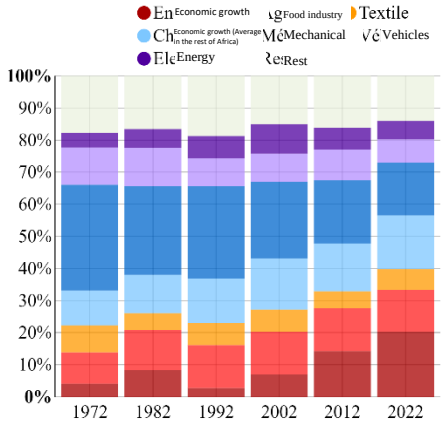
Extra-regional trade, on the other hand, makes it possible to tap into global demand. Trends in extra-regional trade in Sub-Saharan Africa show substantial growth in several sectors over the past five decades. Energy exports, for example, peaked at over $4.8 billion in 1982 before levelling off. Non-ferrous metals have also seen significant growth, particularly in the 2020s, with increasing global demand for raw materials. These sectors will continue to be key drivers of Africa's export earnings, particularly as global demand for energy and industrial inputs increases. However, extra-regional exports are also vulnerable to the volatility of global markets. For instance, energy exports have fluctuated in line with changes in world oil prices, and agri-food exports have suffered periodic declines due to external factors such as trade barriers or fluctuations in global food demand. This highlights the importance of diversifying trading partners and export products, a key objective of AfCFTA. By improving regional trade infrastructure and reducing Africa's dependence on external markets, AfCFTA could help protect African economies from external challenges in the global market.

Graph-2: Structure of exports and imports of goods in Sub-Saharan Africa

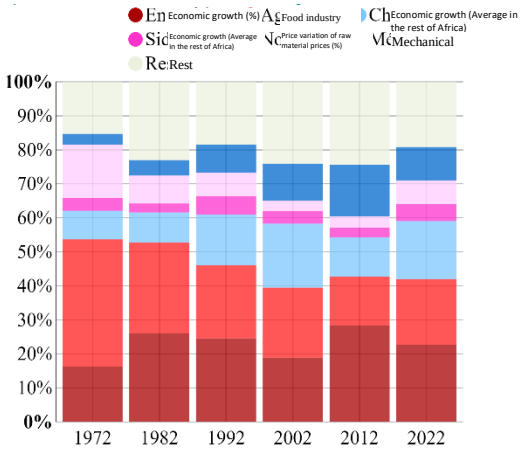
a. Extra-regional exports



b. Extra-regional imports



c. Intra-regional trade



Source: CEPII, CHELEM database - International trade

1.3 Objective and scope of the report

1.3.1 General objective

The main objective of this report is to carry out an in-depth analysis of innovation ecosystems in Central and East Africa, with a view to proposing concrete strategies for accelerating the establishment of high-performance innovation systems tailored to local and regional specificities. Specifically, the aim is to examine the factors that promote or hinder the emergence of these ecosystems, to identify best practices, and to put forward strategic recommendations for strengthening innovation through effective public policies, partnerships and technology dissemination mechanisms.

1.3.1 Scope of the report

The scope of the report is broken down into five key points:

1. Assessing of existing innovation systems and missing dimensions:
   - Identify and assess existing innovation systems in the target regions, while recognising the diversity of economic and social contexts.
   - Examine the missing dimensions in the structural transformation of African economies, in particular as regards the emergence of successful innovation systems in non-metropolitan regions.
2. Analysis of driving forces and innovation ecosystems:
   - Analyse the role of internal and external forces influencing African economies in an uncertain and competitive global environment.
   - Proposing solutions for innovation and the rapid dissemination of specific technologies within entrepreneurial and innovation ecosystems capable of supporting sustainable and rapid economic growth.
3. Enriching diagnostics and strategic recommendations:
   - Complement existing diagnostic analyses with practical case studies to guide African countries in developing effective innovation policies and strategies.
   - Explore ways of promoting local and regional ecosystems conducive to innovation, with a focus on the integration of knowledge, technologies and skills.
4. Evaluating infrastructures and support systems:
   - Assess the quality of the territorial anchoring of innovation clusters and institutional innovation support systems in the regions studied.
   - Examine the state of digital infrastructures and higher education and research establishments, and comparing them with exemplary innovation clusters worldwide.
5. Strengthening interactions and strategic partnerships:
   - Analyse the interactions between regional research and innovation systems, identifying ways of strengthening these links to stimulate local innovation.
   - Propose options for strategic partnerships to build successful regional innovation hubs, highlighting the importance of collective benefits and synergies through cooperation.

1.4 Methodology

A rigorous and multi-dimensional methodology underpins this report, providing a comprehensive and detailed analysis of innovation ecosystems in Central and East Africa. Given the complexity and diversity of innovation dynamics in these regions, a comprehensive approach is required to capture the many factors that influence the development of successful innovation systems. This section describes the main methodological steps followed in this study.

1. Comprehensive and multi-dimensional approach

The analysis covers a wide range of factors that influence innovation, from digital infrastructure to the quality of research institutions, as well as interactions between economic actors and policymakers. These different aspects require in-depth data collection and rigorous analysis that can only be carried out over a long period of time. This methodology aims to capture the complex reality of the innovation ecosystems under study.

2. Practical case studies and comparative analysis

The study includes an assessment of the performance of different innovation ecosystem models at the subregional level in Central and East Africa, as well as a comparison with global innovation systems. This comparative approach, enriched by practical case studies, involves fieldwork, stakeholder surveys and detailed analysis. These steps require a significant investment of time to ensure a detailed understanding of local specificities while taking into account international best practices.

3. Stakeholder consultations

The success of this study depends on close collaboration with various stakeholders, including subregional offices, local governments, research institutions, industry and entrepreneurs. Extensive and recurring consultations will be conducted to gather relevant data, validate hypotheses and refine recommendations. This process requires careful planning and constant monitoring to ensure stakeholder engagement and exploitable results.

4. Dynamic trends in innovation ecosystems

Innovation is an evolving and dynamic process. In order to fully understand drivers and barriers to innovation, it is necessary to incorporate a temporal perspective in order to track changes and emerging trends over time. The one-year duration is justified by the need to track these trends in order to produce a report that accurately reflects the changing realities of the analysed ecosystems.

5. Validation and adjustments

The preliminary findings and recommendations will be validated by stakeholders as well as regional and international experts and partners. This validation cycle, followed by adjustments and review of the recommendations, will take several months to ensure that the final report is both relevant and actionable. This phase is crucial to ensure that the recommendations meet the real needs of regional innovation ecosystems.

1.5 Organisation of the report

This report consists of five parts. These include the assessment of existing innovation systems and missing dimensions; the analysis of drivers and innovation ecosystems; the analysis and role of internal and external forces affecting African economies in an uncertain and competitive global environment; the search for solutions to innovation and the rapid dissemination of specific technologies in entrepreneurial and innovation ecosystems that can support sustainable and rapid economic growth; the assessment of the quality of the territorial framework of innovation clusters and institutional innovation support systems in the regions studied; the examination of the state of digital infrastructure and higher education and research institutions and their comparison with exemplary global innovation clusters; and strengthening strategic interactions and partnerships. Lastly, it proposes strategic partnership options for establishing successful regional innovation poles, emphasising the value of collective benefits and synergies gained through collaboration.

2.0 Innovation for economic diversification and sustainable growth in Africa

2.1 Introduction

Innovation has become a key driver of economic diversification and sustainable development in Africa. As the continent seeks to overcome its dependence on a narrow range of sectors and commodities, fostering innovation is key to ensuring stable, inclusive and environmentally sustainable growth. This chapter explores the multifaceted nature of innovation and its importance for Africa's economic transformation.

It begins by exploring different types of innovation relevant to the African context, such as product versus process innovation, catch-up versus breakthrough innovation, frugal and inclusive innovation, and sustainable innovation. These concepts provide a framework for understanding how innovation can respond to Africa's unique challenges and opportunities. The chapter then examines the theoretical underpinnings and empirical evidence linking innovation to economic diversification and development. It examines how innovation improves productivity, enables countries to move up global value chains and helps build more resilient economies. It also discusses the importance of tailoring innovation strategies to local contexts and the need for complementary policies to create the right environment for innovation to flourish.

2.2 What is innovation?

The Oslo Manual 2018 defines innovation as "a new or improved product or business process (or combination thereof) that differs significantly from the firm's previous products or business processes and that has been introduced to the market or put into use by the firm". This measurable definition provides a sound basis for analysis at the level of the firm.

Over the years, a rich typology has been developed to reflect the multifaceted nature of innovation. This chapter focuses on four key concepts that are particularly relevant to the African experience; namely:

1. **Product innovation versus process innovation:** Product innovation refers to an improvement in the performance of a product or the addition of new features, often visible to customers. Process innovation refers to an improvement in the way a product is made, which may involve changes throughout the value chain, but is often invisible to customers.

2. **Breakthrough innovation versus catch-up innovation:** The distinction between these two types of innovation is particularly important in developing countries. Breakthrough innovation is defined as the first application of a particular innovation in the world, whether radical or incremental. When advanced countries push back the frontiers of innovation, they improve global technology. Catch-up innovation is the first application of an existing innovation in a specific context, such as a particular country or firm. These catch-up innovations are crucial for improving productivity in developing African countries.

3. **Frugal, inclusive and bottom of the pyramid innovation:** Although they differ slightly in their definitions, these forms of innovation all refer to solutions that meet the needs of low-income populations. They can be high-tech, such as digital platforms that bring services to underserved communities, or low-tech, such as a clay refrigerator that keeps perishable food cool without electricity. They can be the outcome of efforts made by businesses, governments, NGOs or individuals.

4. **Sustainable innovation:** This concept involves considering the environmental, social and financial sustainability of an innovation from idea generation through R&D to commercialisation. Sustainable innovation from an environmental perspective includes techniques to reduce waste, use recycled materials and alternative energy sources, and reduce, reuse and sequester carbon dioxide. For example, jeepneys and tuk-tuks powered by electricity or liquefied petroleum gas which promote a cleaner environment and improve the quality of life of the poor, are examples of innovations that are both sustainable and inclusive.

In short, while there are many challenges, there are also many opportunities to boost innovation in Africa. With well-designed policies and strong stakeholder engagement, Africa has the potential not only to catch up but also to become a major player in sustainable innovation on a global scale.

2.3 Innovation and economic diversification and development in Africa: theory and empirical evidence

Innovation is crucial to raising productivity by making better use of the same inputs, producing more goods and services, higher wages, greater profitability and faster economic growth. Early research, building on the pioneering work of Solow (1956), concluded that long-term growth is driven primarily by technological change, which can be continuously renewed, rather than by labour and capital, which have declining marginal productivity. Two defining characteristics of technology are that its use by one firm or person does not limit its use by another, but it can be made exclusive by preventing unpaid access. This gives private firms a strong incentive to innovate. These two characteristics of new ideas generate higher returns as production scales up. This is what sustains long-term growth (Romer 1990).

To better understand the nature of technical change and how it evolves over time, growth accounting exercises were extended to include an innovation component and strong links between, for example, R&D capital and growth were identified (Griliches 1980a, Mansfield 1980). Endogenous growth models then took economic thinking a step further by including other representations of innovation, such as R&D investment by private firms, learning by doing, human capital and knowledge accumulation, and public infrastructure (Romer 1986 and 1990, Lucas 1988, Aghion and Howitt 1992, Barro 1990, Grossman and Helpman 1994). These models suggest that innovation within a firm and positive spillovers to the rest of the economy can lead to sustainable economic growth in the long run, and that these factors are generated by economic incentives within the system.

One strand of the literature has focused on the interaction between competition and innovation and the crucial role of private firms, with implications for a country's industrial and technological policy (Aghion et al. 2005; Aghion, Carlin and Schaffer 2002). The prescriptions

and debates arising from these models have helped to understand the growth trajectories observed in Japan, Germany and the United States from the 1950s onwards, and in Hong Kong, South Korea, Singapore and Taipei, China in the 1980s. These models have recently become relevant for China. The general pattern of innovation in Asian economies includes an initial phase of catch-up innovation, with the adoption of technologies to drive progress and growth, followed by a subsequent phase of growth driven by indigenous innovation (AfDB 2020).

However, research has shown that conventional assumptions and theories are far removed from the experiences of other developing countries, particularly in Africa, which are grappling with social and environmental issues and severe resource scarcity. This called for a reorientation of innovation models, driven by the needs of low-income and resource-sensitive consumers in developing countries, with a strong focus on inclusive and sustainable development. The consensus was that the world's poor have little hope of benefiting from innovation and its impact on growth if it is highly capital and energy intensive, requiring good infrastructure and other networks, skilled labour, abundant credit, and demand for complex products (Chataway, Hanlin and Kaplinsky 2014). Given the wide disparities in the needs and capacities of different economies, even within a region like Africa, one-size-fits-all policy prescriptions appear woefully inadequate.

As a result, the links between innovation, capacity building and development have emerged as a critical concern for African policymakers. Similarly, complementarity in the innovation process between markets and actors outside them, such as the public sector and non-governmental organisations, has become essential. Economic and other literature has explored alternative paths as research has reduced its emphasis on technological progress as the basis for growth. The existence of alternative pathways has challenged long-established models and overturned the belief that only advanced countries innovate. These pathways highlight strategies that integrate the strengths of developing countries to meet their needs. Alternative strategies innovate based on industrial dynamics specific to economies with abundant natural resources (Andersen, Marín and Simensen 2018), grassroots community action for inclusive and context-sensitive solutions (Seyfang and Smith 2007), or efforts to build capacity for technology adaptation, development and implementation, often through incremental and frugal innovations (Katz and Shapiro 1987; Wooldridge 2010). Incremental and frugal innovations used in the short term can be strengthened in the long term through institutional adjustments, targeted public investment and education (AfDB 2014; Calestous and Lee 2005).

In Africa, innovation also plays a critical role in economic diversification, a major challenge for the continent's economies, which are often dependent on a limited number of sectors or commodities. Economic diversification requires not only the adoption of new technologies and the creation of new sectors, but also innovation in existing business practices to increase their value added. This can include the development of more sophisticated agricultural value chains, the sustainable use of natural resources, and the promotion of emerging sectors such as information and communication technologies (ICT).

If Africa is to reap the full benefits of innovation for economic diversification and development, it will need to adopt policies that support education, strengthen institutions, facilitate access to finance and encourage collaboration between the public and private sectors. These policies must be adapted to local circumstances and aim to create an environment in which innovation can flourish, thereby contributing to more inclusive and sustainable economic growth.

2.4 Why is innovation important for Africa's diversification and economic development?

Innovation plays a critical role in Africa's economic and social development, especially in the context of economic diversification. While many African countries are still at a stage of development where innovation focuses mainly on the adoption and adaptation of existing technologies, the importance of innovation continues to grow as these economies move towards middle-income status and beyond.

2.4.1 Reducing economic volatility

Technological innovation allows African economies to diversify, thereby reducing their vulnerability to sectoral or input-specific shocks. More advanced and technologically diversified economies tend to achieve more stable growth rates, in contrast to less developed economies that are often subject to large fluctuations in growth rates. This stability is particularly important for Africa, where many countries are still heavily dependent on a limited number of sectors or commodities.

Innovation also has the potential to make growth more inclusive and greener. Faced with the challenges of inequality and environmental degradation, Africa can benefit from innovations that create affordable solutions for marginalised populations and improve infrastructure for a cleaner environment. Bottom of the pyramid innovations, for example, can provide low-cost solutions to the everyday challenges faced by the poorest people.

2.4.2 Improving productivity and moving up the value chain

Technological diversification through innovation can bring significant gains in productivity and growth. In key sectors such as agriculture, the introduction of new inputs such as high quality seeds, advanced irrigation systems and even digital technologies such as mobile phones can significantly increase productivity while reducing volatility. In addition, innovation enables African firms to adopt more sophisticated technologies, helping them to move up the global value chain, thereby increasing their productivity and competitiveness.

While innovation varies by level of development, new technologies, especially information and communication technologies (ICT), can accelerate economic catch-up in low-income countries. Africa can take advantage of its growing participation in global value chains, which are powerful channels for knowledge transfer, to accelerate its catching-up process and move towards the global technological frontier.

2.4.3 Building resilience to shocks and reducing dependency

Innovation strengthens the resilience of African economies by enabling them to better cope with shocks to specific inputs. For example, an economy that diversifies its energy sources or production methods will be less vulnerable to fluctuations in commodity prices or to disruptions caused by crises such as epidemics or political instability. Innovation can also help African countries reduce their dependence on a limited number of resources or sectors, as in the case of diversifying energy sources to reduce dependence on oil.

2.4.4 Improving business performance

Studies have shown that technological diversification is associated with better business performance in terms of sales and profitability. In Africa, therefore, innovation leading to technological diversification could strengthen the private sector and help to create jobs and improve living conditions.

2.5 Conclusion

Innovation lies at the heart of Africa's quest for economic diversification and sustainable development. By embracing different forms of innovation - from catch-up and frugal innovation to breakthrough innovation - African countries can address pressing socio-economic challenges while laying the foundations for long-term growth.

The evidence presented in this chapter highlights the critical role of innovation in reducing economic volatility, improving productivity and strengthening the resilience of African economies. Innovation not only allows countries to diversify their economic base, but also helps firms move up global value chains, promoting more stable and inclusive growth patterns.

3.0 Innovation and research landscape and development in Central and East Africa

3.1 Introduction

Innovation and R&D are key drivers of economic growth. However, the situation of innovation and R&D in Central and East Africa is complex, with challenges and opportunities. This chapter provides a global overview of the current state of innovation and R&D, focusing on regional disparities and the specific challenges faced by Central and East African countries in particular. It begins with an analysis of innovation gaps and innovation capacity between different African regions, while examining structural constraints to development, particularly in Central and East Africa. It then looks at R&D expenditure in Africa compared to global trends, highlighting the persistent underinvestment in R&D across much of the continent, but also highlighting countries that have made significant progress.

The analysis also examines the link between economic structure and innovation capacity, showing how commodity dependence limits technological diversification and participation in higher value-added activities. The chapter also examines key indicators of innovation capacity, such as the number of researchers, patent applications and scientific publications, which highlight the difficulties many countries face in transforming research into concrete economic results.

Lastly, it examines the role of public policy, showing how targeted policies, international partnerships and strategic investments in education and infrastructure can close innovation gaps and foster a more robust ecosystem on the continent.

3.2 Innovation gaps and capacity: challenges and opportunities

Innovation in Sub-Saharan Africa, even though promising, remains marked by significant disparities between regions, particularly in Central Africa, where structural challenges continue to hamper development. These disparities are reflected in indicators such as R&D expenditure, the capacity to generate patents and the adoption of advanced technologies. While these challenges persist, opportunities are emerging, notably through technological diversification, which can help economies grow by reducing their dependence on commodities and stimulating industrial innovation.

This section examines the innovation gap in Africa, highlighting the obstacles that need to be overcome to improve the innovation capacity. It also examines how the structure of the economy hinders or stimulates firms' ability to innovate, with a particular focus on technological diversification as a lever for development.

3.2.1 The current state of innovation in Africa: an R&D perspective

Innovation is a key driver of economic diversification, technological progress and development. It plays a key role in addressing global challenges such as poverty, health and environmental sustainability. In recent decades, Africa has emerged as a continent with immense potential for innovation, fuelled by a number of factors, including a growing population, increased access to digital technologies and a young, entrepreneurial workforce. However, despite these promising

trends, the continent still faces major challenges in terms of R&D expenditure, a key indicator of a country or region's commitment to fostering innovation (Graph 3-1).

Investment in R&D is often seen as the backbone of innovation ecosystems, enabling countries to generate new knowledge, develop cutting-edge technologies and improve productivity. It is also a key determinant of countries' competitiveness in the global economy. Between 2007 and 2020, global R&D spending increased steadily, with OECD member countries, East Asia and Pacific countries, and European and Central Asian countries leading the way. These countries invest heavily in R&D, often allocating more than 2 per cent of their gross domestic product (GDP) to research and innovation activities (Graph 3-1). In contrast, most African countries spend much less, with many allocating less than 0.5 per cent of their GDP to R&D. This disparity raises important questions about the current state of innovation in Africa and its ability to compete in an increasingly knowledge-based global economy.

Total R&D expenditure in Africa remains low compared to other regions, but this global figure masks significant differences between countries (Graph 3-2). For example, Rwanda, South Africa and Tunisia are among the few African countries that have made significant investments in R&D. South Africa, often regarded as a regional leader in innovation, allocated about 0.72 per cent of its GDP to R&D between 2010 and 2020. This is still below the global average, but well above many other African countries. For its part, Rwanda has made significant progress in technological innovation, particularly in information and communication technologies (ICT), largely thanks to the private sector. The country's R&D expenditure represented about 0.68 per cent of GDP over the same period, making it one of the largest R&D investors in Sub-Saharan Africa. Tunisia, with a long history of academic and scientific research, has also made significant investments in R&D, particularly in agriculture, pharmaceuticals and energy.

Despite these positive examples, the overall picture of R&D spending in Africa is still worrying. Many African countries, particularly in Sub-Saharan Africa, continue to struggle with low levels of investment in scientific research and innovation. The average R&D expenditure in Sub-Saharan Africa is less than 0.5 per cent of GDP, well below the 1 per cent target set by the Science, Technology and Innovation Strategy for Africa 2024 (STISA-2024). This underinvestment in R&D has a significant impact on the continent's ability to innovate, compete globally and address pressing challenges such as food security, health and climate change. In addition, the lack of adequate funding for research and innovation often exacerbates the brain drain, as talented African scientists and innovators seek better opportunities abroad.

Several factors contribute to the low level of R&D expenditure in Africa. One of the main challenges is the limited financial capacity of many African governments. Many countries on the continent face severe economic constraints, with limited budgets to allocate to pressing social needs such as health, education and infrastructure. As a result, R&D is often a lower priority in national budgets. In addition, the private sector in Africa has been relatively slow to invest in R&D compared to other regions. In developed economies, the private sector plays a crucial role in stimulating innovation through significant investment in research and commercialisation of new technologies. In Africa, however, many firms, especially small and medium-sized enterprises (SMEs), lack the financial resources and incentives to invest in R&D.

Another key factor is the lack of a robust innovation ecosystem in many African countries. Although there are pockets of innovation, particularly in countries such as South Africa, Kenya and Nigeria, many African countries lack the infrastructure, institutions and policies needed to support sustainable innovation. For example, universities and research institutions in many

African countries are often underfunded and lack the resources to conduct cutting-edge research. In addition, there is often a disconnect between academia, industry and government, which hinders the commercialisation of research and the development of new technologies.

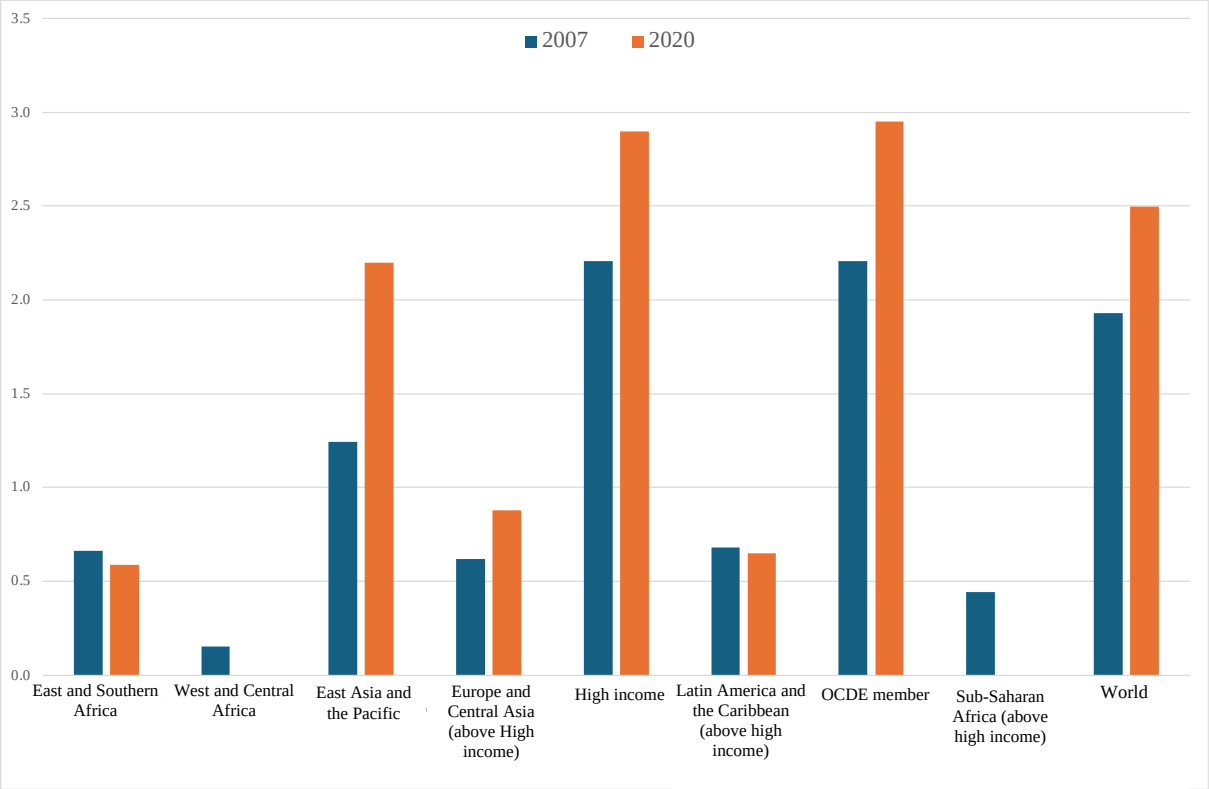
However, there are reasons for optimism. Over the past decade, several African countries have taken steps to improve their innovation ecosystems and increase R&D spending. The establishment of innovation centres and incubators in countries such as Kenya, Nigeria and Ghana has provided a platform for start-ups and entrepreneurs to develop new technologies and bring them to market. In addition, international organisations and development agencies are increasingly involved in supporting R&D initiatives in Africa. For example, the World Bank (2021) has launched several programmes to promote innovation and increase R&D spending in Africa, including the African Centres of Excellence (ACE) programme, which supports research and innovation in higher education institutions across the continent.

African governments are also increasingly recognising the importance of innovation for economic development. Several countries have developed national innovation strategies and reaffirmed their commitment to investing in R&D. Rwanda, for example, has actively positioned itself as a hub for technological innovation in Africa with initiatives such as the Kigali Innovation City which aims to attract investment in technology and research. Similarly, Ethiopia has invested heavily in science and technology education, recognising the importance of building a skilled workforce to drive innovation.

International partnerships have also played a crucial role in promoting the development of innovation in Africa. The African Union's Agenda 2063 explicitly highlights the importance of science, technology and innovation as key pillars in achieving the continent's long-term development goals. In addition, partnerships with countries such as China, India and the European Union have enabled African countries to access funding, technology and expertise to support their innovation efforts. For example, the China-Africa Science and Technology Partnership Programme (CASTEP) has facilitated collaboration between African and Chinese researchers, particularly in areas such as agriculture, health and renewable energy.

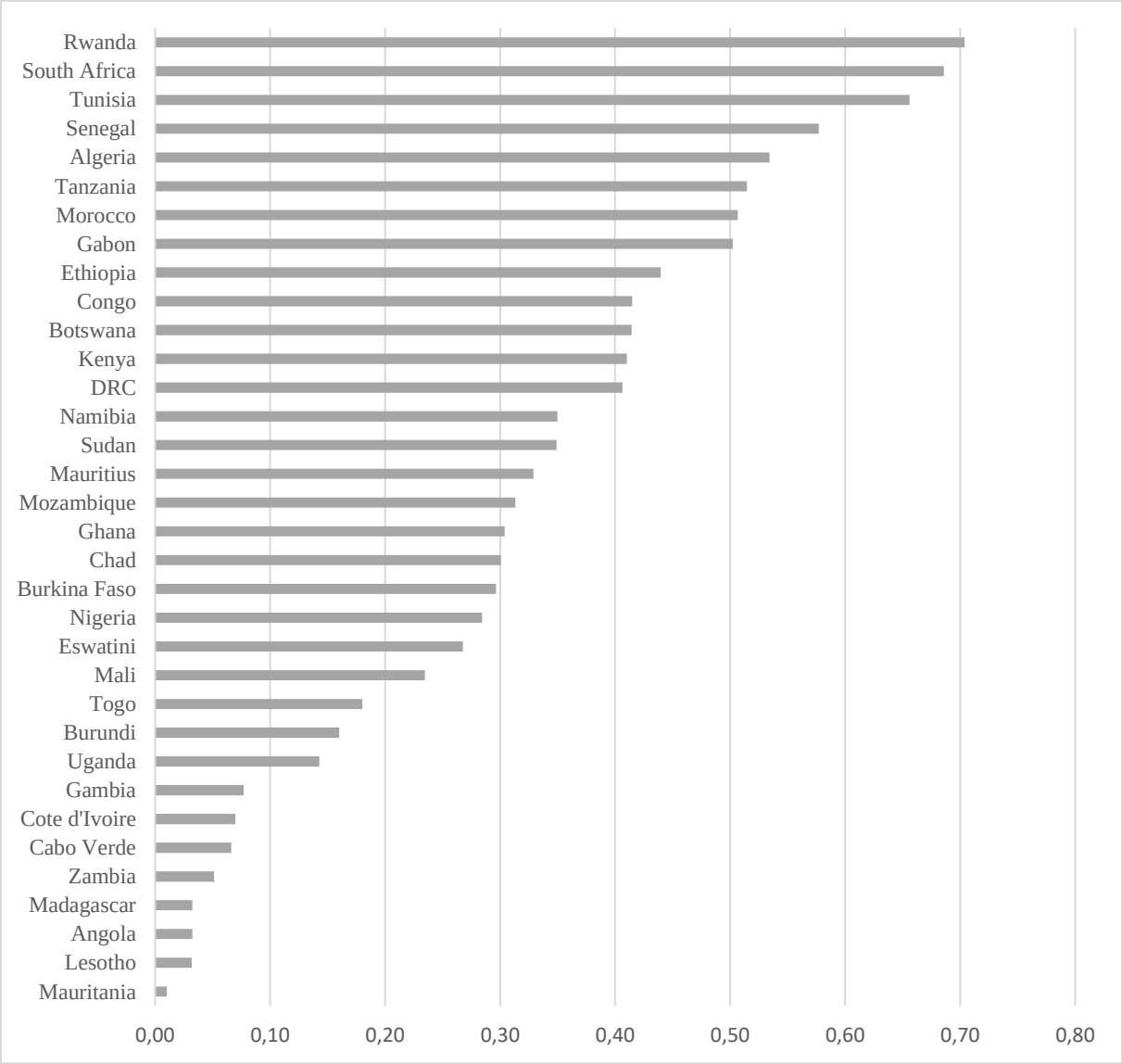
Graph Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**-3: R&D expenditure as a**

percentage of GDP by region in 2007 and 2020



Source: Authors' calculations based on World Bank data and World Development Indicators.

Graph Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**-4: R&D expenditure as a percentage of GDP in selected economies, 2010-2020 (average)**



Source: Authors' calculations based on World Bank data and World Development Indicators.

3.2.2 Innovation gaps and challenges

Despite encouraging progress in some parts of Africa, significant gaps remain, especially in Central Africa. These gaps are reflected in inputs such as R&D expenditure and the number of researchers and outputs such as patents and scientific publications. These indicators are essential for assessing a region's capacity to innovate and translate research into tangible economic results. Against this backdrop, Central Africa faces significant but not insurmountable challenges in closing these gaps and strengthening its role in the global innovation landscape.

One of the key indicators of a region's capacity to innovate is the number of R&D researchers per million inhabitants. According to the data in Graph 3-3a, Central Africa has achieved a modest improvement in this area, but it still lags far behind advanced economies and even some other African regions such as East Africa. However, the number of R&D technicians is slowly declining (Graph 3-3b). This situation partly reflects the challenges of training and retaining

talent in the region. One of the main obstacles to innovation in Central Africa is the brain drain, with many qualified researchers and technicians leaving the region in search of better career opportunities abroad. This situation is exacerbated by insufficient investment in research infrastructure, which limits the capacity of local institutions to generate significant innovation.

Another key indicator is the number of patents filed which is often seen as a direct reflection of a region's ability to transform research into marketable innovations. According to the data in Graph 3-3c, the number of patents filed by nationals in Central Africa remains very low, suggesting difficulties in translating research results into patentable innovations. Conversely, the number of patents filed by foreigners in the region is significantly higher and increasing slightly. This suggests that Central Africa is attracting foreign innovators, probably because of international cooperation or specific economic opportunities, but it also highlights the lack of local capacity to generate and protect innovations specific to the region. This situation underlines the need for Central Africa to strengthen its intellectual property capacity and provide greater support for local innovation.

In terms of scientific publications, Central Africa is also showing signs of progress, although this is still slow compared to other African regions such as East Africa. Graph 3-3e shows a slight increase in the number of articles published in scientific and technical journals, but this progress is still insufficient to be truly competitive at the regional level. Scientific publications are an important indicator of knowledge production, and weakness in this area may limit Central Africa's impact in academic debates and in developing innovative solutions to local and global challenges. It is therefore crucial that the region invests more in academic research and in improving the quality and quantity of scientific publications.

In addition, the volatility and low level of net royalties on intellectual property highlights another major difficulty, namely the monetisation of innovation. While some innovations do occur, they are often not effectively commercialised, limiting their economic impact (Graph 3-3f). This situation reflects the weakness of technology transfer and research commercialisation mechanisms in Central Africa compared to East Africa. To close this gap, it is important to develop policies and infrastructure that facilitate the commercialisation of innovations, especially by strengthening links between universities, research centres and private firms.

In conclusion, although Central Africa has made progress in terms of innovation, significant gaps remain in comparison with advanced economies and even with other African regions. Measured by key indicators such as R&D expenditure, number of researchers, patents and scientific publications, these gaps highlight the challenges that need to be overcome to strengthen the region's innovation capacity. However, with robust policies, targeted investments and better coordination among stakeholders, Central Africa can hope to close these gaps and play a greater role in the global innovation economy.

Table Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**-1: Innovation gaps measured by other indicators**

	Central Africa		East Africa		West Africa	
	2000-2015	2016-2022	2000-2015	2016-2022	2000-2015	2016-2022
Articles in scientific and technical journals	125.76	335.92	393.40	1305.72	1689.33	4013.08
Patent applications, foreigners	3.00	80.09	40.99	32.83	560.52	332.59
Patent applications, nationals		52.67	44.23	110.53	20.35	219.25
R&D researchers (per million population)	21.86	93.50	34.34	70.99	91.79	33.79
R&D technicians (per million population)	21.08	8.31	42.03	15.18	38.15	56.30
Net royalties for the use of intellectual property (BoP, current USD millions)	-4.62	3.79	5.06	10.21	114.80	190.07

Source: Authors' calculations based on World Bank data and World Development Indicators.

3.3 Innovation capacity and economic structure

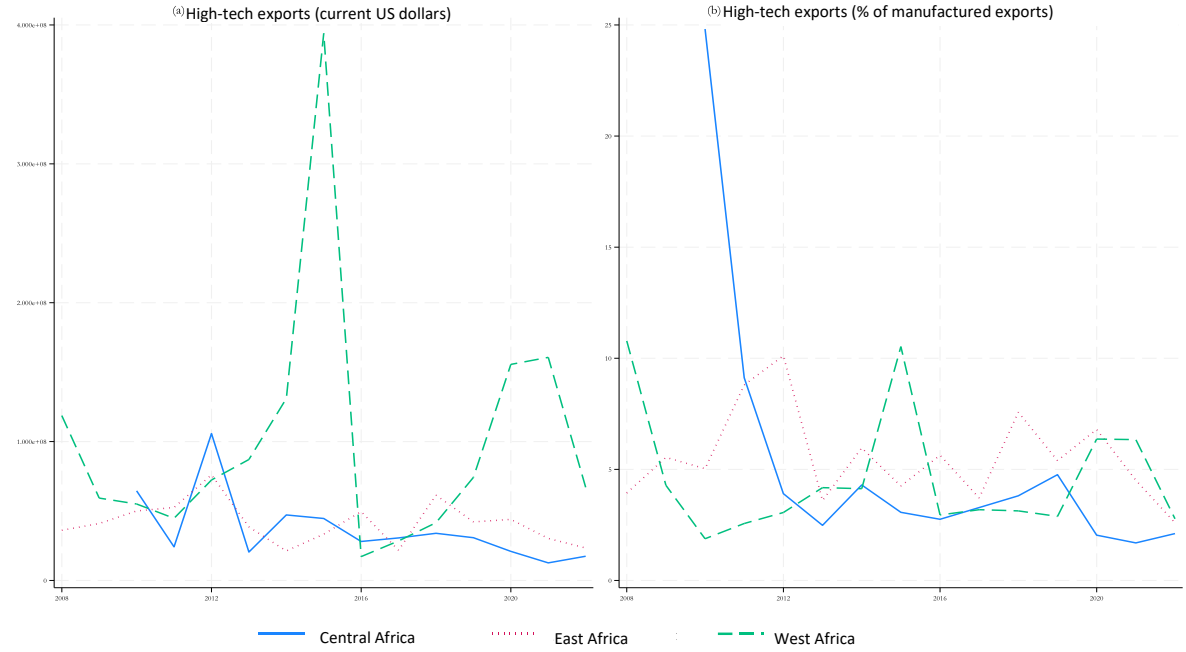
3.3.1 Technological diversification

Although disruptive innovations in advanced economies often attract attention, African countries can derive significant benefits from the adoption and adaptation of existing technologies and inputs. This process of 'technological diversification' can stimulate economic development and reduce macroeconomic volatility. For example, when firms in developing countries broaden their range of inputs and technologies, they become less vulnerable to shocks affecting a single input or sector. The benefits of diversification go beyond risk reduction. Studies show a positive correlation between technological diversification and firm performance, including increases in sales and profitability. This relationship holds even after controlling for product diversification, suggesting that broadening a firm's technological base is a key driver of growth.

However, despite these potential advantages, technological diversification, especially in terms of high-tech exports, is still lagging behind in Central Africa. Graph 4-3a shows that the capacity for innovation in Central Africa is often limited by the economic structure of the countries in the region. These economies are generally characterised by a high dependence on commodity exports and a low degree of industrial diversification, which hampers their ability to innovate. High-tech sectors, which are often the drivers of innovation, are relatively underdeveloped.

Compared with East Africa, Central Africa's high-tech exports remain relatively low in absolute terms. Graph 4-3b shows that although all three regions experience stagnation in high-tech exports over the period 2008-2020, Central Africa has the lowest absolute values. In contrast, West Africa dominates in absolute terms, while East Africa shows a more significant growth trajectory. Graph 4-3b also shows that Central Africa has a clear downward trend in the share of its high-tech exports relative to its manufacturing exports. This suggests that, despite its relative specialisation in high-tech manufacturing, the region is struggling to maintain its competitiveness in this sector. Several factors are responsible for this slowdown, including increased competition from other regions, changes in global demand, difficulties in accessing markets and production capacity constraints. All regions feel the impact of COVID-19.

Graph Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**-5: Capacity for innovation as reflected in the structure of African economies**



Source: Authors' calculations based on data from the World Bank, World Development Indicators.

3.3.2. Productive capacity and technological diversification

Technological diversification involves the adoption of an increasing variety of inputs and production processes, which not only increases average productivity but also reduces vulnerability to shocks specific to certain sectors or technologies. In the African context, improving productive capacity and promoting technological diversification could therefore play a crucial role in stabilising economic growth and reducing vulnerability to external shocks.

This factor is the most significant determinant of economic complexity. Structural change involves the reallocation of productive resources, such as labour, from low-productivity sectors to high-productivity sectors. This process is essential to diversify the economy and increase the sophistication of goods produced and exported. The high covariance (16.128) associated with structural change suggests that it interacts strongly with other variables, underlining the

importance of a holistic approach to economic development.

Human capital (17.482) is the second most important variable. It reflects the crucial role of a well-educated and healthy workforce in the development of complex industries and participation in higher value-added activities. The high covariance (15.052) of human capital with other variables indicates that its impact is amplified by interactions with other factors. This is consistent with the wider literature on economic development, which consistently emphasises the importance of human capital in promoting innovation and technological adoption.

The quality of institutions (5,249), including political stability, regulatory quality and government effectiveness, plays a significant role in enhancing economic complexity. Strong institutions create an environment conducive to innovation and investment, thereby increasing a country's economic complexity. The high covariance (10.01) associated with institutions suggests that they interact substantially with other factors in influencing economic complexity**.**

Table Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**-2: Productive capacity and technological diversification**

	Export of high technologies		
	q2i	Var	Cov
	(1)	(2)	(3)
Energy	0,159	0,1	-2,041
Human capital	17,482	11,045	15,052
ICT	1,666	1,052	-7,913
Institutions	5,249	3,316	10,01
Natural capital	2,429	1,535	6,817
Private sector	0,569	0,359	4,034
Structural change	29,343	18,538	16,128
	1,032	0,652	-5,18

Source: Authors' calculations based on data from UNCTAD and World Bank, World Development Indicators.

3.4 Conclusion

The analysis of the innovation landscape and R&D capacity in Africa, particularly in Central and East Africa, reveals a complex picture of challenges and opportunities. Although the continent as a whole is lagging behind world averages in terms of R&D spending and innovation performance, there are significant variations between regions and countries. Persistent innovation gaps, particularly in Central Africa, are visible in key indicators such as R&D spending, the number of researchers, patent applications and scientific publications. These gaps are mainly due to structural challenges, such as lack of financial resources, underdeveloped innovation ecosystems, and brain drain. However, some countries, such as South Africa, Rwanda and Tunisia, have made significant progress in terms of R&D investment and innovation capacity.

The link between economic structure and innovation capacity plays a crucial role. Many economies in the region remain heavily dependent on commodity exports, limiting their ability to diversify technologically and engage in higher value-added activities, as illustrated by the low share of high-tech exports in the region. Despite these challenges, there are grounds for cautious optimism. Growing recognition of the importance of innovation by African

governments, the emergence of innovation hubs and incubators, and increased international partnerships are creating new opportunities to advance R&D and innovation on the continent. Moreover, technological diversification, even through the adoption and adaptation of existing technologies, offers a promising route to economic development and the reduction of macroeconomic volatility.

4. Cross-border patents: A catalyst for innovation

4.1 Introduction

Innovation is a key driver of economic diversification, particularly in developing regions such as Central and East Africa. As these regions seek to move towards green economies, it is imperative that they develop and disseminate new technologies and practices. In this context, cross-border patents and international collaboration play a crucial role in accelerating not only economic diversification, but also technological complexity. Cross-border patents, which involve securing intellectual property rights in several jurisdictions, are particularly important in a globalised world where innovation often transcends national borders. As indicators of inventive activity, patents provide valuable information on innovation trends and the potential for economic diversification in developing countries.

For Central and East Africa, cross-border patents are essential for facilitating technology transfer by enabling innovators to secure intellectual property rights in several countries, thereby promoting the spread of green technologies and practices and stimulating economic diversification. In addition, these patents encourage collaboration between countries, research institutions and the private sector, facilitating the sharing of resources, knowledge and expertise needed to solve complex problems such as climate change and economic underdevelopment. In addition, patenting innovations internationally makes them more attractive to foreign investors, thereby increasing foreign direct investment (FDI) in sectors that are key to economic diversification. Finally, by obtaining patents in multiple jurisdictions, local innovators can protect their intellectual property from outside exploitation, ensuring that the benefits of innovation remain in the region and contribute to local economic growth and diversification.

The number of patents does not always reflect the quality or economic value of innovations, because the distribution of quality, as measured by citations, is highly skewed. In addition, countries have different propensities to file patents depending on the office, with countries such as the United States, Canada and the United Kingdom favouring the United States Patent and Trademark Office (USPTO). Patenting rates also vary between industries and time periods, and many innovations are not patented. Finally, patent data may be biased in favour of developed countries and large multinationals with more resources to file patents internationally. However, despite these limitations, patents remain a valuable source of information on innovation. They can provide indications of R&D activities that have actually led to technological breakthroughs, unlike R&D expenditure, which mainly represents a short-term cost. In addition, patents can reduce risk and promise future economic returns, which can make them attractive to investors. So, although imperfect, patents remain an important indicator of innovation and the technological performance of companies and countries.

Box 4 1 : Data on patents

The International Patent and Citations across Sectors (INPACT-S) database is a comprehensive resource that tracks patent flows, both international and domestic, across countries and industries from 1980 to 2019. Primarily derived from PATSTAT Global Autumn 2021, it includes patent applications classified according to the International Patent Classification (IPC) system. INPACT-S covers 91 patent authorities, 213 countries of origin, 40 years of data, and 31 industry codes based on 2-digit ISIC Rev. 3 classifications. The database not only captures the number of patent applications by country of origin (inventor or owner residence) and destination (patent filing authority), but also tracks patent flows between sectors and countries, encompassing both cross-border and domestic patents. The dataset was constructed by extracting patent-level data from PATSTAT using SQL queries, applying split-counting for patents with multiple inventors or IPC classifications to avoid double counting, and using a weighted distribution method to allocate patent applications submitted to regional authorities (such as the EPO) to Member States. In addition, missing data on countries of origin has been imputed using family links between worldwide patents, ensuring a more complete dataset.

Compared with other available patent databases, INPACT-S offers several distinct advantages. It is more comprehensive, covering a wider range of patent authorities and offering a more global view of patent activity. The inclusion of both cross-border and domestic patents allows for a more nuanced analysis of patent flows between and within countries and industries. INPACT-S also provides sector-specific bilateral data, enabling detailed sectoral analyses, an improvement on databases that focus solely on aggregate patent counts. By using imputation methods to fill in missing data, INPACT-S captures a larger number of patent applications, increasing the reliability and breadth of the dataset. In addition, the inclusion of cross-border and cross-sector citation data is particularly valuable for studying knowledge flows and technology transfer. Uniquely, INPACT-S tracks both domestic and international patents, allowing a comparison of the effects of globalisation on both. two types of patenting activity. Using a weighted distribution method to allocate patent applications submitted to regional authorities ensures that patent data are more accurately attributed to individual countries, thus avoiding distortions caused by an equal distribution of such applications across all Member States.

Source : Authors

4.2 Patent applications

An analysis of foreign and domestic patent applications from 1980 to 2019 reveals significant trends in the evolution of innovation and intellectual property protection worldwide. This period of almost 40 years offers valuable insights into the dynamics of innovation and the globalisation of inventive activities. Between 1980 and 2019, there has been a substantial increase in both national and foreign patent applications. National applications rose from 399,651.5 in 1980 to 1,841,980 in 2019, a gross increase of around 361%. Foreign applications, meanwhile, have risen from 111,565.5 to 556,518.1 over the same period, an increase of around 399%. This overall growth in patent applications corroborates observations made in other studies on the increase in inventive activity and the globalisation of innovation. The more rapid increase in foreign applications compared with national applications confirms the trend towards the internationalisation of patenting activities observed in the literature.

The evolution of patent applications can be divided into several distinct periods (Graph 4-1, panel A). Between 1980 and 2000, there was moderate growth, with a stable increase in national applications, from 399,651.5 to 754,363.5, and in foreign applications, from 111,565.5 to 408,118.3. During this period, the ratio between foreign and domestic applications rose from 0.28 to 0.54, reflecting the gradual internationalisation of innovation. From 2000 to 2010, internationalisation accelerated,

with foreign applications growing faster than national applications. In 2010, national applications reached 976,512.7 while foreign applications amounted to 582,762.4, bringing the ratio to 0.60, confirming an increase in international patenting activity. Finally, from 2010 to 2018, there was rapid growth and divergence. Domestic applications more than doubled, reaching 2,095,006, while foreign applications also increased, but at a more moderate pace, reaching 670,148.6. This divergence has led to a fall in the ratio of foreign to domestic applications to 0.32 in 2018.

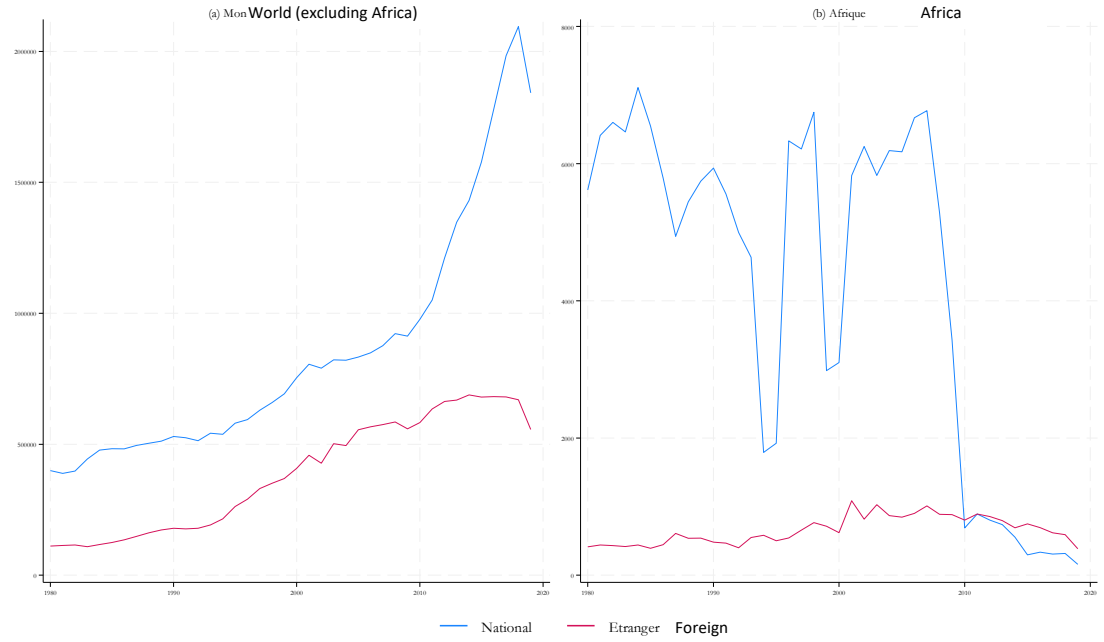
In Africa, the volatility of domestic patent filings reflects a large variability in the number of patents filed by local inventors over the years, suggesting that the instability of the economic and institutional environments in many African countries directly affects local innovation (Graph 4-1, Panel B). There has also been a gradual increase in foreign patents over the same period, from around 400 filings per year in the 1980s to over 800 per year in the 2010s. This trend may indicate a growing interest on the part of foreign companies in African markets, motivated by access to natural resources and economic opportunities. A change in the dynamic after 2010 is notable, marked by a significant drop in domestic patents, while foreign patents remain relatively stable. Finally, the gap between domestic and foreign patents has gradually narrowed, and after 2010, foreign patents have overtaken domestic patents. This reversal could signal persistent structural challenges for local innovators in Africa, such as lack of institutional support, limited access to R&D resources or growing competition from foreign players.

While we can still speculate on the factors influencing the volatility of domestic patents in Africa, several factors may explain the trends observed in the evolution of patent applications. The harmonisation of patent laws, particularly with the adoption of the Patent Cooperation Treaty (PCT), has made it easier to file patent applications abroad, which has contributed to the increase in foreign patent applications. Globalisation has also played a key role, as increased trade and foreign direct investment have encouraged companies to protect their intellectual property on international markets. In addition, the strengthening of intellectual property protection, notably through the addition of dedicated chapters in trade agreements, has encouraged cross-border filings by offering greater legal certainty for innovators. Finally, the emergence of new players in innovation, such as China and South Korea, has contributed to an increase in patent applications, both nationally and internationally, with these countries becoming major centres of technological innovation.

Patent trends have significant implications for economic diversification and complexity, particularly for the emerging economies of Central and East Africa. Firstly, the increase in foreign patent applications can encourage technology transfer, helping to diversify their technological and economic base. This allows countries to benefit from new innovations and advanced technologies, strengthening their ability to diversify beyond traditional sectors. Secondly, this increased exposure to foreign technologies creates learning opportunities for local innovators, giving them the chance to adapt and improve these technologies, which in turn encourages the local economy to become more complex and new sectors to develop. However, this dynamic also creates challenges. The increase in foreign patents can create barriers to entry for local innovators, limiting their ability to innovate freely in certain areas and underlining the importance of national policies that encourage local innovation and the development of internal capabilities. Finally, the effective adoption and adaptation of foreign technologies requires coordination between the various players in the innovation ecosystem - governments, businesses, researchers and investors. This coordination is essential to maximise the benefits of

technology transfer, but represents a particular challenge for developing economies, which often lack adequate coordination infrastructures.

Graph Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**-6:** Patent applications: National or foreign



Source: Authors' calculations based on INPACT-S data (LaBelle et. al, 2023).

4.3 Origin of innovation

The origin of innovation is a complex and multidimensional subject that reflects economic, technological and institutional disparities between countries. Analysis of data on patent applications gives an interesting insight into the global distribution of innovation and its geographical origins.

4.3.1. Origin

Innovation is highly concentrated in a relatively small number of countries. The best performing nations in terms of patent applications per million inhabitants are Japan (372,360), the United States (199,205.4), Germany (93,326.29), Australia (73,963.02) and South Korea (73,694.16). This concentration reflects the complexity of national innovation systems, which are based on interactions between various players such as universities, businesses, governments and research institutions. The predominance of Japan and the United States in this ranking is not surprising. Both countries have historically invested heavily in research and development (R&D), creating robust innovation ecosystems. Japan, in particular, has long been recognised for its systematic approach to innovation, with strong collaboration between government and industry. The US, on the other hand, benefits from a large domestic market, a world-class university system and an entrepreneurial culture that fosters innovation. Japan, in particular, accounts for 19.6% of patents granted by the USPTO, while the US accounts for 55%. Germany, third on the list, illustrates the importance of well-established

innovation systems in advanced economies. The country is renowned for its high-tech manufacturing sector and ongoing investment in R&D. The country accounts for 7.6% of patents granted by the USPTO, reflecting its strength in innovation. Australia and South Korea, which complete the top 5, demonstrate that medium-sized economies can also be major players in global innovation when they put the right policies in place and invest strategically in R&D.

It is interesting to note the position of certain emerging countries in this ranking. China, for example, with 57,257.11 patent applications per million inhabitants, is ahead of many advanced economies. This reflects the considerable efforts made by the country to stimulate innovation and R&D over recent decades. Asia is emerging as a major centre of innovation, with not only Japan and South Korea in the lead, but also notable performances from countries such as Singapore (1,387,536) and Hong Kong (4,068,937). Asia's rise to prominence in innovation reflects the massive investments made by these countries in education, R&D and technological infrastructure.

As far as Africa is concerned, the data show a relatively low level of patenting activity compared with other regions of the world. South Africa, with 3,194.625 patent applications per million inhabitants, stands out as the continental leader in patented innovation. However, this figure remains well below those of the advanced economies and the main emerging economies. Other African countries in the data include Egypt (176,2787), Tunisia (186), Algeria (188,549) and Morocco (196). These figures, while modest compared to the world leaders, nevertheless indicate some innovation activity in these North African countries. However, it is important to note that the low number of patent applications in Africa does not necessarily reflect a lack of innovation on the continent. Many innovations in Africa may be incremental or adaptive in nature, not always meeting the criteria for patentability. In addition, the costs and complexity of the patenting process can be significant barriers for many African innovators. The innovation challenges faced by many developing countries, including in Africa, include a lack of research infrastructure, funding and skilled human capital. These factors help to explain the relatively low rates of patent applications observed in many African countries.

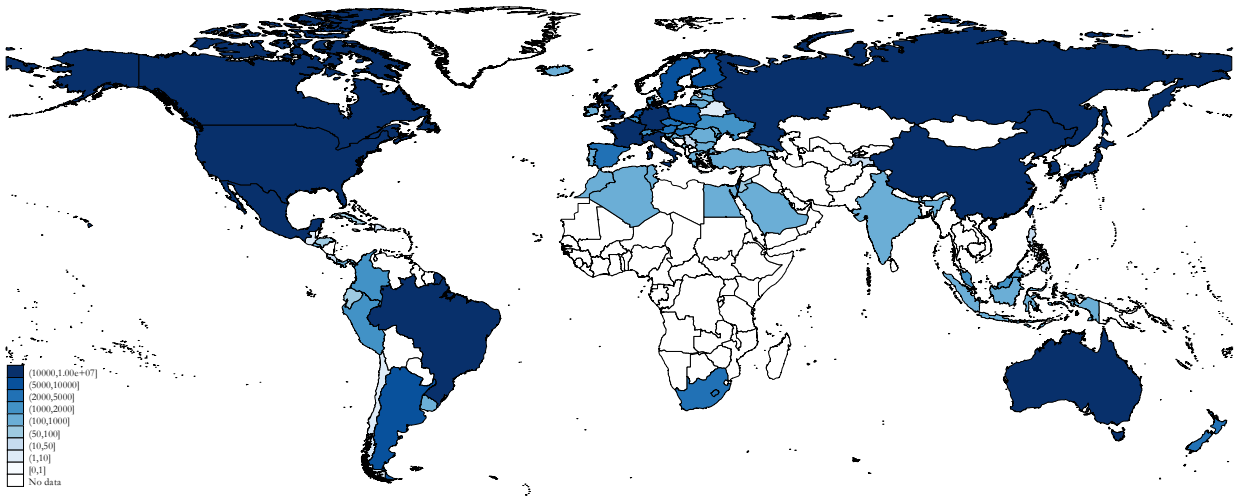
The geographical distribution of innovation also reflects significant regional disparities. Europe, for example, presents a contrasting picture. While countries such as Switzerland (1,889.932), Austria (2,089.554) and the Netherlands (5,867.802) are performing strongly, others such as Greece (294.8133) and Portugal (324.6117) are clearly lagging behind. These differences highlight the importance of national innovation policies and the need for a coordinated approach at the European level to stimulate innovation throughout the region.

Latin America, on the other hand, is performing more modestly in terms of innovation. Mexico (10,053.59) and Argentina (5,070.633) rank highest in the region, but their figures are still well below those of the world leaders. This highlights the challenges faced by countries in this region in developing robust innovation ecosystems, particularly in terms of R&D funding and collaboration between universities and industry.

It is important to note that the number of patent applications is just one indicator of innovation. It does not necessarily capture the full extent of a country's innovative activity, particularly in developing economies where informal and incremental innovation can play an important role. In addition, differences in intellectual property systems and patenting practices between

countries can influence these figures.

Graph Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**-7: Origins of innovation**



Source: Authors' calculations based on INPACT-S data (LaBelle et. al, 2023).

4.3.2 Evolution of patents by region of origin

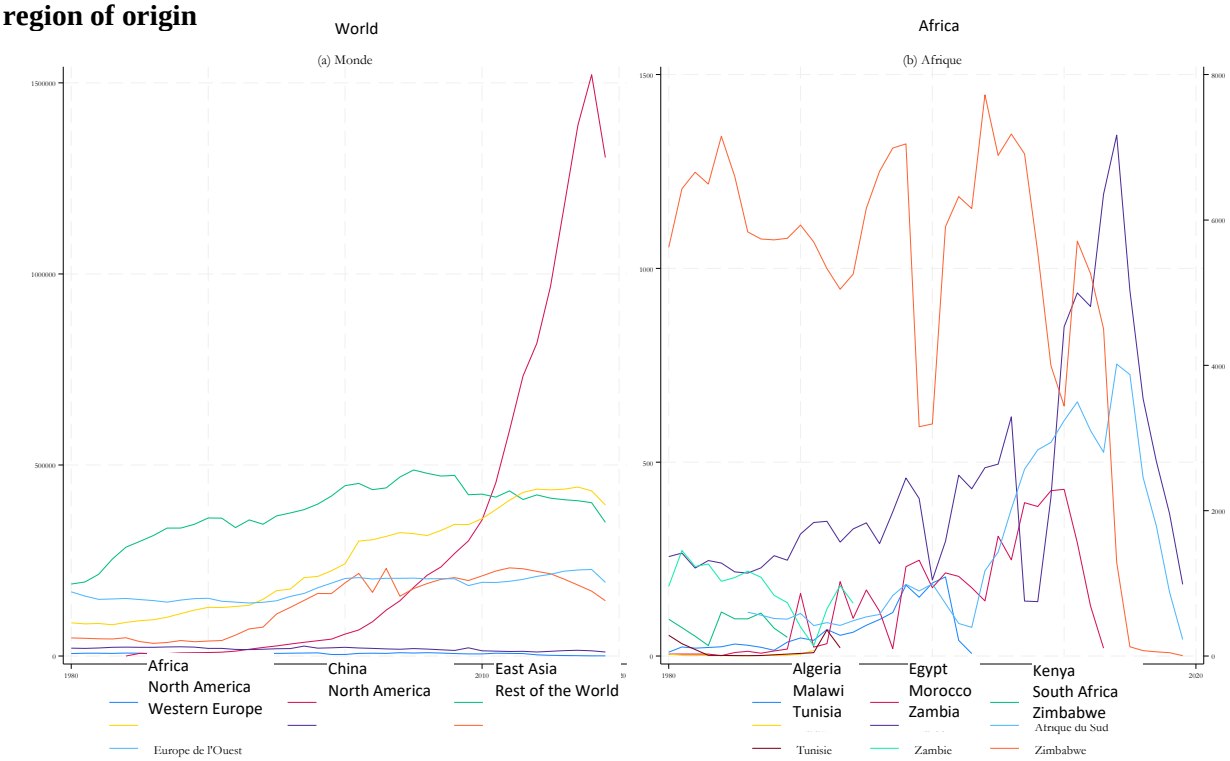
Between 1980 and 2019, the number of patents filed increased significantly in most regions of the world, reflecting an overall increase in innovation and R&D. This trend reflects increased investment in advanced technologies, increased efforts to protect intellectual property, and growing competitiveness among global economies. Advances in various sectors, such as information technology, biotechnology, and renewable energy, have contributed to this acceleration in patenting. This broad-based growth highlights the growing importance of innovation to boost productivity and support economic growth in a globalised context.

The emergence of China is quite remarkable (Graph 4-3, Panel A). China has experienced an exponential increase in the number of patents filed, from a single patent in 1984 to over 1.3 million in 2019. This dramatic increase reflects the rapid development of the Chinese economy, which has become a global leader in technological innovation. This is due to several factors, including massive investment in R&D, an innovation-oriented industrial policy, and strong government support for developing indigenous technologies and protecting intellectual property. China has also introduced incentives to encourage domestic companies to file patents, both domestically and internationally, cementing its position as a key player in global innovation. China’s rise has also led to a redistribution of global market share in innovation, contributing to a relative decline in patents in North America and Western Europe.

The new dynamics of patent filings is concentrated in East Asia. In addition to China, countries such as Japan and South Korea have also played a major role in the rise of innovation in East Asia. Between 1980 and 2019, the number of patents filed in this region increased from 188,000 to over 350,000, which reflects the growing importance of these countries in the global technological competition. Japan, a pioneer in cutting-edge technologies, and South Korea, a leader in electronics and telecommunications, have both focused on innovation-centric development strategies. This increase in patents is a testament to the region’s ability to maintain a high level of competitiveness and technological dynamism. However, this growth in East Asia

also highlights the challenges that other regions, such as Africa, continue to face in terms of their ability to innovate and protect their intellectual property.

Graph Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**-8: Evolution of patents by region of origin**



Source: Authors' calculations based on INPACT-S data (LaBelle et. al, 2023).).

The number of patents in Africa has declined over time, which could indicate persistent challenges in terms of R&D infrastructure and intellectual property protection in the region. However, there are significant variations across countries. South Africa stands out clearly from other African countries in terms of patent filings, with a much higher number throughout the period studied. This trend is mainly explained by its relatively more developed and diversified economy, which benefits from a stronger industrial and technological infrastructure. In addition, South Africa invests substantially in R&D, which allows it to maintain a higher pace of innovation than other regions of the continent. This dynamism is also reinforced by public policies that promote innovation and intellectual property protection, as well as better integration into global value chains.

There are several fluctuations and instabilities. Some countries, such as Algeria and Zimbabwe, show significant fluctuations in the number of patents filed from one year to the next, reflecting political, economic or institutional instabilities. These variations may also be linked to sporadic reforms in intellectual property policies or changes in national innovation priorities. For example, economic crises or periods of political instability can slow down R&D activities and affect the business climate, leading to temporary declines in patenting. Conversely, periods of relative stability or innovation-friendly reforms can lead to spikes in patenting activities. Rapid growth in the number of patents filed is also observed in some countries. Since the 2000s, countries such as Morocco and Egypt have experienced marked growth in the number of patents filed. This increase is likely the result of national policies aimed at encouraging innovation and attracting foreign investment, as well as significant improvements in research and development infrastructure. These countries have implemented reforms to strengthen intellectual property

protection, facilitating local innovation and attracting international companies to protect their inventions. Public-private partnerships, as well as collaborations with international research institutions, have also played a key role in this positive dynamic.

4.4 Destination of Innovation

4.4.1 Evolution of Patents by Region of Origin

The emergence of East Asia as a major destination for cross-border patent applications is confirmed by the data, which show that this region, particularly China, is now a key player on the global innovation scene. China stands out clearly with 8,290,099 patents, far surpassing the United States with 3,466,105, while Japan and South Korea follow with 4,008,194 and 1,744,939 patents, respectively. This rise in importance is explained by two main factors. On the one hand, East Asian countries have become increasingly innovative, by encouraging inventors to protect their technologies against imitation in these growing markets. On the other hand, traditionally leading innovation countries, such as the United States and European countries, are increasingly doing business in this region, requiring them to protect their business assets by filing patents in these jurisdictions. Nevertheless, traditionally innovative Western countries remain important destinations for patents. Germany with 1,131,777 patents, France with 436,356, and the United Kingdom with 258,379 maintain their attractiveness.

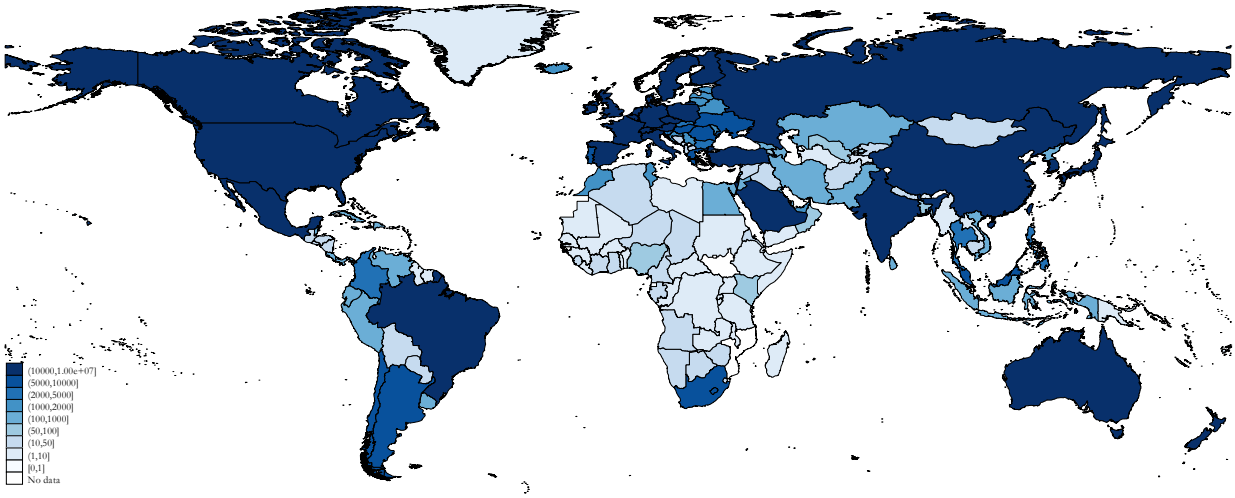
Emerging countries are starting to attract a significant number of patents, reflecting the increase in economic activity and innovation in these regions. For example, India records 41,735 patents, Brazil 48,684, and Russia 212,135. This growth reflects a gradual rise in power of these economies on the global innovation stage. Furthermore, some small countries known for their innovation capacity attract a disproportionate number of patents relative to their size. Singapore has 43,523 patents, Israel 80,303, and Switzerland 251,473. These figures show that, despite their modest size, these countries are managing to position themselves as major technology hubs and innovation centres.

Africa’s low attractiveness for patents is reflected in the very low number of patents filed on the continent. For example, Equatorial Guinea records only 0.2 patents, Benin 1 patent, and even larger countries like Ethiopia have an average of only 2.45 patents. These figures indicate that Africa is not yet perceived as a key destination for the protection of innovations. This can be explained by several factors, including insufficient research and development infrastructure, less developed intellectual property systems, and less integration of Africa into global innovation value chains.

Graph Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**-9: Main destinations for**

cross-border patents in 2022

Authors' calculations based on INPACT-S data (LaBelle et. al, 2023).



Source Authors' calculations based on INPACT-S data (LaBelle et. al, 2023).).

4.4.2. Origin of patents in Africa

The origin of patents shows an uneven distribution across the world and within Africa. The majority of patents (63.4%) come from the "Rest of the World", while North America accounts for 25% of patents filed (Table 4-1). In contrast, Africa itself produces only 4.6% of patents destined for the continent. These data reveal that Central and East Africa receive a particularly low proportion of patents filed in Africa, and the contribution of patents from these regions is also relatively low. It is also important to note that South Africa dominates the patent landscape on the continent, attracting 51% of total patents, of which 46.7% come from African inventors. This highlights a significant concentration of patenting activity in South Africa, thus accentuating regional disparities in innovation and technology transfer. In comparison, patenting in Central and Eastern Africa remains low, highlighting a significant gap compared to other regions of the continent and illustrating the challenges these regions face in technological innovation.

The destination of patents in Central Africa reveals relatively low patenting activity compared to other regions of the continent. For example, Cameroon receives 0.7% of total patents filed in Africa, of which 0.8% are from African inventors. The Central African Republic, on the other hand, receives 0.4% of patents, but none are from Africa. Similarly, Chad receives 0.4% of patents, of which 0.6% are of African origin. In contrast, Congo and the Democratic Republic of Congo record 0.2% and 0.1% of total patents respectively, with no patents from African inventors. These figures highlight the low level of patenting activity in Central Africa, as well as the dependence on foreign patents, with almost no contribution from local or regional innovation. This situation highlights the challenges these countries face in terms of technological development and the promotion of local innovation.

In East Africa, the destination of patents also shows limited patenting activity, with a relatively low contribution from African inventors. Burundi receives 0.4% of total patents filed, of which 0.2% come from African inventors. Ethiopia receives only 0.1% of patents, with none coming from Africa. Kenya stands out with 1.4% of total patents, of which a notable share of 4.1% comes from the African continent. Uganda and Tanzania, on the other hand, receive 0.3% of patents respectively, with an African contribution equivalent to 0.3% in both cases. These

figures illustrate not only a relatively low level of local innovation, but also a strong reliance on foreign patents to protect inventions in the region. Kenya, although more dynamic in terms of African patents, remains an exception in a region where local involvement in patenting remains marginal.

Table Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**-3**: **Origin of patents in Africa**

	Origin					
	Africa	China	East Asia	North America	Rest of the world	Total
Total	1,356 (4.6%)	779 (2.6%)	1,267 (4.3%)	7,372 (25.0%)	18,680 (63.4%)	29,454 (100.0%)
Destination						
Algeria	35 (2.6%)	0 (0.0%)	20 (1.6%)	129 (1.7%)	360 (1.9%)	544 (1.8%)
Angola	0 (0.0%)	0 (0.0%)	0 (0.0%)	76 (1.0%)	28 (0.1%)	104 (0.4%)
Benin	0 (0.0%)	0 (0.0%)	0 (0.0%)	23 (0.3%)	15 (0.1%)	38 (0.1%)
Burkina Faso	0 (0.0%)	0 (0.0%)	0 (0.0%)	50 (0.7%)	19 (0.1%)	69 (0.2%)
Burundi	3 (0.2%)	4 (0.5%)	4 (0.3%)	41 (0.6%)	52 (0.3%)	104 (0.4%)
Cameroon	11 (0.8%)	7 (0.9%)	6 (0.5%)	121 (1.6%)	63 (0.3%)	208 (0.7%)
Cape-Verde	30 (2.2%)	0 (0.0%)	3 (0.2%)	28 (0.4%)	19 (0.1%)	80 (0.3%)
Central African Republic	0 (0.0%)	0 (0.0%)	0 (0.0%)	30 (0.4%)	79 (0.4%)	109 (0.4%)
Cchad	8 (0.6%)	2 (0.3%)	2 (0.2%)	14 (0.2%)	93 (0.5%)	119 (0.4%)
The Comoros	23 (1.7%)	0 (0.0%)	0 (0.0%)	13 (0.2%)	23 (0.1%)	59 (0.2%)
Congo	0 (0.0%)	0 (0.0%)	0 (0.0%)	26 (0.4%)	45 (0.2%)	71 (0.2%)
Côte d'Ivoire	6 (0.4%)	6 (0.8%)	0 (0.0%)	160 (2.2%)	171 (0.9%)	343 (1.2%)
Democratic Republic of the Congo	4 (0.3%)	0 (0.0%)	0 (0.0%)	7 (0.1%)	28 (0.1%)	39 (0.1%)
Djibouti	0 (0.0%)	0 (0.0%)	0 (0.0%)	41 (0.6%)	17 (0.1%)	58 (0.2%)
Egypt	63 (4.6%)	52 (6.7%)	68 (5.4%)	596 (8.1%)	613 (3.3%)	1,392 (4.7%)
Equatorial Guinea	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.1%)	11 (0.1%)	15 (0.1%)
Eritrea	0 (0.0%)	0 (0.0%)	0 (0.0%)	8 (0.1%)	61 (0.3%)	69 (0.2%)
Ethiopia	0 (0.0%)	0 (0.0%)	8 (0.6%)	17 (0.2%)	6 (0.0%)	31 (0.1%)
Gabon	0 (0.0%)	0 (0.0%)	0 (0.0%)	142 (1.9%)	53 (0.3%)	195 (0.7%)
The Gambia	0 (0.0%)	6 (0.8%)	0 (0.0%)	39 (0.5%)	18 (0.1%)	63 (0.2%)
Ghana	8 (0.6%)	3 (0.4%)	3 (0.2%)	82 (1.1%)	62 (0.3%)	158 (0.5%)
Guinea	5 (0.4%)	0 (0.0%)	3 (0.2%)	53 (0.7%)	141 (0.8%)	202 (0.7%)
Guinea -Bissau	3 (0.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (0.0%)
Kenya	10 (0.7%)	7 (0.9%)	30 (2.4%)	322 (4.4%)	209 (1.1%)	578 (2.0%)
Lesotho	8 (0.6%)	0 (0.0%)	0 (0.0%)	1 (0.0%)	0 (0.0%)	9 (0.0%)
Libéria	0 (0.0%)	0 (0.0%)	31 (2.4%)	154 (2.1%)	257 (1.4%)	442 (1.5%)
Libyan Arab Jamahiriya	9 (0.7%)	0 (0.0%)	5 (0.4%)	28 (0.4%)	39 (0.2%)	81 (0.3%)
Madagascar	25 (1.8%)	6 (0.8%)	0 (0.0%)	48 (0.7%)	110 (0.6%)	189 (0.6%)
Malawi	26 (1.9%)	0 (0.0%)	0 (0.0%)	21 (0.3%)	10 (0.1%)	57 (0.2%)
Mali	18 (1.3%)	0 (0.0%)	15 (1.2%)	83 (1.1%)	41 (0.2%)	157 (0.5%)
Mauritania	0 (0.0%)	0 (0.0%)	0 (0.0%)	6 (0.1%)	64 (0.3%)	70 (0.2%)
Mauritius	65 (4.8%)	65 (8.3%)	97 (7.7%)	491 (6.7%)	1,021 (5.5%)	1,739 (5.9%)
Morocco	112 (8.3%)	10 (1.3%)	19 (1.5%)	469 (6.4%)	759 (4.1%)	1,369 (4.6%)
Mozambique	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (0.1%)	3 (0.0%)	7 (0.0%)
Namibia	34 (2.5%)	25 (3.2%)	7 (0.6%)	78 (1.1%)	167 (0.9%)	311 (1.1%)
Niger	10 (0.7%)	3 (0.4%)	21 (1.7%)	232 (3.1%)	62 (0.3%)	328 (1.1%)
Nigeria	0 (0.0%)	0 (0.0%)	23 (1.8%)	227 (3.1%)	114 (0.6%)	364 (1.2%)
Rwanda	0 (0.0%)	4 (0.5%)	0 (0.0%)	25 (0.3%)	7 (0.0%)	36 (0.1%)
Sao Tome and Principe	12 (0.9%)	0 (0.0%)	21 (1.7%)	0 (0.0%)	381 (2.0%)	414 (1.4%)
Senegal	0 (0.0%)	3 (0.4%)	0 (0.0%)	69 (0.9%)	80 (0.4%)	152 (0.5%)

Seychelles	24 (1.8%)	83 (10.7%)	119 (9.4%)	489 (6.6%)	1,092 (5.8%)	1,807 (6.1%)
Sierra Leone	0 (0.0%)	0 (0.0%)	10 (0.8%)	74 (1.0%)	144 (0.8%)	228 (0.8%)
Somalia	0 (0.0%)	0 (0.0%)	0 (0.0%)	11 (0.1%)	3 (0.0%)	14 (0.0%)
South Africa	633 (46.7%)	429 (55.1%)	701 (55.3%)	2,057 (27.9%)	11,199 (60.0%)	15,019 (51.0%)
Sudan	3 (0.2%)	0 (0.0%)	4 (0.3%)	45 (0.6%)	61 (0.3%)	113 (0.4%)
Swaziland	28 (2.1%)	10 (1.3%)	7 (0.6%)	145 (2.0%)	59 (0.3%)	249 (0.8%)
Togo	7 (0.5%)	6 (0.8%)	7 (0.6%)	7 (0.1%)	17 (0.1%)	44 (0.1%)
Tunisia	75 (5.5%)	26 (3.3%)	25 (2.0%)	338 (4.6%)	605 (3.2%)	1,069 (3.6%)
Uganda	4 (0.3%)	0 (0.0%)	0 (0.0%)	67 (0.9%)	12 (0.1%)	83 (0.3%)
United Republic of Tanzania	4 (0.3%)	0 (0.0%)	0 (0.0%)	46 (0.6%)	40 (0.2%)	90 (0.3%)
Zambia	4 (0.3%)	0 (0.0%)	0 (0.0%)	38 (0.5%)	14 (0.1%)	56 (0.2%)
Zimbabwe	46 (3.4%)	22 (2.8%)	8 (0.6%)	97 (1.3%)	133 (0.7%)	306 (1.0%)

Source: **calculations based on INPACT-S data (LaBelle et. al, 2023).).**

4.4.3. Evolution of patents by industrial sector

Patents filed in Africa are mainly concentrated in five sectors: machinery not elsewhere classified (27.9%), chemical manufacturing (23.3%), radio/TV/telecom equipment (21.9%), medical and optical equipment (17.0%), and information technology (9.9%) (Table 4-2). The machinery sector predominates, reflecting the importance of industrialization and infrastructure modernization, followed by chemical manufacturing, which is essential for the pharmaceutical and polymer industries. Telecom and radio/TV equipment, as well as medical devices, reflect the growing importance of ICT and health, while information technology plays a key role in technological innovation.

Central Africa receives a very limited share of patents filed on the continent, and this in key industrial sectors for technological development. Analysis by industrial sector in Central Africa reveals a very low distribution of patents in key industries. In chemical manufacturing, Cameroon has 40 patents (0.6% of the African total), the Central African Republic 19 (0.3%) and Chad 16 (0.2%). For IT, Cameroon leads with 31 patents (1.1%), followed by the Central African Republic (9 patents, 0.3%) and Chad (4 patents, 0.1%). In the n.e.c. machinery sector, Cameroon (47 patents, 0.6%) is ahead of the Central African Republic (33 patents, 0.4%) and Chad (50 patents, 0.6%). For medical/optical equipment, Cameroon has 46 patents (0.9%), compared to 23 (0.5%) for the Central African Republic and 5 (0.1%) for Chad. Finally, for radio/TV/telecom equipment, Cameroon and Chad each have 44 patents (0.7%), while the Central African Republic has 25 (0.4%). The low patenting activity in Central Africa is explained by the weakness of R&D infrastructure, the lack of institutional support for innovation and the low attractiveness of foreign investment in technological sectors, unlike countries such as Kenya or South Africa.

Additionally, there are significant disparities in the sectoral analysis of patents in East Africa. In chemical manufacturing, Kenya leads with 107 patents (1.6 per cent), while Uganda (21 patents, 0.3 per cent) and Tanzania (19 patents, 0.3 per cent) lag behind. In the IT sector, Kenya is also in the lead with 73 patents (2.5 per cent), followed by Tanzania (14 patents, 0.5 per cent) and Uganda (7 patents, 0.2 per cent), while Ethiopia has no patents in this field. In the machinery n.e.c. sector, which is crucial to the African economy, Kenya filed 140 patents (1.7 per cent), followed by Burundi with 34 patents (0.4 per cent). In medical/optical equipment, Kenya dominates with 136 patents (2.7 per cent), while Uganda and Tanzania are far behind with 22

patents (0.4 per cent) and 19 patents (0.4 per cent). Finally, for radio/TV/telecom equipment, Kenya remains in the lead with 122 patents (1.9 per cent), while Tanzania has 23 (0.4 per cent) and Uganda just 12 (0.2 per cent). East Africa faces significant challenges regarding patenting, including an underdeveloped R&D infrastructure, insufficient institutional support, and a brain drain, all of which hinder local innovation. Nonetheless, there are promising opportunities, such as the technological advancements in Kenya, positioning the country as a technology hub in Africa, and the growing demand for medical technologies, which could stimulate patenting activities in this sector. Furthermore, increased foreign investment in technological and industrial infrastructure has the potential to foster local innovation and lead to a rise in patent filings within the region.

Table Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**-4: Patent industries**

	Chemical manufacturing	Information technology	Machinery n.e.c.	Medical/optical equipment	Radio/TV/Telecom equipment	Total
Total	6.851 (23.3%)	2.923 (9.9%)	8.209 (27.9%)	5.021 (17.0%)	6.450 (21.9%)	29.454 (100.0%)
Destination						
Algeria	95 (1.4%)	53 (1.8%)	162 (2.0%)	125 (2.5%)	109 (1.7%)	544 (1.8%)
Angola	15 (0.2%)	10 (0.3%)	37 (0.5%)	14 (0.3%)	28 (0.4%)	104 (0.4%)
Benin	9 (0.1%)	5 (0.2%)	9 (0.1%)	7 (0.1%)	8 (0.1%)	38 (0.1%)
Burkina Faso	21 (0.3%)	16 (0.5%)	7 (0.1%)	9 (0.2%)	16 (0.2%)	69 (0.2%)
Burundi	20 (0.3%)	7 (0.2%)	34 (0.4%)	11 (0.2%)	32 (0.5%)	104 (0.4%)
Cameroon	40 (0.6%)	31 (1.1%)	47 (0.6%)	46 (0.9%)	44 (0.7%)	208 (0.7%)
Cap Verde	12 (0.2%)	6 (0.2%)	26 (0.3%)	21 (0.4%)	15 (0.2%)	80 (0.3%)
Central African Republic	19 (0.3%)	9 (0.3%)	33 (0.4%)	23 (0.5%)	25 (0.4%)	109 (0.4%)
Chad	16 (0.2%)	4 (0.1%)	50 (0.6%)	5 (0.1%)	44 (0.7%)	119 (0.4%)
The Comoros	6 (0.1%)	5 (0.2%)	25 (0.3%)	10 (0.2%)	13 (0.2%)	59 (0.2%)
Congo	12 (0.2%)	7 (0.2%)	18 (0.2%)	18 (0.4%)	16 (0.2%)	71 (0.2%)
Côte d'Ivoire	71 (1.0%)	51 (1.7%)	98 (1.2%)	46 (0.9%)	77 (1.2%)	343 (1.2%)
Democratic Republic of the Congo	11 (0.2%)	1 (0.0%)	16 (0.2%)	1 (0.0%)	10 (0.2%)	39 (0.1%)
Djibouti	10 (0.1%)	6 (0.2%)	23 (0.3%)	9 (0.2%)	10 (0.2%)	58 (0.2%)
Egypt	262 (3.8%)	121 (4.1%)	424 (5.2%)	284 (5.7%)	301 (4.7%)	1.392 (4.7%)
Equatorial Guinea	3 (0.0%)	2 (0.1%)	3 (0.0%)	5 (0.1%)	2 (0.0%)	15 (0.1%)
Eritrea	13 (0.2%)	5 (0.2%)	21 (0.3%)	17 (0.3%)	13 (0.2%)	69 (0.2%)
Ethiopia	6 (0.1%)	0 (0.0%)	11 (0.1%)	7 (0.1%)	7 (0.1%)	31 (0.1%)
Gabon	40 (0.6%)	23 (0.8%)	57 (0.7%)	40 (0.8%)	35 (0.5%)	195 (0.7%)
The Gambia	13 (0.2%)	11 (0.4%)	22 (0.3%)	7 (0.1%)	10 (0.2%)	63 (0.2%)
Ghana	39 (0.6%)	17 (0.6%)	31 (0.4%)	35 (0.7%)	36 (0.6%)	158 (0.5%)
Guinea	44 (0.6%)	21 (0.7%)	62 (0.8%)	18 (0.4%)	57 (0.9%)	202 (0.7%)
Guinea-Bissau	1 (0.0%)	1 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.0%)	3 (0.0%)
Kenya	107 (1.6%)	73 (2.5%)	140 (1.7%)	136 (2.7%)	122 (1.9%)	578 (2.0%)
Lesotho	1 (0.0%)	0 (0.0%)	5 (0.1%)	1 (0.0%)	2 (0.0%)	9 (0.0%)
Liberia	68 (1.0%)	29 (1.0%)	168 (2.0%)	70 (1.4%)	107 (1.7%)	442 (1.5%)
Libyan Arab Jamahiriya	15 (0.2%)	11 (0.4%)	21 (0.3%)	19 (0.4%)	15 (0.2%)	81 (0.3%)
Madagascar	52 (0.8%)	33 (1.1%)	37 (0.5%)	20 (0.4%)	47 (0.7%)	189 (0.6%)
Malawi	5 (0.1%)	9 (0.3%)	17 (0.2%)	9 (0.2%)	17 (0.3%)	57 (0.2%)
Mali	33 (0.5%)	12 (0.4%)	45 (0.5%)	44 (0.9%)	23 (0.4%)	157 (0.5%)
Mauritania	12 (0.2%)	8 (0.3%)	22 (0.3%)	7 (0.1%)	21 (0.3%)	70 (0.2%)
Mauritius	348 (5.1%)	189 (6.5%)	535 (6.5%)	361 (7.2%)	306 (4.7%)	1.739 (5.9%)
Morocco	395 (5.8%)	128 (4.4%)	391 (4.8%)	166 (3.3%)	289 (4.5%)	1.369 (4.6%)
Mozambique	0 (0.0%)	0 (0.0%)	4 (0.0%)	1 (0.0%)	2 (0.0%)	7 (0.0%)
Namibia	73 (1.1%)	35 (1.2%)	90 (1.1%)	44 (0.9%)	69 (1.1%)	311 (1.1%)

Niger	62 (0.9%)	30 (1.0%)	96 (1.2%)	88 (1.8%)	52 (0.8%)	328 (1.1%)
Nigeria	67 (1.0%)	46 (1.6%)	96 (1.2%)	83 (1.7%)	72 (1.1%)	364 (1.2%)
Rwanda	7 (0.1%)	3 (0.1%)	13 (0.2%)	10 (0.2%)	3 (0.0%)	36 (0.1%)
São Tomé and Príncipe	104 (1.5%)	46 (1.6%)	99 (1.2%)	58 (1.2%)	107 (1.7%)	414 (1.4%)
Senegal	34 (0.5%)	17 (0.6%)	40 (0.5%)	33 (0.7%)	28 (0.4%)	152 (0.5%)
Seychelles	367 (5.4%)	139 (4.8%)	618 (7.5%)	392 (7.8%)	291 (4.5%)	1.807 (6.1%)
Sierra Leone	43 (0.6%)	19 (0.7%)	72 (0.9%)	46 (0.9%)	48 (0.7%)	228 (0.8%)
Somalia	3 (0.0%)	3 (0.1%)	2 (0.0%)	4 (0.1%)	2 (0.0%)	14 (0.0%)
South Africa	3.837 (56.0%)	1.475 (50.5%)	3.900 (47.5%)	2.293 (45.7%)	3.514 (54.5%)	15.019 (51.0%)
Sudan	25 (0.4%)	11 (0.4%)	28 (0.3%)	29 (0.6%)	20 (0.3%)	113 (0.4%)
Swaziland	42 (0.6%)	27 (0.9%)	67 (0.8%)	74 (1.5%)	39 (0.6%)	249 (0.8%)
Togo	14 (0.2%)	2 (0.1%)	13 (0.2%)	7 (0.1%)	8 (0.1%)	44 (0.1%)
Tunisia	264 (3.9%)	112 (3.8%)	284 (3.5%)	199 (4.0%)	210 (3.3%)	1.069 (3.6%)
Uganda	21 (0.3%)	7 (0.2%)	21 (0.3%)	22 (0.4%)	12 (0.2%)	83 (0.3%)
Republic of Tanzania	19 (0.3%)	14 (0.5%)	15 (0.2%)	19 (0.4%)	23 (0.4%)	90 (0.3%)
Zambia	12 (0.2%)	2 (0.1%)	26 (0.3%)	5 (0.1%)	11 (0.2%)	56 (0.2%)
Zimbabwe	43 (0.6%)	31 (1.1%)	128 (1.6%)	23 (0.5%)	81 (1.3%)	306 (1.0%)

Source: Authors' calculations based on INPACT-S data (LaBelle et. al, 2023).

4.4.4 Factors driving intra-African patent flows

Increasing intra-African patent flows is vital for enhancing innovation and supporting the continent's economic diversification and development. These flows facilitate knowledge transfer, reduce technology gaps, and promote balanced development across countries. They also strengthen regional integration by fostering collaboration in R&D and creating new opportunities. Supporting local innovation can curb brain drain by offering promising prospects for African talent within the continent.

Theoretically, key factors influencing patent flows include economic development, indicated by GDP per capita, as more developed countries typically generate and attract more patents. Additionally, intensified intra-African trade encourages patent circulation, and regional trade agreements that promote collaboration and technological exchanges positively impact these flows. In addition, favourable tax policies can promote the mobility of inventors and stimulate patent flows within the continent. Protecting intellectual property is also crucial, and harmonising intellectual property regimes can encourage the exchange of patents. Investment in R&D is essential to increasing countries' capacity to innovate, and inventors' mobility between countries, facilitated by flexible immigration policies, reinforces this dynamic. Finally, the sectoral specialisation of African nations, where certain countries become centres of innovation in specific sectors, can also shape intra-African patent flows.

As far as intra-African patent flows are concerned, GDP per capita plays a decisive role in stimulating innovation, highlighting the importance of economic development (Table 4-3). Wealthier nations generally possess more robust innovation systems, advanced R&D infrastructures, and a greater ability to generate and export patents. This implies that policies promoting economic growth can also yield positive effects on innovation. Upon analysing specifications (1) and (2), it is evident that there is a positive and statistically significant correlation between GDP per capita and patent flows: a 1 per cent increase in GDP per capita corresponds to an increase of approximately 1.9 per cent in patent flows, all other factors being constant.

Secondly, the significant role of bilateral trade in patent flows underscores the importance of international economic connections for disseminating knowledge and innovation. Trade facilitates technology transfer, idea exchange, and collaboration in research and development. Therefore, policies promoting open trade and regional economic integration could have a favourable impact on innovation. Bilateral trade emerges as a decisive factor in all the specifications. In specification (3), which excludes GDP per capita and population, the trade elasticity is notably pronounced: a 1 per cent increase in trade is associated with a 3.1 per cent increase in patent flows. This emphasises the critical role of trade connections in facilitating the exchange of knowledge and innovation among nations.

Thirdly, the positive effect of WTO membership on patent flows underscores the significance of international regulations and standards on intellectual property. The WTO's Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) has established minimum standards for protecting intellectual property rights, which can stimulate innovation and facilitate patent flows between member countries. WTO membership emerges as a significant factor in all specifications, with a positive and statistically significant coefficient. This suggests that WTO member countries are inclined to have higher patent flows, likely due to enhanced protection of intellectual property rights and greater integration into the global trading system, which promotes technological cooperation and exchange.

Fourthly, the positive impact of regional trade agreements (RTAs) on patent flows suggests that regional economic integration can significantly contribute to promoting innovation in Africa. RTAs not only reduce trade barriers but also standardise regulations, facilitate the movement of researchers, and promote collaboration in research and development. The coverage of RTAs has shown a positive and statistically significant effect on patent flows across all specifications. A one percentage point increase in RTA coverage is associated with an increase of approximately 0.12 per cent to 0.17 per cent in patent flows. This indicates that RTAs not only facilitate trade but also knowledge and innovation flows among participating countries.

Table Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**-5: Gravity estimates for patent flows**

	Patent flows (1)	Patent flows (2)	Patent flows (3)
GDP per capita (in logarithms)	1.967**	1.878***	
	(0.855)	(0.412)	
Trade volume (in logarithms)	1.625***	1.706***	3.082***
	(0.967)	(0.213)	(0.565)
Population (in logarithms)	0.064		
	(0.702)		
Country’s WTO membership	3.267***	3.255***	2.302***
	(0.875)	(0.836)	(0.572)
Regional trade agreements between countries	0.120***	0.121***	0.173***
	(0.044)	(0.037)	(0.061)
Constant	-26.064***	-26.693***	-48.397***
	(9.161)	(4.138)	(10.621)
Observations	54	54	54

Note: This table estimates the impact of 'standard' gravity variables on cross-border patent flows, with patent applications as the dependent variable and PPML as the estimator. The data spans 1980–2022, and standard errors, clustered at the country level, are presented in brackets. Robust standard errors are also included in brackets. *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors

4.5 Conclusion

Though cross-border patents can significantly drive innovation and economic diversification, realising these benefits requires a comprehensive approach. This should focus on enhancing local innovation capacity, fostering international collaborations, and establishing supportive policies and institutions. For regions such as Central and East Africa, leveraging cross-border patents could be crucial for achieving economic diversification and advancing technology Analysis of cross-border patents and innovation trends reveals a number of key lessons with considerable implications for economic diversification and technological complexity.

Firstly, the global innovation landscape, as reflected in patent applications, has changed substantially over the last four decades. The emergence of East Asian countries, particularly China, as major innovation hubs has shifted the centre of gravity of global innovation. This trend highlights the potential of emerging economies to rapidly develop their innovation capabilities through strategic investments and policies (Hu & Jefferson, 2009).

Secondly, the growing internationalisation of patent applications, illustrated by the increase in the ratio of foreign to domestic patent applications up to 2010, highlights the importance of cross-border collaboration and knowledge diffusion in stimulating innovation (Guellec & van Pottelsberghe de la Potterie, 2001). This trend is particularly relevant for developing regions seeking to diversify their economies and increase their technological sophistication.

Thirdly, the ongoing disparities in patenting activity between developed and developing countries, particularly in Africa, reveal enduring challenges in establishing robust innovation systems. These challenges include inadequate R&D infrastructure, limited access to finance and insufficient human capital (Cirera & Maloney, 2017). Overcoming these barriers is key to fostering innovation-led economic diversification in these regions.

Fourth, it is important to consider the quality of patents, not just the quantity, as a crucial factor in transforming innovation into economic growth and diversification. Akcigit et al. (2017) have pointed out that the distribution of inventor quality is highly skewed, indicating that policies should not only focus on increasing the number of patents but also on promoting high-quality innovations.

Lastly, the role of cross-border patents in facilitating technology transfer, attracting foreign direct investment, and protecting local innovations is particularly relevant for developing regions. By encouraging international patent applications and creating an environment conducive to innovation, these regions could accelerate their economic diversification and technological progress (Branstetter, 2006).

5. Dynamics of innovation and the survival of businesses in Africa

5.1 Introduction

Understanding what drives innovation in African businesses is key to fostering economic diversification and improving regional survival. Innovation is a key element in a competitive landscape. It enables companies to adapt to rapidly changing markets, differentiate their products, and improve their operational efficiency. A substantial body of empirical literature emphasises the favourable influence of innovation on business performance and productivity, even in developing nations. Nonetheless, the nature of innovation in these regions, particularly in Africa, notably differs from that observed in advanced economies. In Africa, innovation often manifests as incremental enhancements in processes or products, entailing the adoption, imitation, and adaptation of technologies which are distanced from the global technological frontier. Despite this, such endeavours can still lead to the development of a comparative advantage. However, there is limited understanding of the specific activities and processes through which African companies stimulate innovation.

In recent years, African governments have increasingly prioritised the advancement of high-growth entrepreneurship as a means of driving economic development. Between 2014 and 2015, the continent accounted for around 30 per cent of global regulatory reforms, with many initiatives aimed at reducing the complexity and cost of regulatory processes and strengthening legal institutions to support local entrepreneurs (World Bank, 2016). While these efforts have been somewhat successful in encouraging self-entrepreneurship, they have been less effective in fostering an entrepreneurial culture that stimulates business creation, employment growth and income generation (Cho and Honorati, 2014; Grimm and Paffhausen, 2015; McKenzie and Woodruff, 2014). Despite these efforts, survival rates for African businesses, particularly in export markets, remain alarmingly low. Studies show that nearly half of African companies are likely to fail within six years (McKenzie and Paffhausen, 2017), and exports from Sub-Saharan Africa typically survive just over two years (Brenton et al., 2012). These findings underline the crucial need to understand the factors contributing to business survival and the role of innovation in this process.

This chapter contends that innovation is crucial for the survival of African companies, especially in international markets. We analyse the effects of product and process innovation on business survival and how these effects differ by country. To achieve this, we create a unique dataset by combining business-level panel data from the World Bank Enterprise Survey (WBES) with sector-level information on intra-sector linkages from the Global Trade Analysis Project (GTAP) database.

Box 5-1: Data on innovation at company level

World Bank Enterprise. A notable advantage of the WBES is that it uses a uniform implementation methodology, making the survey comparable across 80 countries and over an extended duration. The WBES data captures comprehensive business information, encompassing business and managerial attributes, innovation activities, and workforce details, and is administered within the manufacturing and services sectors. The sample for each country is stratified by industry, company size, and geographic location. To ensure representativeness of the private non-agricultural sector of the economy, the survey applies weights to the sample. While survey timing varies across countries, we advocate for the panel structure due to our interest in export behaviour over multiple periods. Our sample is drawn from a panel of 23 countries and 7,108 companies, with sample periods spanning approximately from 2006 to 2022, although varying by country. The dataset we use is a balanced panel of factories that were operational for two or more rounds of the sample years and have the necessary innovation data. This includes data based on companies' experiences and perceptions of the operating environment. Data is primarily collected at the factory level, but for analysis purposes, we also treat factories and companies as interchangeable variables in some models. Of the factories in the sample, 19 per cent were owned by companies that operated only one factory.

Source: Authors

5.2 State of innovation

This study utilises three innovation measures based on business managers' subjective assessments. The first measure is product innovation, defined as transforming ideas into new or significantly improved products and services. A company is considered product innovative if it has introduced such improvements in the three years prior to the survey. This is assessed through two questions: (i) has the establishment launched new or significantly improved products or services? and (ii) has it implemented new or significantly improved production or supply methods? The second measure, process innovation, focuses on improvements introduced by companies in the last three years. WBES asked about several indicators, including (i) new or significantly improved logistics, delivery, or distribution methods; (ii) enhancements in support processes like maintenance, purchasing, accounting, or IT; (iii) new or significantly improved marketing methods; and (iv) new or significantly improved organisational structures during the past three years. Companies reporting any of these four activities are classified as process innovators. The final measure assesses whether the company has invested in research and development (R&D).

5.2.1 Innovation dynamics by region

Product innovation, which entails introducing new or significantly improved goods and services, varies widely across African countries. In East Africa, Kenya leads with a product innovation rate of 56.56 per cent, comparable to high rates in certain Asian regions. Rwanda and Uganda follow closely with rates of 58.88 per cent and 54.23 per cent, respectively, outpacing the 33.9 per cent average for developing Asia. In Central Africa, the situation is more varied: Cameroon has a rate of 50.78 per cent, while the Democratic Republic of the Congo (DRC) trails at 31.58 per cent, with the Central African Republic in between at 39.75 per cent.

Process innovation, referring to the adoption of new or significantly improved production or delivery methods, generally occurs at higher rates than product innovation across Africa,

mirroring trends in developing Asia. In East Africa, Rwanda leads with a process innovation rate of 59.01 per cent, followed by Kenya at 51.44 per cent. These rates are on par with those in the Pacific, South Asia, and East Asia regions. Uganda also performs well, with 45.98 per cent of companies involved in process innovation. Central African countries demonstrate lower rates of process innovation. The data indicates that Burundi has the highest rate of companies reporting process innovation at 54.20 per cent, followed by Chad at 41.96 per cent. In contrast, the Democratic Republic of the Congo lags behind with only 17.03 per cent of companies engaged in process innovation.

R&D spending, a critical factor for innovation, varies significantly across African countries. In East Africa, Kenya leads in R&D expenditure with 25.28 per cent of companies reporting, closely followed by Uganda at 22.59 per cent. Despite high product and process innovation rates, Rwanda reports a lower R&D expenditure of 13.61 per cent. In Central Africa, the Central African Republic has the highest R&D expenditure rate at 31.79 per cent, surpassing its neighbours. Cameroon and Chad have more modest rates at 19.95 per cent and 18.09 per cent respectively.

An analysis of the three indicators suggests that East Africa is emerging as a hub of innovation on the continent, with countries such as Kenya, Rwanda, and Uganda demonstrating high rates in all three dimensions of innovation. This fits with the broader narrative of East Africa as a booming technology hub, often referred to as the ‘Silicon Savannah’. East African countries outperform the averages of developing Asia. For instance, Kenya's product innovation rate of 56.56 per cent surpasses the 33.9 per cent average for developing Asia, and its process innovation rate of 51.44 per cent is close to the 47.7 per cent average. In Central Africa, however, the situation is more mixed. While some countries like Cameroon excel in certain areas, others like the Democratic Republic of the Congo fall behind. This disparity can be attributed to factors such as political stability, infrastructure development, and the overall business environment.

TableErreur ! Il n'y a pas de texte répondant à ce style dans ce document.**-6: Share of innovative companies, by country**

	Product innovation	Process innovation	R&D spending
Benin	36.28	31.27	22.19
Botswana	35.70	27.66	14.03
Burundi	27.34	54.20	19.14
Cameroon	50.78	32.04	19.95
Central African Republic	39.75	28.60	31.79
Chad	41.66	41.96	18.09
Côte d'Ivoire	34.27	28.43	17.40
Democratic Republic of the Congo	31.58	17.03	18.12
Eswatini	37.81	24.27	31.36
Ethiopia	30.78	21.89	2.06
The Gambia	55.13	43.83	13.73
Ghana	39.73	36.41	17.89
Guinea	40.72	31.16	19.37
Kenya	56.56	51.44	25.28
Lesotho	32.33	27.69	14.32
Liberia	69.33	61.70	19.35
Madagascar	36.28	31.27	22.19
Malawi	34.71	52.76	18.94
Mali	45.98	49.79	23.89
Mauritania	36.18	55.82	19.14
Mauritius	60.49	43.43	26.55
Mozambique	42.42	42.39	15.10
Namibia	44.72	66.26	43.30
Niger	57.85	55.20	19.27
Nigeria	30.69	49.56	14.22
Rwanda	58.88	59.01	13.61
Senegal	28.42	43.93	4.07
Seychelles	65.93	52.95	21.65
Sierra Leone	58.51	56.28	19.86
South Africa	36.28	31.27	22.19
South Sudan	30.03	28.30	13.63
Sudan	36.28	31.27	22.19
Tanzania	36.73	30.81	10.97
Togo	40.61	33.36	22.35
Uganda	54.23	45.98	22.59
Zambia	51.50	45.22	21.24
Zimbabwe	41.85	34.46	25.01

Source: Authors' calculations based on data from the World Bank, WBES.

5.2.2 Innovation and level of development

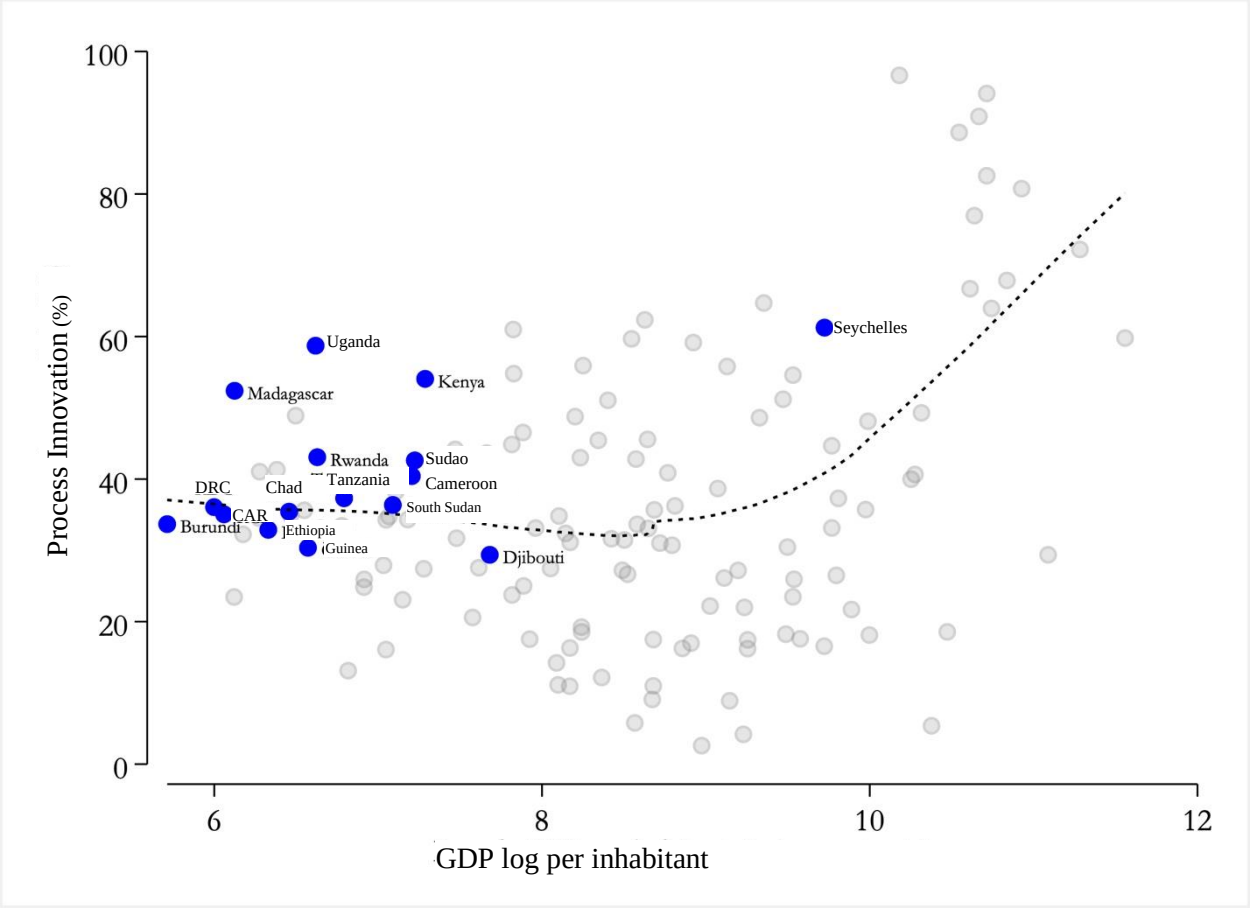
The correlation between product innovation and economic development in East Africa demonstrates a positive trend, albeit with some noteworthy exceptions. For instance, Kenya exhibits a substantial product innovation rate of 54.06 per cent alongside a GDP per capita of 7.29 on a logarithmic scale. This finding aligns with the commonly accepted notion that innovation can effectively spur economic growth and development. On the other hand, Uganda presents an even more compelling case, boasting the highest rate of product innovation in the

dataset at 58.71 per cent, yet with a comparatively lower GDP per capita of 6.62. This suggests that while Uganda has fostered a highly innovative business environment, it has yet to fully translate these innovations into broader economic benefits. Consequently, this may indicate that Uganda is poised to accelerate its economic growth, provided that innovations are more comprehensively integrated into the economy. Meanwhile, Rwanda presents an intriguing scenario, featuring a product innovation rate of 43.07 per cent and a GDP per capita of 6.63. This relatively high innovation rate, coupled with a more moderate GDP per capita, may signify that Rwanda is in a transitional phase and could potentially experience future economic growth driven by its innovative capacity.

In Central Africa, the situation is more diversified. Cameroon, in particular, stands out in the region with a product innovation rate of 40.42 per cent and a GDP per capita of 7.21. This suggests a relatively balanced relationship between innovation and economic development. Meanwhile, the Democratic Republic of the Congo, has a product innovation rate of 36.06 per cent, which is higher than would be expected given its lower GDP per capita of 6.00. This could indicate untapped potential for economic growth if the country capitalises on its capacity for innovation. The Central African Republic, on the other hand, has relatively low product innovation rates (35.05 per cent) and GDP per capita (6.06) compared to its regional peers. This finding could indicate structural challenges holding back innovation and overall economic development.

It is important to note that the relationship between innovation and economic development is not always direct or immediate. As the literature discusses, factors such as market competition, institutional ownership, and government policies can significantly influence innovation rates and economic outcomes. In addition, the efficiency with which countries transform innovation into economic growth can vary. Some countries exhibit high innovation rates but struggle to generalise these innovations or integrate them into their economies. For example, Uganda has significant innovation but has not seen a corresponding rise in GDP per capita. The nature of innovation varies by country: some prioritise incremental innovation, adapting existing technologies to local needs, while others pursue more radical innovations. The data does not differentiate between these types, which may affect the correlation between innovation rates and GDP per capita. Incremental innovations may yield diffuse and less visible gains in traditional economic metrics, whereas radical innovations, though potentially more impactful, often demand substantial R&D investment and longer timelines to translate into economic benefits.

Graph 5-10: Correlation between product innovation and GDP per capita



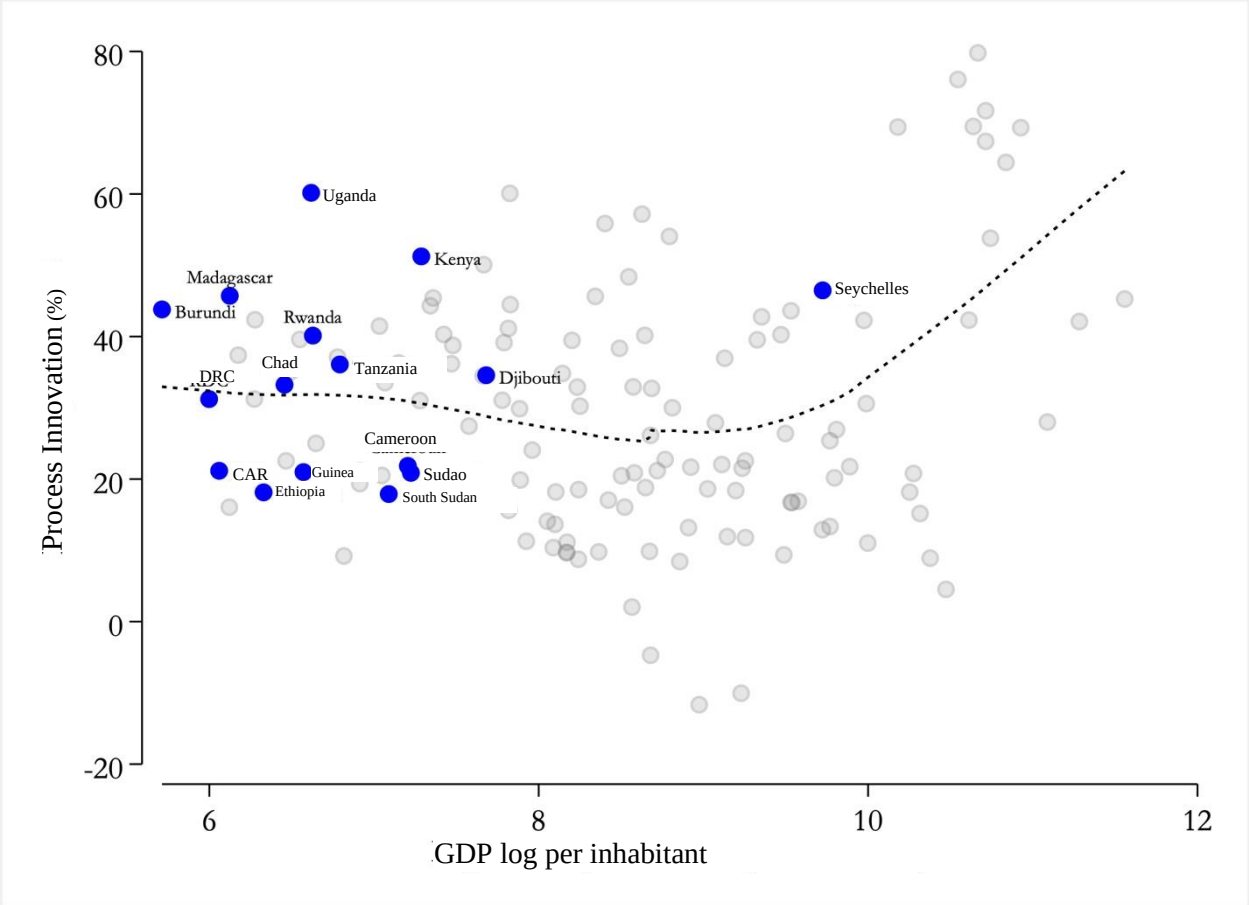
Source: Authors' calculations based on data from the World Bank, WBES and World Development Indicators.

In East Africa, some interesting patterns are emerging. Uganda has the highest rate of process innovation at 60.17 per cent among the countries studied, yet its GDP per capita remains low at 6.62 on a logarithmic scale. This suggests that while Uganda excels in fostering process innovations, it faces challenges in translating them into broader economic gains. Similarly, Kenya has a high process innovation rate of 51.24 per cent coupled with a moderate GDP per capita of 7.29. These examples show that while innovation is crucial, other factors such as market conditions, institutional quality and the ability to scale up innovations play an important role in economic outcomes. Rwanda is also an interesting case in East Africa, with a process innovation rate of 40.13 per cent and a GDP per capita of 6.63. This relatively high innovation rate, coupled with a more moderate GDP per capita, may signify that Rwanda is in a transitional phase and could potentially experience future economic growth driven by its innovative capacity.

In Central Africa, the situation is more diversified. For instance, despite a higher GDP per capita (7.21), Cameroon exhibits a lower rate of process innovation (21.85 per cent) compared to some of its neighbouring countries. This observation suggests that Cameroon's economic development may be influenced by factors other than innovation, such as natural resources or other economic sectors. On the other hand, the Democratic Republic of the Congo demonstrates a process innovation rate of 31.22 per cent, which surpasses expectations considering its lower

GDP per capita of 6.00. This may indicate significant untapped potential for economic advancement if the country can leverage its capacity for innovation and address other developmental hurdles.

Graph 5-11: Correlation between process innovation and GDP per capita



Source: Authors' calculations based on data from the World Bank, WBES and World Development Indicators.

5.2.3 Innovation and characteristics of companies

The data reveals a strong link between a company's export status and innovation activities. Exporters demonstrate higher product innovation rates (49.06 per cent vs. 39.99 per cent) and process innovation rates (48.61 per cent vs. 38.56 per cent) compared to non-exporters. This is consistent with existing literature, which posits that companies involved in international trade are more innovative due to increased exposure to competition and knowledge transfer.

In terms of sectoral differences, manufacturing companies slightly outpace service companies in innovation. They display greater product innovation rates (43.09 per cent vs. 39.76 per cent), process innovation rates (43.48 per cent vs. 37.22 per cent), and R&D spending (20.26 per cent

vs. 16.48 per cent). This may be attributed to the nature of manufacturing, which likely provides more opportunities for technological advancements and process innovations.

The most notable trend is the positive correlation between company size and innovation activities. Larger companies (over 100 employees) exhibit the highest rates of product innovation (50.91 per cent), process innovation (49.53 per cent), and R&D expenditure (31.56 per cent), followed by medium-sized companies, while small firms report the lowest rates across all categories. Furthermore, data indicates that the variance in innovation rates between medium-sized and large companies is less pronounced than between small and medium-sized companies. This observation suggests the potential for diminishing returns to size regarding innovative capacity or highlights the dynamic nature of innovation efforts in medium-sized companies. This relationship aligns with the Schumpeterian hypothesis, which posits that large businesses hold an advantage in innovation activities.

Several factors are likely to contribute to this trend. Large companies typically possess greater financial and human resources for innovation, providing them with a significant advantage. They also benefit from economies of scale in research and development (R&D), as the costs of R&D can be distributed across a larger production base, potentially increasing the profitability of innovation efforts. Moreover, their ability to leverage the synergies between various innovation strategies and other company activities enables them to optimise their overall performance. Additionally, their diversified operations allow large companies to better manage the risks associated with innovation, facilitating the pursuit of more ambitious and innovative projects. However, it is important to emphasise that the relationship between company size and innovation is not always straightforward or linear. Other factors, such as market structure, institutional quality, and specific company characteristics, also significantly impact innovation outcomes.

Table Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**-7: Innovation and characteristics of companies**

	Product innovation	Process innovation
Trade		
Exporter	49.06	48.61
Non-exporter	39.99	38.56
Sector		
Manufacturing industry	43.09	43.48
Services	39.76	0.00
Size		
Small (<20)	37.27	35.60
Size (20–99)	44.58	43.92
Large (100 and over)	50.91	49.53

Source: Authors' calculations based on data from the World Bank, WBES

5.3 Determinants of innovation

As discussed above, Africa is making substantial investments in innovation, yielding impressive outcomes. Key factors influencing this environment include R&D expenditure, governance, fiscal and regulatory conditions, human capital, infrastructure investment, and trade openness. Recognising these factors is crucial for informing public policy. This section presents empirical analyses using country-level data to identify the primary drivers of innovation in Africa.

5.3.1 Determinants of innovation

The main determinant of innovation, whatever the type of innovation and sector, is unquestionably R&D investment. Whether for product or process innovations, and in both industry and services sectors, R&D spending has a significant and positive effect (Table 5-3). This is in line with the well-established literature that emphasises the importance of R&D in stimulating innovation. The slightly higher coefficients for R&D expenditure in the industrial sector compared to services (0.278 versus 0.248 for product innovation) suggest that R&D investment may be marginally more effective in encouraging innovation in manufacturing firms. In this context, it is possible that industrial firms benefit more from R&D because of the opportunities for technological improvement and new product development.

Institutional and governance factors also play a crucial role in stimulating innovation, with a positive and significant impact on both types of innovation, whatever the sector. However, the effect appears to be slightly stronger for process innovation (0.025) than for product innovation (0.016). This highlights the importance of the institutional environment in enabling innovation, which is consistent with the findings of the research literature on innovation and economic development. A strong institutional framework can reduce uncertainty and provide incentives for firms to invest in innovation.

The tax and regulatory environment also has a positive and significant effect on innovation, with fairly similar effects across types of innovation and sectors, ranging from 0.019 to 0.023. This suggests that a favourable tax and regulatory environment can boost innovation activities, possibly by reducing innovation barriers or offering tax incentives to businesses. Reforms designed to simplify regulations or offer tax incentives for R&D could therefore play a crucial role in the innovation efforts of African businesses.

The quality of infrastructure also has a positive and significant impact on both types of innovation.
Interestingly, this effect appears to be slightly stronger for product innovation in the service sector (0.027) than in the industrial sector (0.022). This could suggest that innovation in services depends particularly on the quality of infrastructure, possibly due to the nature of services, which often require efficient communication and transport networks to be delivered in innovative ways. The availability of modern infrastructure could therefore play a key role in the digital transformation and innovation of service companies.

Although the patterns are generally consistent across sectors, there are some subtle differences. For example, R&D spending appears to have a slightly stronger effect on product innovation in industries compared to services (0.278 compared to 0.248), while the opposite is true for process innovation (0.244 compared to 0.260). This could reflect differences in the nature of innovation processes across sectors. In the manufacturing sector, product innovation will probably be essential for competitiveness, while in services, process innovations may be more crucial for improving the efficiency and quality of the services offered.

To conclude, this analysis highlights the key importance of R&D spending, institutional quality, the regulatory environment and infrastructure in driving innovation in African firms. The consistency of these effects across different types of innovation and sectors highlights their fundamental importance. However, the differences in effect sizes and R^2 values between product and process innovation suggest that these two types of innovation may have slightly

distinct determinants, an observation that is consistent with the wider innovation literature. These results call for a nuanced approach to encouraging innovation in Africa, tailored to the sectoral and institutional specificities of each country.

Table Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**-8: Innovation drivers**

	Product innovation			Process innovation		
	Total	Industries	Service	Total	Industries	Service
	(1)	(2)	(3)	(4)	(5)	(6)
Expenses in R&D	0.262***	0.278***	0.248***	0.253***	0.244***	0.260***
	(0.008)	(0.012)	(0.011)	(0.007)	(0.011)	(0.010)
Institutional quality and governance	0.016***	0.017***	0.017***	0.025***	0.025***	0.025***
	(0.003)	(0.005)	(0.005)	(0.003)	(0.005)	(0.004)
Tax and regulatory environment	0.021***	0.023***	0.019***	0.021***	0.019***	0.022***
	(0.003)	(0.005)	(0.004)	(0.003)	(0.005)	(0.004)
Infrastructure quality	0.025***	0.022***	0.027***	0.021***	0.018***	0.023***
	(0.003)	(0.005)	(0.004)	(0.003)	(0.005)	(0.004)
Sample	23,364	9.677	13.687	23.211	9.627	13.584
R-square	0.160	0.158	0.163	0.318	0.302	0.318

Note: This table presents ordinary least squares estimates of the drivers of product and process innovation. Control variables include years, sectors, and countries. Standard errors in parentheses are clustered at the country level. Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors

5.3.2 R&D expenditure performance by country

The empirical evidence presented in the previous section shows significant impacts on the R&D returns across different sectors. This analysis is extended by assessing cross-country heterogeneity. Studying these variations in R&D returns is critical for policy makers and researchers who wish to promote innovation-led growth. Such cross-country differences are not surprising, given that innovation is fundamentally shaped by each country's institutional, economic and human context. The history of economic development is marked by diverging paths of technological progress, ranging from the rapid industrialisation of advanced economies to the persistent technology gaps faced by many developing countries. This difference in R&D returns between nations can be attributed to a number of factors, such as differences in human capital, institutional factors (such as the quality of education systems, research infrastructure and the protection of intellectual property rights), the level of economic development, as well as the specificities of each industry, which also contribute to the variations observed in R&D returns between countries.

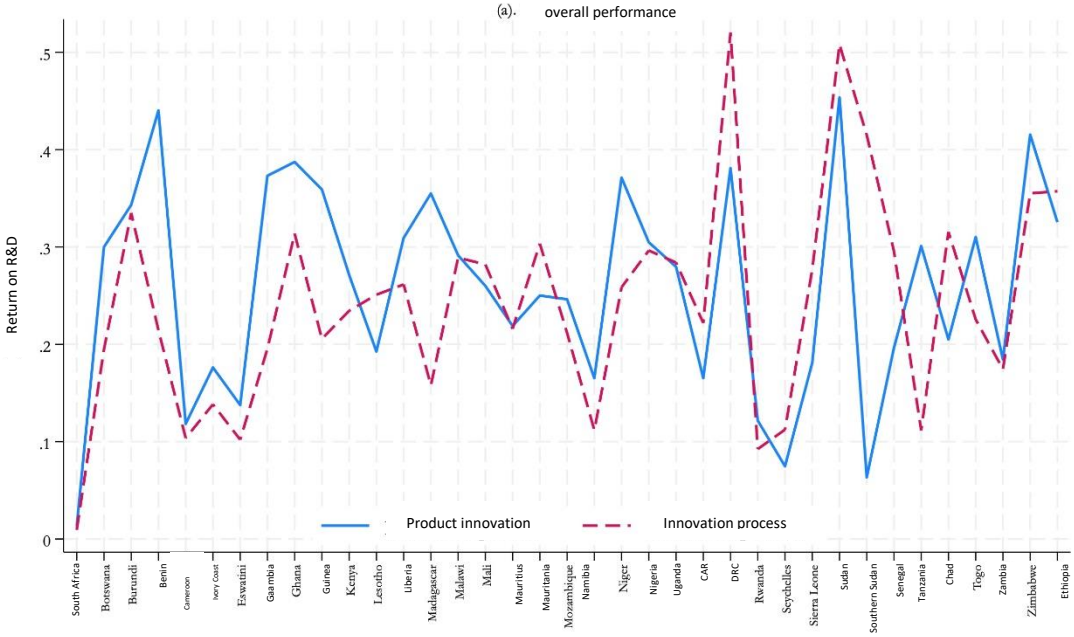
On average, Central African countries appear to have slightly higher R&D performance than East African countries, mainly due to the results observed in the DRC and the CAR. This may be linked to Central Africa's growth potential, often associated with its natural resources, despite the region's economic and political challenges. There is also greater variation in R&D returns within Central Africa compared to East Africa. This suggests that country-specific factors play a dominant role in the effectiveness of R&D investment in Central Africa, making it necessary to tailor innovation policies to national contexts. The DRC stands out for its particularly high returns on R&D investment, in both process and product innovation, which reflects its remarkable effectiveness in these areas, mainly due to its growth potential based on its natural resources. Conversely, Cameroon shows lower returns for both product and process innovation, underlining the importance of institutional and governance factors in R&D efficiency. Chad has moderate returns, with greater emphasis on improving existing processes

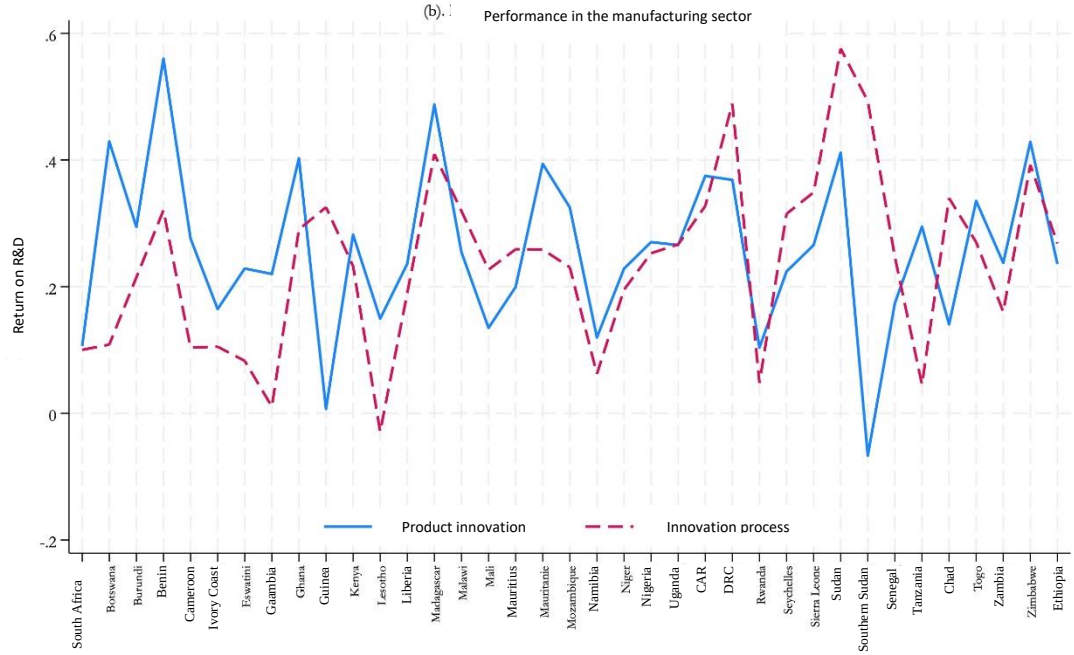
rather than developing new products. For its part, the CAR shows relatively high returns to product and process innovation, suggesting a more balanced innovation ecosystem.

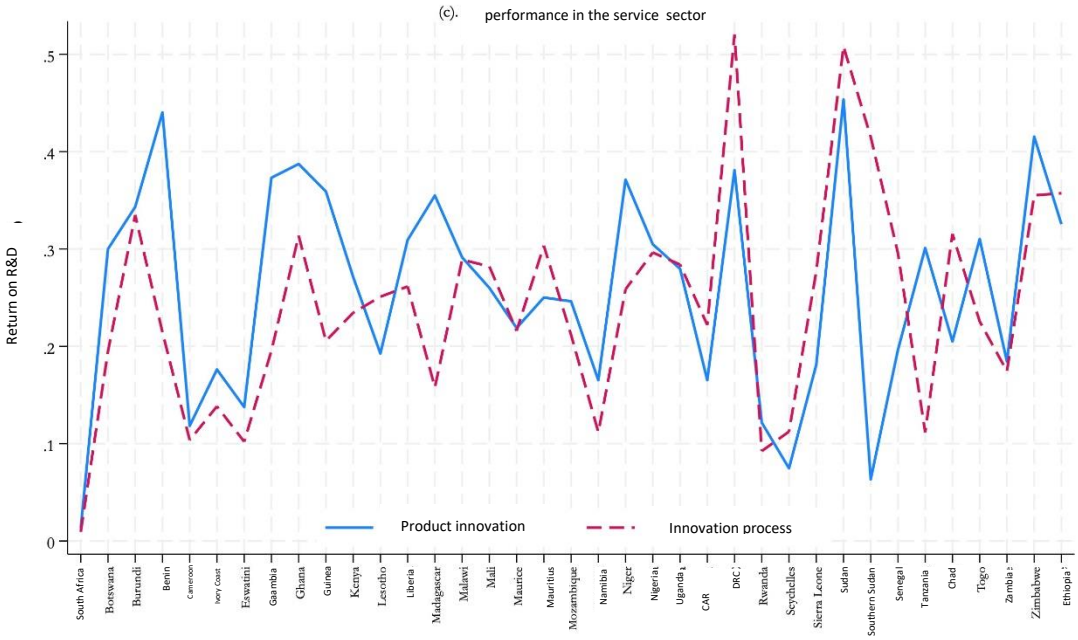
East African countries also show different patterns of R&D returns. Kenya which is often regarded as a technology hub in the region, shows moderate returns to product and process innovation, although these results are lower than might be expected given the country's reputation for innovation. In Ethiopia, returns are relatively high for process innovations, especially in the services sector, in line with the country's recent industrialisation efforts. Uganda also shows moderate and balanced returns between product and process innovations in the manufacturing and services sectors. Rwanda, on the other hand, despite its ambitions to become a regional technology hub, shows relatively low returns to product and process innovation, suggesting challenges in converting R&D investment into tangible results and the need to reassess its innovation strategies.

Finally, R&D returns to product and process innovation are relatively similar in most countries. However, there are some noteworthy exceptions. The DRC and Sudan show significantly higher returns to process innovation than to product innovation, which may reflect a greater focus on improving existing production processes rather than developing new products. Madagascar and Benin, on the other hand, show higher returns for product innovation, suggesting a greater focus on new product development in these countries.

Graph Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**-12: R&D expenditure returns by country**


(a). overall performance
Return on R&D
.5
.4
.3
.2
.1
0
Product innovation
Innovation process
South Africa
Botswana
Burundi
Benin
Cameroon
Ivory Coast
Eswatini
Gambia
Ghana
Guinea
Kenya
Lesotho
Liberia
Madagascar
Malawi
Mali
Mauritius
Mauritania
Mozambique
Namibia
Niger
Nigeria
Uganda
CAR
DRC
Rwanda
Seychelles
Sierra Leone
Sudan
Southern Sudan
Senegal
Tanzania
Chad
Togo
Zambia
Zimbabwe
Ethiopia


(b). Performance in the manufacturing sector
Return on R&D
.6
.4
.2
0
-.2
Product innovation
Innovation process
South Africa
Botswana
Burundi
Benin
Cameroon
Ivory Coast
Eswatini
Gambia
Ghana
Guinea
Kenya
Lesotho
Liberia
Madagascar
Malawi
Mali
Mauritius
Mauritanie
Mozambique
Namibia
Niger
Nigeria
Uganda
CAR
DRC
Rwanda
Seychelles
Sierra Leone
Sudan
Southern Sudan
Senegal
Tanzania
Chad
Togo
Zambia
Zimbabwe
Ethiopia



Source: Authors' calculations based on data from the World Bank, WBES.

5.4 Spread of innovation and business survival

Business survival is a crucial element for sustainable economic diversification in Africa, contributing to several essential aspects of development. It fosters economic stability by reducing vulnerability to external shocks, which is particularly important for resource-dependent economies (Bloom and Sachs, 1998). It encourages technological innovation and the adoption of new technologies, which are of crucial importance in sectors such as agriculture, where progress has historically been slow (Boserup, 1966). Business survival is also important for job creation, strengthening economic institutions and regional integration, especially through cross-border ethnic networks (Spolaore and Wacziarg, 2013). Finally, it plays a key role in reducing poverty, a major challenge in many African countries, especially those rich in natural resources (Meredith, 2005). Thus, business sustainability is a key factor in overcoming historical barriers to development in Africa, such as low population density and institutional challenges (Boserup, 1966; Spolaore and Wacziarg, 2013).

The procedure we used to measure the survival of companies on the export market involved analysing companies' responses regarding their export status, be it direct or indirect. We combined this information to determine whether a company exports, and then compared its progress between two survey cycles. The transition rate shows that 50.8 per cent of non-exporting companies in the base year start exporting the following year, while 49.1 per cent remain non-exporting. On the other hand, companies that were already exporting had a 39.4 per cent chance of continuing to export the following year. We have separated the analysis into two categories: entry into the export market and survival of exporting companies, because the determinants of survival differ from those of entry into the market. The average survival rate is

9.48 per cent for the sample as a whole, with a wide variation between countries. South Africa has the highest survival rate (38.22 per cent), followed by Senegal (29.73 per cent) and Kenya (19.87 per cent). On the other hand, countries such as Angola, Cape Verde and the DRC have the lowest export participation rates. Furthermore, countries with low entry rates also tend to have low survival rates, while countries such as Tanzania, Rwanda and Senegal stand out for their low exit rates and relatively high survival.

Table Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**-9: Spread of innovation and business survival**

Country	Non-exporting (%)	Output (%)	Input (%)	Survival (%)	Total (%)
Angola	92.35	4.37	3.28	0.00	100
Benin	65.65	11.45	10.69	12.21	100
Botswana	77.31	9.24	5.04	8.40	100
Burkina	72.73	13.64	5.68	7.95	100
Cameroon	68.24	9.02	13.33	9.41	100
Cape Verde	90.57	5.66	3.77	0.00	100
Ivory Coast	82.07	7.59	7.59	2.76	100
DRC	87.31	6.09	6.60	0.00	100
Ethiopia	81.18	3.23	9.95	5.65	100
Ghana	48.39	16.13	19.35	16.13	100
Kenya	54.30	13.25	12.58	19.87	100
Lesotho	68.85	13.11	9.84	8.20	100
Malawi	76.83	7.93	7.93	7.32	100
Mali	74.53	11.32	8.81	5.35	100
Niger	72.99	9.49	10.22	7.30	100
Rwanda	77.14	5.71	7.14	10.00	100
Senegal	48.65	13.51	8.11	29.73	100
South Africa	27.75	18.32	15.71	38.22	100
Tanzania	69.57	6.09	13.04	11.30	100
Togo	48.33	18.33	15.00	18.33	100
Uganda	72.25	10.05	10.05	7.66	100
Zambia	70.22	9.78	9.33	10.67	100
Zimbabwe	71.85	7.62	14.24	6.29	100

Source: Authors' calculations based on data from the World Bank, WBES.

5.4.1. Determinants of business survival

We now extend the analysis to explore whether product or process innovation plays a role in determining firm survival. We find that, overall, innovative firms are more likely to survive than non-innovative firms. The results indicate that product innovation is positively associated with firm survival. It should be noted, however, that the ratio of product innovation remains unchanged from the findings in column 1. We also observe that process innovation is positively and statistically associated with firm survival. Our findings appear to be consistently strong across different specifications. The magnitude of this coefficient would seem to indicate that process innovation is more important for firm survival than product innovation.

Process innovation plays a crucial role in firm survival for several reasons. Firstly, it significantly improves operational efficiency, reducing costs and increasing productivity, which has a direct and lasting impact on a company's profitability and competitiveness. In addition, it facilitates economies of scale, which are particularly advantageous for large companies, as pointed out by Schumpeter (Bloom et al., 2007). Unlike product innovations, process innovations are often more difficult to copy, offering a more sustainable competitive advantage (Aghion et al. 2005). They also make the company more flexible and capable of adapting

quickly to market changes, which is crucial to long-term survival. Process innovations can also create positive interactions with other business strategies, such as scale of production or adoption of other technologies, thereby strengthening the overall organisational system. Adopting specialised software, for example, can have a significant impact on a company's productivity, which is vital to its survival, especially in a market liberalised context. Finally, these innovations help to reduce operational and financial risks, which is particularly important for the survival of companies in competitive environments.

A logical question in this context is to know whether there is complementarity in the introduction of product and process innovations. Our estimation strategy to explore this possibility is to introduce interaction between these two types of innovation, thus following the work on innovative complementarities (Kretschmer et al., 2012). The results of the model with interaction (column 4) are very interesting. It is observed that the interaction term is positive, albeit small and statistically insignificant, suggesting some complementarity effect between the two types of innovation. This approach is in line with equilibrium models that not only look at the adoption of innovations, but also at the scale of firms' production. Although the point estimate for product innovation is lower than in previous specifications, the joint effect with the interaction term indicates that product innovation offers a higher probability of survival in the presence of process innovation. This supports the idea that the combined effect of product and process innovation contributes positively to firm survival, in line with discussions on the relationship between competition and innovation (Holmes et al., 2008). Findings on the interaction effect between competition and innovation are extremely relevant in the light of the renewed debate on industrial policy and regional integration efforts in Africa. These results could have major repercussions for understanding the mechanisms by which competitive pressure influences the adoption of complementary innovations, a crucial aspect for economic development and the long-term growth of firms and economies.

5.4.2. Mechanisms

To understand the ways in which innovation improves firm participation and export survival, we are investigating the potential spillover effect. Previous work has shown that economic structure and linkages are strongly associated with the spillover effects of innovation. In this section, we estimate the effect of four spillover indicators on innovation indicators by linking WBES data and social accounting matrix data. We extend the analysis to include variables reflecting the spillover effect of innovation through backward and forward linkages, as well as self-induced effects in inputs and outputs. The results of the regression analysis with the full set of controls show that the backward spillover effects of innovation are positive and significant for both firm entry and firm survival, meaning that higher backward spillovers of innovation increase the probability of exporting and surviving in the export market. The estimated coefficient is higher for entry than for survival, at 0.896 compared with 0.142. For downstream propagation, we find that the coefficient for entry is very positive and significant. The estimates for downstream propagation are also positive and significant in the business survival model, but the strength of the coefficient is lower. Our results show that the greater impact of downstream propagation on entry is consistent with previous findings that innovation effects were greatest among upstream sectors. This is particularly important given that the concept of innovation as perceived by developing countries includes both radical innovators and mere copycats.

We then examine the spillover effects of innovation as measured by self-induced changes. The results show that the marginal effect of the spread of self-induced outputs is 1.821. Column 6

shows the estimates for export survival. This coefficient is lower than that for business entry at 1.821 compared to 0.212. Finally, columns 7 and 8 contain estimates for the spread of self-induced inputs. The pattern of the coefficient remains the same, but the coefficient in the export survival model is not statistically significant. Nevertheless, these results provide consistent evidence that innovation spillovers are important mechanisms through which innovation is likely to affect firm entry and export survival.

Table Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**-10: Mechanisms**

	Entry (1)	Survival (2)	Entry (3)	Survival (4)	Entry (5)	Survival (6)	Entry (7)	Survival (8)
Upstream propagation	0.896***	0.142**						
	(0.0560)	(0.0690)						
Downstream propagation			1.156***	0.142*				
			(0.0460)	(0.0820)				
Self-induced outputs					1.821***	0.212***		
					(0.2540)	(0.2540)		
Self-induced inputs							1.174***	0.13
							(0.2540)	(0.1190)

Source: Authors' calculations based on data from the World Bank, WBES and GTAP.

5.5 Conclusion

Innovation plays a vital role in the survival and growth of African businesses, especially in a situation of constant international competition and economic challenges. By analysing the different forms of innovation - notably product and process innovation - this study shows that Africa, although lagging behind advanced economies, is showing promising dynamics, especially in East Africa.

The data shows significant variation in innovation rates between African regions and countries, with countries such as Kenya, Rwanda and Uganda emerging as innovation hubs, often compared to developing economies in Asia. However, Central Africa shows more mixed results, with countries such as the DRC and the Central African Republic having relatively low innovation rates, which are partly due to institutional and economic challenges. Investment in R&D, the quality of infrastructure, and institutional and regulatory frameworks appear to be major drivers of innovation. Large companies and exporters are also more likely to innovate, supporting the idea that size and access to international markets boost innovation activity.

However, innovation does not always result in immediate economic gains. Some countries, such as Uganda, show high rates of innovation but are still struggling to convert these innovations into tangible economic results, suggesting a need for improvement in the ability to integrate these innovations into the wider economy.

In conclusion, although Africa has made significant progress in innovation, further efforts are needed to strengthen infrastructure, improve governance and invest in human capital. An innovation strategy tailored to local and sectoral specificities could enable African countries to move from simple technological adaptations to genuine production of high value-added innovations, thereby fostering sustainable economic growth.

6. General and specific recommendations

6.1. Strengthen research and development (R&D) capacity

Governments should significantly increase their investment in R&D, aiming for a target of 1 per cent of GDP in the medium term, in line with the recommendations of the African Union (African Union, 2014). This implies:

- Increasing public funding for research in universities and research institutes.
- Putting in place tax incentives to encourage private investment in R&D.
- Developing public-private partnerships for applied research in strategic sectors.

6.2. Improve the protection and marketing of intellectual property

- Strengthen their legal and institutional frameworks for protecting intellectual property.
- Simplify patent filing procedures and reduce associated costs.
- Create technology transfer offices in universities to facilitate the marketing of innovations.

6.3. Promote regional and international collaboration

- Set up joint research programmes between countries in the region.
- Facilitate the mobility of researchers and innovators at regional level.
- Develop partnerships with world-class innovation centres.

6.4. Develop skills in science, technology, engineering and mathematics (STEM)

- Reform educational programmes to emphasise STEM and entrepreneurship.
- Invest in vocational and technical training.
- Set up scholarship programmes for higher education in STEM.

6.5. Create a favourable environment for innovative entrepreneurship

- Simplify procedures for setting up and running businesses.
- Improve access to finance for innovative start-ups.
- Develop support infrastructure (incubators, accelerators, etc.).

6.6. Promote the adoption and adaptation of green technologies

For sustainable economic diversification, it is essential to integrate environmental considerations. Governments should:

- Provide incentives for the adoption of clean technologies.
- Support R&D in renewable energy and the circular economy.
- Integrate sustainability criteria into public contracts.

6.7. Strengthen governance and coordination of policies for innovation, integration and the sharing of new technologies

Effective implementation of innovation policies requires good governance. Recommendations include:

- Going beyond national and regional research and innovation agencies to create regional research and innovation financing funds.
- Set up more effective mechanisms for coordinating technology dissemination and transfer efforts.
- Set up mechanisms for monitoring and assessing innovation and technology transfer policies. This includes setting up technology sharing and integration centres.
- Encourage dialogue between stakeholders in the innovation ecosystem.

References

African Development Bank (AfDB). (2014). Unlocking the Potential of African Industries: The Role of Innovation and Industrialization. African Development Bank Group.

African Development Bank (AfDB). (2020). African Economic Outlook 2020: Developing Africa's Workforce for the Future. African Development Bank Group.

Aghion, P., Carlin, W., & Schaffer, M. (2002). Competition, Innovation, and Growth: Theory, Empirical Evidence, and Policy Implications. Oxford Review of Economic Policy, 18(3), 391-407.

Aghion, P., & Howitt, P. (1992). A Model of Growth Through Creative Destruction. Econometrica, 60(2), 323-351.

Aghion, P., Bloom, N., Blundell, R., Griffith, R., & Howitt, P. (2005). Competition and Innovation: An Inverted-U Relationship. The Quarterly Journal of Economics, 120(2), 701-728.

Andersen, A. D., Marín, A., & Simensen, H. (2018). Innovation in Resource-Based Economies: The Role of Firm Capabilities. Innovation and Development, 8(2), 179-197.

Barro, R. J. (1990). Government Spending in a Simple Model of Endogenous Growth. Journal of Political Economy, 98(5), S103-S125.

Calestous, J., & Lee, K. (2005). Innovation and Economic Development: Lessons from East Asia. World Development, 33(5), 731-754.

Chataway, J., Hanlin, R., & Kaplinsky, R. (2014). Inclusive Innovation: An Architecture for Policy Development. Innovation and Development, 4(1), 33-54.

Griliches, Z. (1980a). R&D and the Productivity Slowdown. American Economic Review, 70(2), 343-348.

Deaton, A. 1999. 'Commodity prices and growth in Africa'. Journal of Economic Perspectives 13 (3): 23–40.

Grossman, G. M., & Helpman, E. (1994). Endogenous Innovation in the Theory of Growth. Journal of Economic Perspectives, 8(1), 23-44.

Katz, M. L., & Shapiro, C. (1987). R&D Rivalry with Licensing or Imitation. American Economic Review, 77(3), 402-420.

LaBelle, J., Martinez-Zarzoso, I., Santacreu, A. M. & Yotov, Y. 2023. Cross-border Patenting, Globalization, and Development, Working Papers 2023-031, Federal Reserve Bank of St. Louis. https://ideas.repec.org/p/fip/fedlwp/97470.html

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

Mansfield, E. (1980). Basic Research and Productivity Increase in Manufacturing. American Economic Review, 70(5), 863-873.

Romer, P. M. (1986). Increasing Returns and Long-Run Growth. Journal of Political Economy, 94(5), 1002-1037.

Romer, P. M. (1990). Endogenous Technological Change. Journal of Political Economy, 98(5), S71-S102.

Seyfang, G., & Smith, A. (2007). Grassroots Innovations for Sustainable Development: Towards a New Research and Policy Agenda. Environmental Politics, 16(4), 584-603.

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

Wooldridge, J. M. (2010). Econometric Analysis of Cross Section and Panel Data. MIT Press.

Appendices

Table A 1: List of indicators making up the Productive Capacity Index

Energy	Share of population with access to electricity
	Transmission and distribution losses as a share of primary supply
	Renewable energy consumption as a share of total final energy consumption
	GDP per kg of oil consumption
	Total primary energy supply per capita
	Total energy consumption per capita
Human capital	Number of expected years of schooling
	Research and development expenditure as a share of GDP
	Researchers conducting research and development per million population
	Health-adjusted life expectancy (years)
	Health expenditure as a share of GDP
	Fertility rate
ICT	Fixed broadband subscriptions per 100 people
	Number of mobile phone subscriptions per 100 people
	ICT Number of fixed lines per 100 people
	Secure internet servers per one million people
	Number of internet users as a percentage of the population.
Institutions	Controlling corruption
	Government effectiveness
	Political stability and lack of violence/terrorism
	Quality of regulation
	Rule of law
	Vote and accountability
Natural capital	Agricultural land as a percentage of land area
	Forest area as a percentage of land area
	Share of all extraction flows in GDP
	Material intensity (total extraction flows as a proportion of industrial added value)
	Total natural resource income as a percentage of GDP
Private sector	Domestic credit to the private sector as a percentage of GDP
	Cost of exporting a container
	Export time (days)
	Cost of importing a container
	Import time (days)
	Contract performance (days)
	Setting up a company (days)
	Trademark applications
	Patent applications
Structural change	Export concentration index
	Economic complexity index
	Gross fixed capital formation as a percentage of GDP
	Industrial ratio (industry and services as a percentage of total GDP)
Transport	Air transport, departures by carriers registered worldwide per 100 people
	Air transport, freight (million ton-km) Air passengers per capita
	Logarithm of number of km of roads/100 km² of land
	Logarithm of total number of km of railway lines per inhabitant

Table A 2: Productive capacity in Central and East Africa, growth between 2021-2022 (%)

	Aggregate productive capacity	Energy	Human capital	ICT	Institutions	Natural capital	Private sector	Structural change	Transport
Angola	0.22	0.72	1.67	0.00	1.45	0.39	-0.54	-0.65	-1.22
Burundi.	1.59	8.19	1.92	3.13	-2.13	0.05	2.18	-0.02	-0.27
Cameroon	-1.48	0.56	3.22	-2.15	0.78	-0.02	-4.09	1.18	-10.66
Central African Republic	2.06	-0.24	3.92	4.19	-1.51	0.36	1.86	8.98	-0.64
Chad	0.29	-0.36	3.60	1.78	1.69	0.89	0.48	-3.38	-2.21
Comoros	1.05	0.94	0.71	3.89	0.16	0.47	1.16	0.78	0.35
Congo	0.12	1.31	1.77	0.00	-1.94	0.07	1.01	-0.46	-0.72
Democratic Republic of Congo	0.56	0.64	2.65	0.00	-0.74	-2.89	0.53	7.39	-2.74
Djibouti	0.93	1.39	1.30	3.31	0.51	0.35	0.39	0.21	-0.01
Equatorial Guinea	-0.13	-0.17	1.18	-0.04	0.85	-2.01	-0.34	-0.01	-0.43
Eritrea	1.28	1.03	0.28	2.94	3.32	0.04	0.39	2.66	-0.36
Ethiopia	1.59	6.06	1.30	3.41	3.27	-1.82	-0.29	1.83	-0.79
Gabon	0.05	-0.70	1.75	2.32	-1.20	-0.24	0.19	-0.61	-1.08
Kenya	0.44	0.32	1.76	2.88	-0.48	-0.38	0.14	0.13	-0.77
Madagascar	0.74	-0.33	0.86	2.89	0.09	-0.05	-0.27	-0.51	3.31
Rwanda	2.23	8.44	1.02	2.59	0.31	-0.64	-0.84	4.56	2.71
Sao Tome and Principe	-0.54	1.64	0.31	0.24	0.05	-0.56	0.12	-5.51	-0.48
Seychelles	2.11	-0.23	1.03	1.70	-0.12	0.13	0.44	15.22	-0.40
Somalia	1.11	6.87	4.36	7.95	-2.08	-0.85	-4.31	4.32	-6.41
Southern Sudan	-0.81	0.00	1.59	0.00	0.00	-0.01	-0.49	-7.20	-0.14
Tanzania	0.26	0.41	1.39	2.47	-0.24	-1.59	0.27	-0.77	0.20
Uganda	0.40	0.89	1.72	2.60	0.18	-0.40	0.13	-0.03	-1.86
Reference									
United States of America	-0.63	-0.14	0.00	-0.29	0.25	-4.41	-0.19	-0.02	-0.16
China	0.64	0.84	1.01	2.52	0.53	-1.26	0.36	0.42	0.79