United Nations
Economic Commission for Africa

African Science, Technology and Innovation Review 2013

United Nations
Economic Commission for Africa

African Science, Technology and Innovation Review 2013

Ordering information

To order copies of **African Science, Technology and Innovation Review 2013** by the Economic Commission for Africa, please contact:

Publications
Economic Commission for Africa
P.O. Box 3001
Addis Ababa, Ethiopia

Tel: +251 11 544-9900
Fax: +251 11 551-4416
E-mail: ecainfo@uneca.org
Web: www.uneca.org

© United Nations Economic Commission for Africa, 2014
Addis Ababa, Ethiopia
All rights reserved

Language: English
Sales No.: E.14.II.K.2
ISBN: 978-99944-61-36-3
eISBN: 978-99944-62-36-0

Material in this publication may be freely quoted or reprinted. Acknowledgement is requested, together with a copy of the publication.

Contents

CHAPTER 3: The African STI Policy Environment

Chapter 4: Africa's pharmaceutical industry

List of Figures

List of Tables

List of Boxes

NOTE

The term "country" as used in this publication also refers, as appropriate, to territories and areas. The designations employed and the presentation of the material do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries. In addition, the designations of country groups are intended solely for statistical or analytical convenience and do not necessarily express a judgment about the stage of development reached by a particular country or area in the development process. Mention of any firm, organization or policies does not imply endorsement by the United Nations.

The use of the symbol "$" or "US$" refers to United States dollar unless stated otherwise. Its use is primarily intended for statistical or analytical convenience and does not imply its use in the country, territory or region.

The term "innovation" is used to largely refer to the application of knowledge in product, process, design, market and organizational improvements that are new, not necessarily to the world but to the region, country, centre, firm and/or individual. Unless otherwise stated, it may not include "policy innovations" or entrepreneurship in general.

The terms "number", "proportion" and "percentage" refer only to the totals of datasets of organization and for centres that chose to complete the survey and not of a country. Therefore, statements such as "ten per cent of the researchers have PhDs" do not refer to the national average of researchers but to that of centres that chose to participate in the surveys or provide data.

The material contained in this publication may be freely quoted with appropriate acknowledgement. However, the data and information is not generated by the United Nations and the United Nations is not responsible for any inaccuracies, interpretations and damages associated with the use of the publication or any material contained therein.

Foreword

Welcome to the first Africa Science, Technology and Innovation Review 2013. This series of reviews is intended to provide sound data and evidence to enable member States to make informed policy decisions in the areas of science, technology and innovation as drivers of economic growth. The review is also designed to be a powerful and useful resource for researchers, analysts, civil society and media wishing to understand the levels of technological and industrial development as well as inspire national, regional and international agencies and other organizations to collect and share data to help policy-making in this key area.

Africa's share of the global modern knowledge base, technology application to development challenges and trade in technology assets and products remains very small. The current trends in STI that this review presents should encourage Governments, development partners and the private sector to double their efforts to enable Africa to claim its rightful share of the global knowledge economy and transform the continent from one dependent on exhaustive extractive industries to one that relies on knowledge industries.

Africa can ensure its future economic prosperity through an STI agenda that mobilizes all science and technology resources, especially human capital, in services of socio-economic transformation of the continent. The current wave of mega projects in the construction and mining industries, among others, should help build Africa's technological and industrial base.

The Review highlights some examples of strategic policy designs, implementation and evaluation drawn from within and outside Africa that can be used to unleash such a transformation of the continent. Africa is perhaps the continent that most needs science and technology to meet its education, energy, food, health and employment challenges, among others, within its limited resources. Collective efforts are required to close the major gaps and limitations in data noted in this Review.

Acknowledgements

This study is part of the policy research activities of the ECA New Technologies and Innovation Section (NTIS), headed by Kasirim Nwuke, under the overall supervision of Fatima Denton, the director of the Special Initiatives Division (SID). It was initiated by the erstwhile ICT, Science and Technology Division under Aida Opoku-Mensah and finalized by NTIS/SID.

This Review was prepared by a team of ISTD staff composed of Aida Opoku-Mensah, Abebe Chekol, Afework Temtime, Andre Nonguierma, Aster Denekew, Hopestone Chavula, Eskedar Nega, Makane Faye, Louis Lubango, Matti Sinko, Thierry Amoussougbo and Victor Konde with substantial technical support from Asfaw Yitna, Girum Asrat, Meron Kinfemichael and Fetsum Kurabachew.

The Review benefited from earlier work on: Technology Transfer for Africa's Development by ISTD, which demonstrated serious data gaps; an Assessment of the Innovation Ecosystem in Africa, which revealed inadequacy of Science, Technology and Innovation (STI) policies; and the Innovation Framework that provided a road map for addressing some of these challenges.

The current structure of the Review stemmed from an Expert Group Meeting held from 17 to 19 October 2011 in Addis Ababa. This meeting reviewed the structure and some of the initial drafts of the Review. Meeting participants included Professor Aggrey Ambali and Dr. Chimwemwe Chamdimba of NEPAD (South Africa), Dr. Godfred Frempong of the Council of Scientific and Industrial Research (Ghana), Professor Clement K. Dzidonu of the Accra Institute of Technology (Ghana), Dr. Wanjiku Ng'ang'a of the University of Nairobi (Kenya), Mr. Richard M. Liahona of the Ministry of Higher Education, Science and Technology (Kenya), Professor Timothy Mwololo Waema of the University of Nairobi (Kenya), Andre Bassole, Director General CERPINEDD (Burkina Faso), Olajide Kufoniyi, Sives Govender, Executive Director, EISAfrica, Esayas Dagnew, President, GIS Society of Ethiopia, Dr. Alexandra Graham of LaGray Chemical Ltd (Ghana), Dr. Hulda Swai and Dr Rose Hayeshi of CSIR (South Africa) and the staff of ISTD.

Independent comments and contributions on the drafts were received from Mr. Alex Twinomugisha of Global eSchools and Communities Initiative (Kenya), Mr. Jussi Impiö of Nokia Research Center (Kenya), Dr. Jonathan Tambatamba of the National Technology Business Centres (Zambia), Dr. Yee Kwan Tang of Glasgow University (UK) and Mr. Geoff Banda and Dr. Julius Mugwagwa of Open University (United Kingdom). Dr Robert Ridley, University of Malawi (Malawi) provided substantive input and editorial support. However, any errors and omissions are the responsibility of the authors.

ISTD also wishes to thank the heads of institutions and senior policy makers in Ghana, Kenya and Zambia who completed the Innovation Policy Surveys and provided valuable information on their national policies, laws and initiatives; the heads of intellectual property offices of Egypt, Ethiopia, Madagascar, Mauritania, Morocco, Seychelles and South Africa that completed the Intellectual Property Survey; the following universities for providing raw data on students and staff: Cape Town University (South Africa), Durban University of Technology (South Africa), ILORIN University (Nigeria), Rhodes University (South Africa), Stellenbosch University (South Africa) University of Pretoria (South Africa), Makerere University (Uganda), University of Algiers1 (Algeria), University of Mauritius (Mauritius) and University of Limpopo (South Africa), and AU-ASTII initiative for making their data available.

This work was supported by funds from the United Nations and Finland. The views expressed by the authors do not necessarily reflect those of UNECA, the United Nations or its members.

Abbreviations

ASTII	African Science, Technology and Innovation Indicator
AU	African Union
EU	European Union
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
ICT	Information and Communication Technologies
ISTD	ICT, Science and Technology Division
ILO	International Labour Organization
IPR	Intellectual Property Rights
MSEs	Micro and Small Enterprises
MSMEs	Micro, Small and Medium-Sized Enterprises
NEPAD	New Partnership for Africa's Development
NIS	National Innovation System
OECD	Organization for Economic Cooperation and Development
R&D	Research and Development
S&T	Science and Technology
SITC	Standard International Trade Classification
SMEs	Small and Medium-Sized Enterprises
STI	Science, Technology and Innovation
UN	United Nations
UNECA	United Nations Economic Commission for Africa
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
USPTO	United States Patent and Trademark Office
WDI	World Development Indicators
WIPO	World Intellectual Property Organization

Executive Summary

The generation, diffusion and application of technology in the public and private sectors to meet economic and social aspirations and challenges, have been one of the drivers of Africa's success in the last decade. The visible face of the contribution of technology to Africa's socio-economic success story include the rapid diffusion of mobile communication technologies that have opened up new business opportunities, created jobs, especially for the youth and women and connected more people to modern communication systems, as well as the rapid uptake of anti-retroviral drugs that are extending and improving the quality of the lives of millions of HIV/AIDs infected people. There is hope that Africa can leapfrog several stages of development by capitalizing on the abundant technologies to improve the lives of its citizens.

For this to happen, policy makers and industrialists would require some basic, but critical, data that can inform and support policy making and business decisions in the STI area. This Review is but one of the efforts to institute processes for broad-based STI data collection and analysis of emerging national and regional trends, presented in a way that reflects the needs of STI policy makers. This first Africa STI Review has four main objectives:

- Provide sound data or evidence to enable member States to make informed policy decisions in the areas of science and technology;
- Serve as a powerful and useful resource for researchers, analysts, civil society and media wishing to understand the levels of technological and industrial development on the continent;
- Help member States track and monitor their performance over a period of time in a wide range of STI-related issues; and
- Inspire member States, academia, industrialists and not-for-profit organizations and their institutions and experts to design tools needed to collect, sort, analyse and visualize STI data at the national and regional levels.

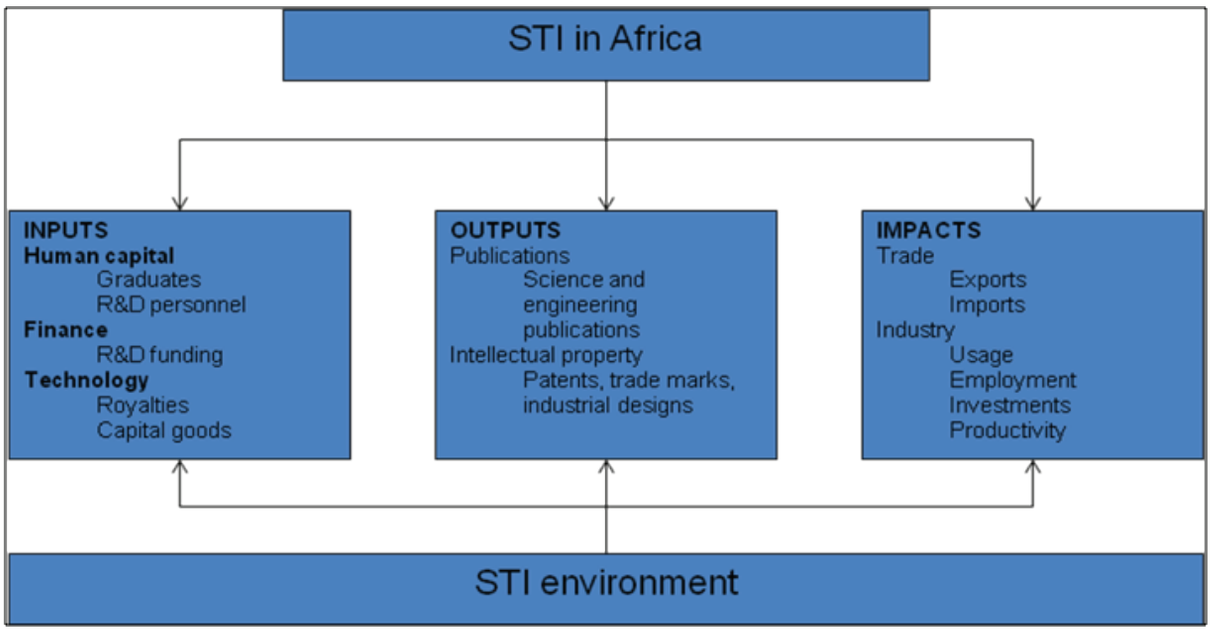
It is further anticipated that this review will inspire various interest groups at the national level to collect data that can inform policy making and policy learning. It is as important to document and demonstrate that data is missing as it is to present data that exists. It is also critical to ensure that available data is correct, of high quality and up to date. Future reviews of this series, and that of the AU-NEPAD African Science, Technology and Innovation Indicator (ASTII) initiative, must strive to stimulate improved collection and analysis of relevant data beyond research and development (R&D) and innovation to include the impact of STI on development.

The increasing importance of innovation

Over the last two centuries, the pace of technological development has grown exponentially, leading to formalization and professionalization of R&D activities. Innovation is now a key determinant of the competitiveness of firms and economies. While resource-based firms (e.g. Exxon Mobil) and financial firms (e.g. Citi Bank) have historically dominated the list of rich companies globally, technology-based firms such as Apple (US$362 billion), IBM ($213 billion) and Microsoft ($212 billion) have not only overtaken many resource and financial firms but are also worth more in market value than the gross domestic product (GDP) of a number of petroleum exporting African countries such as Angola (GDP $113 billion) and Sudan (GDP $97 billion). The main asset of these firms is their knowledge or intellectual capacities.

The need to understand and stimulate the growth of such knowledge-based firms in key sectors such as agriculture, health, communication, energy and industry has assumed increasing importance. As shown in Figure 1.0, the number of measures used to undertake such an assessment is often beyond the scope of one agency or institution. Future Reviews will strive to include new indicators as data and partners emerge.

Figure 1.0: Some of the elements in the STI Report



The STI Review in Africa addresses the entire innovation value chain from training and research and development to technology development, acquisition, use and application. It also attempts to describe the innovation ecosystem in Africa. A lack of data and data that is poor or inaccessible reduces our ability to address all the key areas. In addition to UNECA–supported studies, the review builds on and complements other sources of data, including reports published by the United Nations Conference on Trade and Development (UNCTAD), the United Nations Educational, Scientific and Cultural Organization (UNESCO), United Nations Statistics Division, the World Banks' World Development Indicators, the World Economic Forum, the UNDP Human Development Report, as well as reports generated through the AU-NEPAD ASTII.

Care, thus, needs to be taken in interpreting change in a single indicator or a single set of indicators. For instance, a change in the number of publications may be driven by changes in R&D funding, number of post-graduate students and researchers, collaborations or incentives to researchers for publications, among others, and they may differ from one country to another.

The structure of this review is as follows:

Chapter 1: Provides broad-based information and data on the **performance of science, technology and innovation in Africa**, with foci on: human resources; levels of academic activity; research publications; national expenditure on R&D; and intellectual property, including patents, industrial designs and trademarks. It also assesses royalty payments and imports as a measure of technology transfer and utilization.

Chapter 2: Focuses on developments in **Information and Communication Technologies (ICT)** across the continent. ICT deserves a dedicated chapter given its continued rapid development, both technically and socially, and its central role in improving knowledge management globally and in supporting science, technology and innovation across the African continent. Geospatial information systems (GIS) are singled out in this chapter for specific focus given the increasing convergence of GIS, mobile location based services and enterprise information technology into integrated systems.

Chapter 3: Focuses on elements critical for **STI policy determination and implementation**. In particular, it seeks to identify areas that require specific policy consideration, stressing the need for an integrated, cross-cutting approach to national policies. Some specific recommendations are made.

Chapter 4: Looks specifically at **pharmaceutical innovation**. Pharmaceutical innovation and related policy issues have become increasingly important to Africa over the last decade, stimulated in particular by the challenges of HIV/AIDS. In recent years, this interest has been more broadly extended to public health, innovation and access to medicines. In future years other topics will be highlighted for special discussion.

Highlights of the STI Review 2012

A surge in human capital development

Although the overall enrolment rate in tertiary institutions in sub-Saharan Africa in 2008 was only 6 per cent compared to 26 per cent in Asia and 38 per cent in Latin America and the Caribbean, tertiary enrolment in Africa has been growing at an annual rate of about 15 per cent in the last decade. For example, from 1999 to 2008, tertiary enrolment increased by about 1950 per cent for Angola, 980 per cent for Djibouti and 770 per cent for Ethiopia.

In terms of researchers, a survey of 13 countries by ASTII revealed that the number of researchers per million inhabitants ranged from fewer than 30 in Mozambique, Uganda and Ghana to over 500 in Senegal and South Africa, which is comparable with countries such as Brazil, but is a lot lower than that of innovative economies such as the Republic of Korea (4,627 researchers per million inhabitants). More than half of the thirteen countries surveyed have fewer than 1,000 R&D researchers in total. More importantly, only three countries (Gabon, Senegal and South Africa) have more than 20 per cent of their total R&D personnel with PhD qualifications, while two countries (Mozambique and Kenya) reported less than 2 per cent of their R&D personnel having PhDs (AU-NEPAD, 2010).

R&D expenditure remains below 1 per cent of GDP

Of the 13 countries surveyed, only Uganda, South African and Malawi have attained the targeted 1 per cent of GDP expenditure on R&D activities by 2008. However, in the case of Malawi, a significant proportion of these resources came from external sources. It was estimated that Uganda invested about $200,000 per R&D personnel, followed by Senegal, Gabon and South Africa and two-thirds of the countries spent less than $70,000 per research personnel. If salaries and other personnel benefits (pension, education etc.) and utilities are deducted, there may be very little left to directly invest in undertaking R&D activities in such countries.

Africa registers a significant rise in science and engineering publications

All but one of the top 30 publishing countries, the Democratic Republic of Congo, registered an increase in the number of papers published in peer-reviewed journals. For example, Tunisia recorded the fastest growth in the number of papers published among the top six countries – from about 300 in 1990 to over 3000 in 2010. Similarly, Uganda saw its number of papers increase by over 1,200 per cent from 1990 to 2010.

In absolute terms, South Africa is the only country that produced over 8000 papers in the last two years (2009 and 2010) followed by Egypt, Tunisia, Algeria and Nigeria. If this trend continues, over the next few decades, Africa may start to compete internationally as an emerging producer of science and engineering knowledge of global interest.

A mixed picture for intellectual property

Africa's global share of knowledge generation and ownership remains low. A proper assessment is hindered by a severe lack of data. For instance, based on national reports to the World Intellectual Property Organization (WIPO), data is available for only 10 intellectual property (IP) offices in 2006 and four in 2008. Only nine

(IP offices have data for 10 or more years over the years 1990-2009, making it difficult to make a meaningful assessment on the status of African-owned intellectual property.

Based on reports from six countries[1], four countries registered a substantive increase while one, South Africa, reported a steady decline. The South Africa Company and Intellectual Property Registration Office (CIPRO) granted 5,429 patents in 1990, 3,399 in 2000 and 1,468 in 2010 while patents granted by Morocco over the same period increased three times - from 302 to 915. In Egypt, patent applications increased nearly two and half-fold, while patents granted largely remained unchanged in the last decade.

Other types of intellectual property assessed were designs and trademarks. From data available on designs, both resident and non-resident applications and granted designs have grown significantly over the last 20 years. About 3,300 applications were received in 2010 and approximately 2,600 were granted. Resident applications and registrations are consistently and significantly higher than non-resident applications and registrations. For trademarks, resident and non-resident trademark applications rose about three times while resident and non-resident trademark registrations grew almost seven times (600 per cent) from 1990 to 2009.

The financial crisis negatively impacts Africa's growth in technology transfer

Technology acquisition and transfer in this Review is indirectly measured in terms of royalties and licensing fees and also capital goods imports. Africa's royalty and licensing fee payments rose from a little over $250 million in 1990 to about $2.45 billion in 2008 before dropping marginally to $2.37 billion in 2009, following the financial crisis. That pace of growth is equal to that of Europe and Central Asia but lower than that of East Asia and the Pacific.

In terms of capital goods, the value of imports by African countries increased from about $7.3 billion in 1995 to $54.0 billion in 2008, representing an increase of over 600 per cent in capital goods imports over the period. Data for 2009 is still incomplete, but some of the major capital goods importing countries, i.e. South Africa, Nigeria and Morocco have reported reduced imports in 2009, presumably due to a knock-on effect of the global financial crisis.

Africa's information economies go wireless

Africa registered a fast growth in mobile phone subscriptions, from 1.7 per cent in 2000 to 44.7 per cent in 2010, an almost 26-fold increase. It is second only to the Arab world, which posted a 29-fold increase over the same period. Similarly, internet penetration in sub-Saharan Africa grew about 22 times from 2000 to 2010, faster than that of East Asia and the Pacific and Latin America and the Caribbean. However, there are wide variations in internet penetration among countries. There are at least seven African countries with Internet penetration of more than 25 per cent and 12 countries with an Internet penetration of less than 2.5 per cent.

The majority of Africans access broadband wirelessly. Africa's wireless broadband Internet access is growing faster than the fixed line broadband. By the beginning of 2010, about 95 per cent of the 19 million broadband subscribers in Africa accessed broadband via wireless technologies. However, the subscriber base is concentrated in a few countries such as Egypt, Nigeria and South Africa.

Africa is leading the mobile money revolution. Safaricom's M-PESA platform alone is used by 14 million users in Kenya and is generating a flow of about $300 million in person-to-person transactions each month

1 Egypt, Ethiopia, Madagascar, Mauritania, Morocco, Seychelles and South Africa

(about 10 per cent of Kenya's annual GDP). Similar services are now available in many other African countries such Democratic Republic of the Congo, Ethiopia, Madagascar, South-Africa, Tanzania and Zambia.

Technology infrastructure investment is on the rise

The number of submarine cables with landing points in sub-Saharan Africa has a total design capacity of 14.0 terabytes per second and this is expected to double by the end of 2012. A similar trend is observed in terrestrial transmission networks. In 2009, Africa had only 465,659 km of terrestrial high capacity transmission networks. This figure has increased to 676,739 know m by September 2011. In other words, about 36 per cent of Africans are within reach of operational fibre nodes, compared to 31 per cent in June 2010.

Africa is also claiming its place in satellite ownership and application. Among the pioneers, South Africa launched its first satellite, SUNSAT in 1999, and its second, SumbandilaSat, in 2009. Nigeria launched its first satellite, NigeriaSat-1, in September 2003 and its second and third, NigeriaSat-2 and NigeriaSat-X, in 2011. Today, there are several African-owned operational earth observation satellites in orbit such as Alsat-1 (belonging to Algeria), and Egyptsat-1 (belonging to Egypt).

Contribution of ICT to development in Africa

ICT service exports have become an important source of foreign exchange, employment, technological learning and diversification of the economies. As a proportion of total exports, ICT service exports from the continent increased from less than 0.1 per cent in 1990 to about 1.5 per cent of total exports in 2009, while that of ICT goods grew from 0 per cent in 1990 to about 0.4 per cent in 2009 of total merchandise exports. As such, the ICT sector is also a major employer in Africa. A greater percentage is employed in the mobile sector which accounted for approximately 1.4 percent of the total African workforce, suggesting a total workforce of 5.8 million people.

A rethink in STI policy formulation

Significant progress has been made in ensuring that STI is integrated into national development agendas. However, Africa still lacks well-informed and organized policy research institutions and advisory bodies to help identify key priority areas where countries may invest their limited resources and set clear and measurable targets. As a result, many African STI policies seem to be static rather than dynamic. A strategic and dynamic approach to STI policy design, development and implementation will help to significantly increase the policy impact.

Most STI policies to date on the continent are not designed to create a vibrant innovation ecosystem. While the importance of innovation in national development is recognized and expressed in key national development strategies, mechanisms to assess and track the performance of measures for "innovation climate" and "innovation culture" are lacking. Governments do not seem to monitor and evaluate the impact of their innovation policy measures. Notwithstanding ongoing efforts to measure innovation, there is an urgent need for African countries to improve their STI policy assessments and the monitoring and evaluation of the impact of their policy actions.

There are many legal and regulatory issues that need to be addressed to improve STI performance and development. For instance, very few African countries have national intellectual property policies that provide guidelines on ownership, protection and commercialization of publicly funded research products and processes. A survey of Ghana, Kenya and Zambia revealed that many institutions find the general lack of technology commercialization a hindrance to bringing technologies to market.

Besides legal issues, it was observed that the greatest hurdles faced by the R&D centres surveyed in commercializing their research include: lack of clear guidelines and policies for technology commercialization; limited time allocation for technology commercialization activities; low personal rewards and hence low motivation to undertake technology commercialization; the fact that technology commercialization is not a priority area for many institutions, including academic and research ones.

The pharmaceutical industry gathers momentum but lacks strategic policy direction.

The global market for pharmaceuticals is estimated to have reached $880 billion in 2011 and is expected to reach $1.1 trillion by 2014. Africa's pharmaceutical industry is relatively small, accounting for only about 1 per cent of the global market; and much of this is dominated by South Africa, Egypt and Nigeria. In 2006, the pharmaceutical market in sub-Saharan Africa was $3.8 billion. The sector is growing rapidly at an annual average rate of between 10 to 20 per cent.

Africa's exports of pharmaceuticals grew from about $287 million to roughly $800 million from 2000 to 2009, before falling slightly to $798 million in 2010. Egypt and South Africa account for more than 59 per cent of Africa's total pharmaceutical exports. Other major exporting countries of pharmaceutical products include Kenya, Morocco, Nigeria, Tunisia, Mauritius and Swaziland; these countries, collectively, account for an additional 30 per cent of Africa's total pharmaceutical exports. Pharmaceutical exports make up more than 1 per cent of total merchandise exports for Kenya and Swaziland. Interestingly, these percentages compare favourably with Brazil and China but below that of India where pharmaceuticals make up more than 3 per cent of merchandise exports. Neighbouring and internal regional markets account for up to 98 per cent of Africa's pharmaceutical exports. Africa is, however, a net importer of pharmaceutical products.

There is an emerging capacity for basic research and discovery, clinical trials and final production and distribution on the continent. However, only a handful of African pharmaceutical firms have the capacity to reproduce or design their own active pharmaceutical ingredients for drugs and vaccines. In most countries in the world where pharmaceutical industries have emerged, there has been major Government support, strategically and legislatively, to assist and maintain the industry. This is lacking in most African countries.

The lack of a clear national strategic direction for the development of the pharmaceutical industry in many African countries is hampering the ability to exploit traditional knowledge and medicine to meet healthcare needs. Africa's ability to convert its abundant indigenous knowledge and medicinal plants into effective and acceptable health products remains low. While a number of databases have been created, there are very few dedicated national and regional R&D centres for traditional medicine.

There is also a low level of application of new and emerging technologies in the pharmaceutical sector. For instance, there are very few biopharmaceutical firms outside Egypt and South Africa and almost no pharmaceutical firms have adopted nanotechnology platforms in a significant way. As such, Africa is not participating in the global $92 billion market for biopharmaceuticals and $53 billion market for nanomedicine. These segments of the pharmaceutical industry are growing fast and the technologies are changing the way drugs are discovered, produced and delivered. For instance, nanotechnology has shown potential in improving the efficacy, targeting, toxicity and dosage of TB, Malaria and HIV/AIDS drugs, which are of particular interest in Africa.

Opportunities exist for pharmaceutical sector development. There is rapid expansion of the African market for pharmaceutical products (drugs, vaccines, diagnostics reagents, cosmetics and nutraceutical products). There is also an emerging research and development capacity in this sector, as well as some basic pharmaceutical production capacity. The number of African countries with good pharmaceutical research centres or

units is large enough to support intra-regional strategic alliances for R&D in, and manufacture of, pharmaceutical products.

There are also a number of general challenges to be addressed. Governments should recognize the strategic value of a strong indigenous pharmaceutical sector in terms of employment, revenues and balance of trade. Placing pharmaceutical R&D within a more general promotion of a research-driven innovation culture could be one strategy. In addition to building capacity, there is a need to appreciate the size of the market for active pharmaceutical ingredient (API) in order to justify investment in API production, a major bottleneck especially for landlocked countries. There may be a need to consider pan-African institutions that specifically promote healthcare innovation, undertake regulatory issues and promote and support industrial development.

CHAPTER 1

Africa's STI performance

1.0 Introduction

This chapter assesses Africa's trends in production of manpower by tertiary institutions of learning, especially in science, engineering and technology (SET) graduates at university level, and the trends in the number of R&D researchers and R&D expenditure. It also assesses academic and industrial research outputs by tracking trends in the number of papers published in peer-reviewed journals, intellectual property applications and registrations and technology transfer. The main goal is to track R&D capacity and activities and industrial learning in Africa.

1.1 Human capital development and availability

Every society needs qualified, skilled and talented individuals to generate new ideas, products, processes and commercial enterprises. From a science and technology perspective, such a stock of human capital can be divided into three broad classes: (a) science and technology leaders; (b) R&D managers; and (c) researchers.

Science and technology (S&T) leaders run, manage and coordinate the various disparate components of the innovation system to help create an environment for generating ideas and technological products, processes and commercial enterprises to meet a target national development agenda. They set the national goals and influence the activities of other players. Such leaders may include national funding agencies, ministries of science and technology, innovation promoters and academic and political leaders, among others.

Research and development managers influence R&D activities at the institutional level (e.g. university, R&D centre and commercial enterprise). R&D managers oversee the resource investment in areas where the institution is likely to generate the most value or returns. They further, help the institution navigate complex legal and regulatory issues, mobilize funding, pick areas of interest and foster beneficial relationships with other institutions, among others.

Researchers involved in R&D "are professionals engaged in the conception or creation of new knowledge, products, processes, methods, or systems and in the management of the projects concerned".[2] They include PhD students and post-doctoral workers involved in R&D activities. A country may have a high number of scientists and engineers but not all are involved in research for the creation of new ideas, products, processes or organizational systems.

The numbers of researchers, the work they are engaged in and the funds available for different types of research are the most straightforward indicators of research activity. Thus, in this review we focus on: (a) the generation of scientists and engineers at university level, i.e. the stock of researchers involved in R&D; and (b) R&D funding levels in selected African countries. While focusing on the "researcher category" of human capital discussed above, we acknowledge the importance of concentration of talented and visionary S&T leaders and R&D managers. Their absence, or poor performance, can paralyze the performance of the entire innovation system. Their presence and capabilities for a strong and effective system is critical.

2 World Development Indicators

1.1.1 Higher education trends – The case of university graduates

Investment in the generation of human capital in areas of importance to national development is seen as essential to meeting development challenges and realizing opportunities. For example, countries such as Nigeria and South Africa that depend on mining operations have institutions dedicated to training of mine managers and professionals. Agricultural-based economies such as Burkina Faso and Kenya are likely to invest heavily in the production of agricultural experts. Despite these biases in different economies, skilled manpower is required in all sectors of society. This makes generic training particularly important. For instance, engineers may be employed in a variety of sectors such as communication, education, energy, health, sanitation and transport among others.

It is evident that higher education plays a pivotal role in the socio-economic transformation of countries. The fast growth of countries such as the Republic of Korea was simultaneously accompanied by a rapid growth in university enrolment (Moyer, 2007). The recent fast pace of poverty reduction and economic growth in China has also been accompanied by a significant growth in university enrolment. For instance, the number of PhDs granted in China rose from about 3,000 in 1990 to about 50,000 in 2009 – higher than the combined total of PhDs granted by Germany and the United Kingdom (Cyranoski and others, 2011).

Box 1.1: Attracting top universities to improve quality of education: Case of China

The case of China could be of interest to African countries seeking to develop their human capital. China has setup science parks to attract top universities from developed countries, set goals to increase the number of foreign students studying in China and sought to increase recruitment of foreign teaching and research staff. Also, foreign universities are encouraged to cooperate with local universities in a bid to improve the standard of education. For instance, the University of California, Berkeley is establishing a campus for the School of Engineering in Shanghai. The campus will focus on research in telecommunication, green technology and manufacturing, and biotechnology. This deal involves cooperation with the Shanghai Jiaotong University and Fudan University on curriculum development.

The number of foreign students studying in China's universities is estimated to have increased from about 52,000 in 2000 to about 240,000 in 2009 – almost a five-fold increase in a decade. This is 8 per cent of the global 3 million university students studying outside their home countries. Countries such as Brazil, China, India and South Africa are also starting to attract foreign students. Foreign students can provide a major business for local universities and economies: a single university student can easily spend in excess of $10,000 to $100,000 for fees and services over the course of his/her studies. It may also be seen as a measure of quality of education. Good universities attract more applications from students at home and abroad. The extent to which African countries are broadly establishing themselves as attractive learning centres is not well understood.

Source: Zhao, L. (2011) available from http://www.nytimes.com/2011/11/17/world/asia/cal-berkeley-reveals-plan-for-engineering-center-in-china.html

Higher education enrolment in Africa remains very low in comparison to the rest of the world. About 6 per cent of the tertiary education cohort was enrolled in tertiary institutions in sub-Saharan Africa in 2008 (UNECA, 2010). This is much lower than that of Asia (26 per cent), Latin America and the Caribbean (38 per cent) and the Organisation for Economic Co-operation and Development (OECD) (70 per cent). However, it is perhaps important to point out that tertiary enrolment in Africa is estimated to have been growing at an annual rate of about 15 per cent in the last decade, more than matching population growth of the tertiary education cohort. This accounts for the increase in the enrolment ratio from about 4 per cent in 2000 to 6 per cent in 2008. In some countries, the growth has been staggering. For example, from 1999 to 2010, some increases recorded were: 1950 per cent for Angola, 980 per cent for Djibouti and 770 per cent for Ethiopia.[3]

3 Estimates based on UNESCO datacenter http://stats.uis.unesco.org/

Quality remains a major source of concern. As shown in Table 1.1, the number of African universities in the top 500 remains low (only 4). South Africa had three universities in the top 500 and Egypt had one university while China had 42 and Brazil 6. While the rankings of universities seem academic, they are assuming significant importance beyond academic circles. For instance, a number of countries are defining "skilled or educated workers" based on graduation with a masters or PhD from top-ranked universities.[4] They have become a measure of quality of university education as they often look at the outputs of the university: number of awards and recognitions received by staff and alumni, papers published in top journals (nature and science) and publication of highly cited papers, among others.

Table 1.1: 2012 Ranking of the top 500 universities in the world

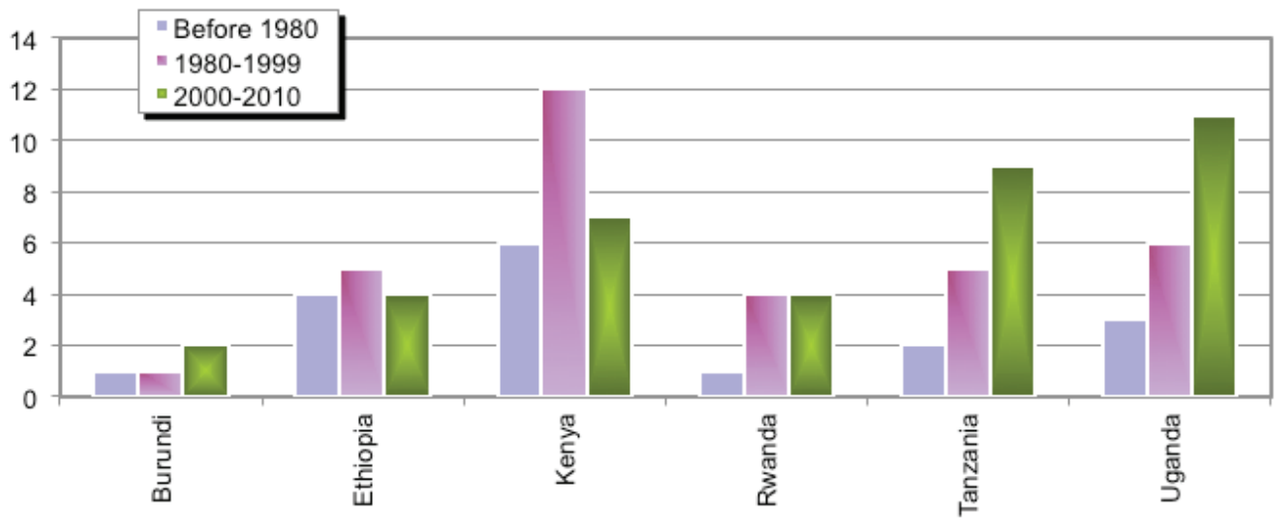
	Top 20	Top 100	Top 200	Top 300	Top 400	Top 500
Northern America	17	57	92	126	155	172
Latin America	—	—	3	4	7	10
Europe	2	31	75	123	158	202
Asia	1	7	22	35	60	88
Oceania	—	5	8	11	18	24
Africa	—	—	—	1	2	4
Selected countries						
United States	17	53	85	109	137	150
China	—	—	7	15	24	42
Brazil	—	—	1	2	5	6
Singapore	—	—	1	2	2	2
Argentina	—	—	1	1	1	1
Saudi Arabia	—	—	—	1	3	3
South Africa	—	—	—	1	2	3
Egypt	—	—	—	—	—	1
Malaysia	—	—	—	—	—	1

Source: Academic Ranking of World Universities (http://www.shanghairanking.com/)
NB: Each column should be read independently

Notwithstanding the issues of quality, university establishments in Africa have been expanding rapidly, both in terms of number and size, though the total number of universities is not documented. Based on the World University Rankings, Africa has more universities than India. A closer look at East African countries revealed that their combined total of universities founded before 1980 was only 17. By 2010, an additional 70 universities had been established and included in the World University Rankings (see Figure 1.1). The number is an underestimate because not all universities are included. For example, Kenya, according to its Commission of Higher Education (UNESCO, 2010) has about 23 public and private registered universities and another 11 with interim letters of authorization, which are not recorded in the World University Rankings.

4 Holmes, R. (2012) Power and responsibility – The growing influence of global rankings, University World News, Global Edition Issue 228

Figure 1.1: Number of universities established in East African countries by date founded



Source: www.4icu.org/

The number of students in established universities has also exploded since the 1980s. For example, a total of about 59,193 students were enrolled in the entire university system in Kenya in 2000. A decade later, the University of Nairobi in Kenya alone had about 60,000 students. Similar trends have been observed at other established universities such as Makerere University and Addis Ababa University. The remarkable growth in university student enrolment in Africa in the 2000s follows on from the huge expansion of primary and secondary school systems in the 1980s and 1990s.

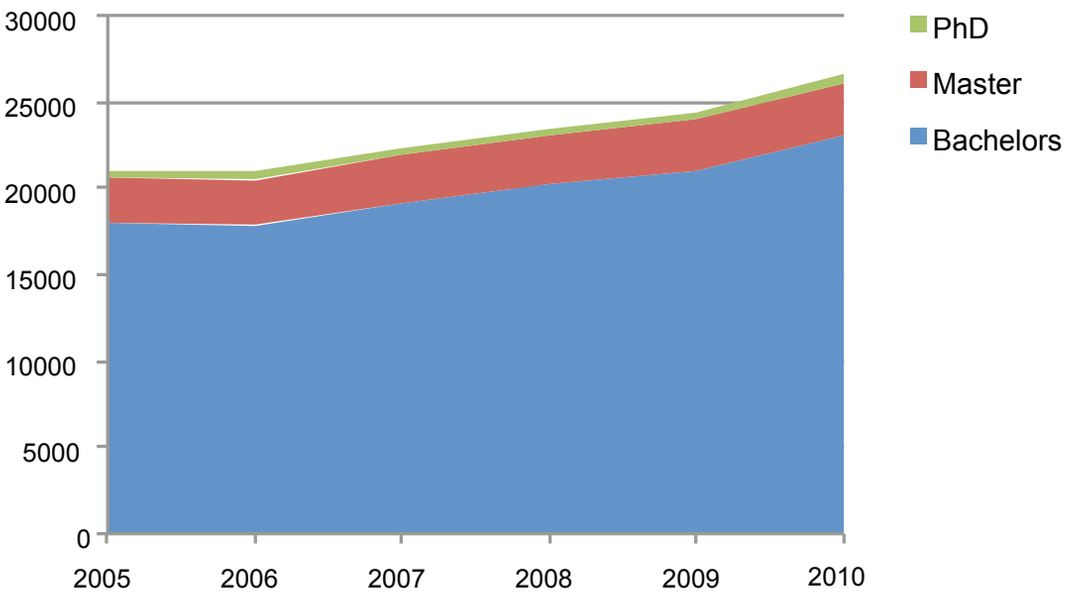
In order to gain a detailed insight, UNECA surveyed several universities and received complete data on enrolment and graduation from nine established universities.[5] As established universities, their growth trends are less than for new universities, but their information is still indicative of ongoing transformation of the higher education sector. The data focused on the number of students admitted each year by the universities (entrants) and the number of students graduating each year (graduates) at three levels – bachelor's, master's and PhD. It also looked at staff establishment and their qualifications at three levels – academic (researchers and lecturers), management and technicians.

The data revealed that student enrolment for the nine universities grew by about 19 per cent from 2005 to 2010, with first year intakes increasing from 43,000 to about 53,000. The fastest growth was recorded in natural sciences (56 per cent), followed by forestry and environment (36 per cent), engineering (32 per cent) and mining (31 per cent). This growth rate is expected to be significantly higher for the hundreds of new universities that have been established in Africa since 2000.

In the Science, Engineering and Technology (SET) fields, the number of students admitted to PhD programmes has grown much faster than those admitted to Bachelor's or Master's programmes for the 9 universities surveyed. New entrants into PhD programmes grew by about 52 per cent between 2005 and 2010 while the rate of growth for new entrants into BSc and MSc programmes grew by 32 per cent and 16 per cent, respectively. An increase in PhD students may indicate an increase in research activity at the universities.

5 Cape Town University (South Africa), Durban University of Technology (South Africa), ILORIN University (NIGERIA), Rhodes University (South Africa), Stellenbosch University (South Africa) University of Pretoria (South Africa), Makerere University (Uganda), University of Algiers1 (Algeria), University of Mauritius (Mauritius) and University of Limpopo (South Africa)

Figure 1.2: Growth in number of entrants by level of study in science, engineering and technology at nine African universities



Source: UNECA survey of universities

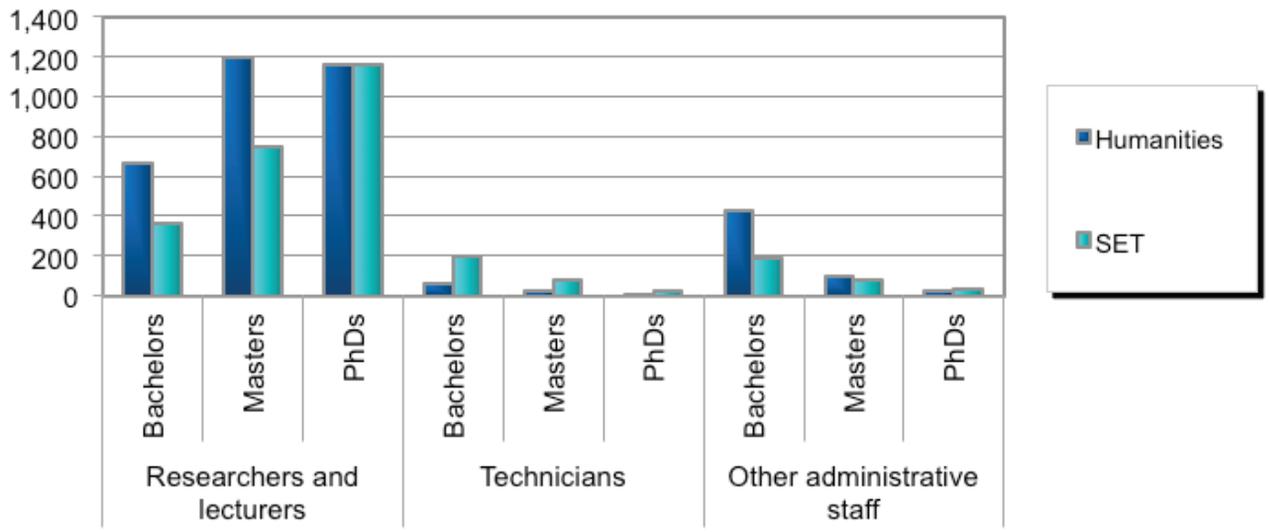
A major concern as universities undergo this expansion is the maintenance of quality. Graduation rates and drop-out rates as measures of quality assessment will need to be monitored carefully. There are no figures for dropout rates, but a brief report based on student surveys indicates that average dropout rates across the continent may be as high as 50 per cent[6]. For example, South Africa reported that 30 per cent of students who enrolled in higher education in 2000 dropped out in their first year and 20 per cent dropped out during their second and third years. Only 22 per cent graduated within the specified three years duration for a generic Bachelors degree. Estimates suggest that dropout rate was costing the Government about "R4.5 billion (about S$ 625 million) in grants and subsidies to higher education institutions without a commensurate return on investment" (Letseka and Maile, 2008). The two authors estimate that higher education graduate rate in South Africa is about 15 per cent. By comparison, the same authors report the dropout rates for the United States (46 per cent), United Kingdom (16 per cent), Germany (28 per cent) and France (45 per cent). In another study focusing on South Africa (Letseka and Maile, 2008), it was reported that 30 per cent of students who enrolled in higher education in 2000 dropped out in their first year and 20 per cent dropped out during their second and third years. Only 22 per cent graduated within the specified three years duration for a generic Bachelors degree. Estimates suggest that the dropout rate was costing about "R4.5 billion (about US$ 625 million) in grants and subsidies to higher education institutions, without a commensurate return on investment". The two authors estimated the higher education graduate rate in South Africa to be about 15 per cent.

Staffing of African universities

One of the challenges that African universities face is the shortage of highly qualified and experienced researchers, lecturers, technicians and management staff. The UNECA survey of the nine universities revealed that less than 50 per cent of researchers and lecturers held PhDs (see Figure 1.3). The figure was lower for the humanities and social sciences (38 per cent) than in SET-related fields (51 per cent). The numbers of researchers and lecturers holding PhD qualifications may be substantively lower in some of the new universities being established.

6 For details, see the Harvard University's Higher Education in Africa project at http://ent.arp.harvard.edu/AfricaHigherEducation/Data.html

Figure 1.3: Staff qualification for nine selected universities



Source: UNECA survey of 9 universities

An increase in the number of PhD lecturers and researchers in African universities is critical for university capacity to initiate indigenous research and to award their own postgraduate degrees such as PhD. In general, one needs to hold a PhD to be able to properly supervise a PhD student.

If the overall trend of growth in higher education is sustained, Africa could catch up with the rest of the world in the next few decades. It is noteworthy that key partners, such as the World Bank (Bloom and others, 2005), which, until recently, operated policies based on the assumption that investment in primary and secondary education yielded greater returns for the economy than higher education, are modifying their policies and significantly investing in higher education. A recent study supported by the World Bank concludes that "It is encouraging that the World Bank has come to the realization, albeit late, that the neglect of higher education spells doom, not only for other levels in the educational structure, but for meaningful human development" (Tettey, 2006). There is a need to increase investment in higher education to meet the increasing demand and foster technological and economic development.

1.1.2 Africa's R&D researchers and their qualifications

Data collection on R&D researchers in Africa has just started. The first set of systematic surveys are being undertaken by the NEPAD ASTII initiative, which currently covers a small, but growing, proportion of African countries (AU-NEPAD, 2010). Continued efforts to collect and collate such data will yield improvements in both the quality and quantity of such data. The first survey showed a low number of researchers in all African countries.

For the 13 countries covered in the first survey, the number of researchers per million inhabitants ranged from fewer than 30 in Mozambique, Uganda and Ghana to a high of over 500 in Senegal and South Africa (see Table 1.2 for details). South Africa's figure of 815 researchers per million population is comparable with that of countries such as Brazil, but is a lot lower than that of innovative economies such as the Republic of Korea (4,627 researchers per million inhabitants). Another area of concern is that over half of the countries in the survey have fewer than 1,000 researchers in total.

Table 1.2: Number of researchers involved in R&D

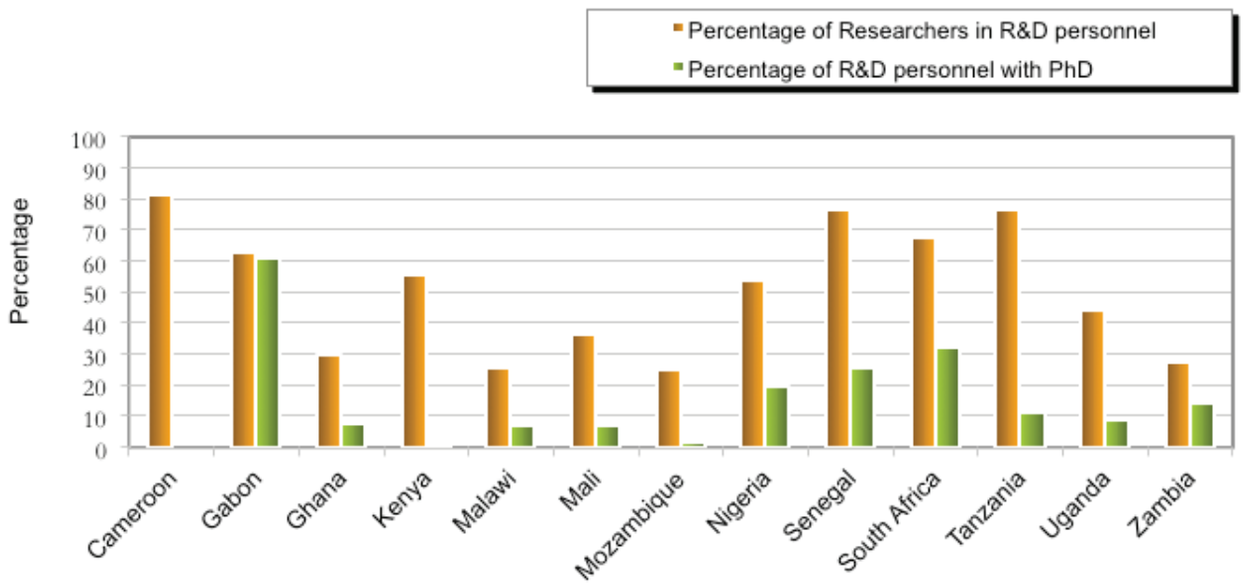
Country	Total researchers (headcount)	Researchers per million inhabitants
Mozambique	522	24
Gabon	527	371
Zambia	612	50
Ghana	636	28
Malawi	733	49
Uganda	785	26
Mali	877	71
Tanzania	2755	67
Kenya	3794	100
Cameroon	4562	244
Senegal	7859	661
Nigeria	17624	119
South Africa	40084	815

Source: AU–NEPAD (2010), African Innovation Outlook 2010, African Union–NEPAD, Pretoria, South Africa

The level of postgraduate qualifications is low (see Figure 1.4). Only three countries (Gabon, Senegal and South Africa) have more than 20 per cent of their total R&D personnel with PhD qualifications while two countries (Mozambique and Kenya) reported less than 2 per cent of their R&D personnel having PhDs (AU-NEPAD, 2010).

The NEPAD survey also sought to distinguish between R&D personnel and "researchers". R&D personnel are those associated with research, but may not be active researchers themselves. They may be administrators or support or other staff. The data are presented in Figure 1.4. In about half of the countries surveyed, researchers make up less than 50 per cent of R&D personnel and R&D personnel with PhD qualifications make up less than 30 per cent in all the countries except Gabon and South Africa. More clarification on this data is needed. It could be that: (a) the research institutions in these countries are involved in R&D activities that require a substantial proportion of technical and support staff (e.g. surveys and trials); and/or (b) that there is an administrative structure in place for activities but limited funding to actually employ researchers to undertake research; and/or (c) there is simply lack of PhD holders to occupy research posts.

Figure 1.4: Characteristics of R&D Personnel in Selected African Countries



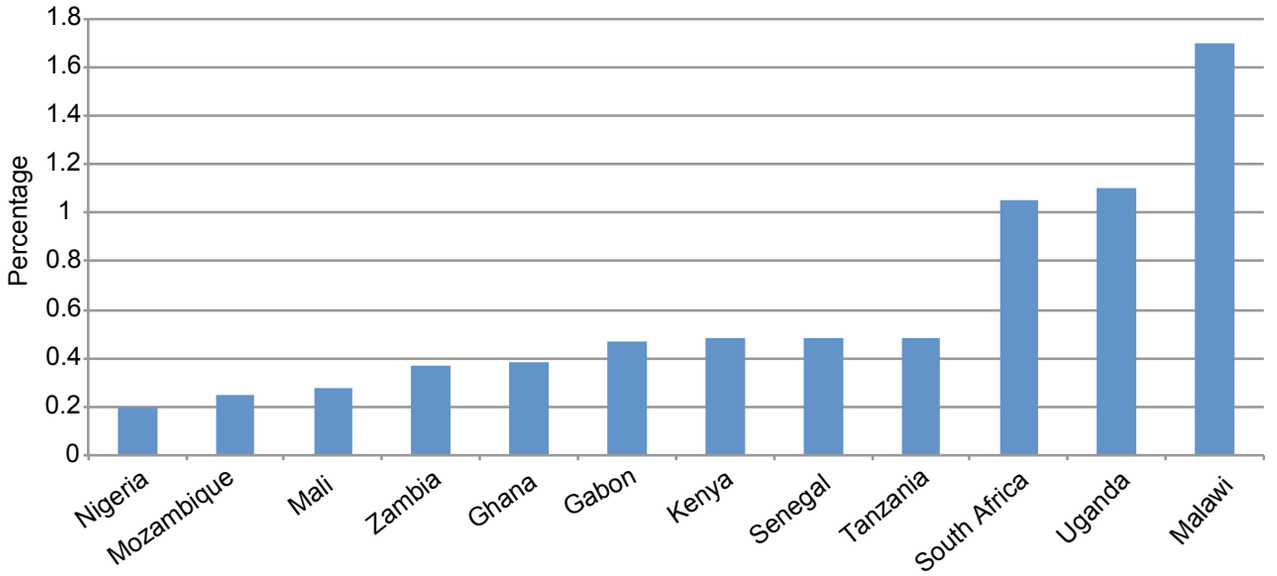
Source: AU–NEPAD (2010)

1.1.3 National R&D expenditure

African Governments have committed themselves to working towards investing about 1 per cent of their gross domestic product (GDP) in R&D (AU-NEPAD, 2010). This target has a different impact in different economies. For instance, 1 per cent of GDP for South Africa and Malawi is equivalent to about 3 per cent of national expenditure (budget) while it is more than 6 per cent of national expenditure in Ethiopia and Nigeria. Similarly, 1 per cent of GDP may be as little as $100 million in Guinea-Bissau and as high as $6 billion for South Africa. Thus the target could have a small or major impact in driving R&D activities, depending on the background economic status of the country concerned. Despite those difficulties, it is a good starting point for mobilizing R&D investment in Africa.

Of the countries surveyed by the NEPAD initiative, only Malawi, Uganda and South Africa had attained the targeted 1 per cent of GDP expenditure on R&D activities by 2008 (see Figure 1.4). However, 1 per cent of GDP presents a huge difference in absolute investment value among countries, and determines the amount of research activities they can support. For example, South Africa invests about $5 billion a year while Malawi invested only $180 million in R&D activities and yet, as a proportion of GDP, Malawi invested more in R&D than South Africa did. This difference in amount invested has a major influence on the number of R&D activities that a country can support. Significantly, 33.1 per cent of Malawi's R&D funding came directly from foreign sources, and it may be that other funding came indirectly from foreign sources, whereas only 10.7 per cent of the R&D expenditure in South Africa came from foreign sources. Therefore, care needs to be taken in interpreting R&D investments.

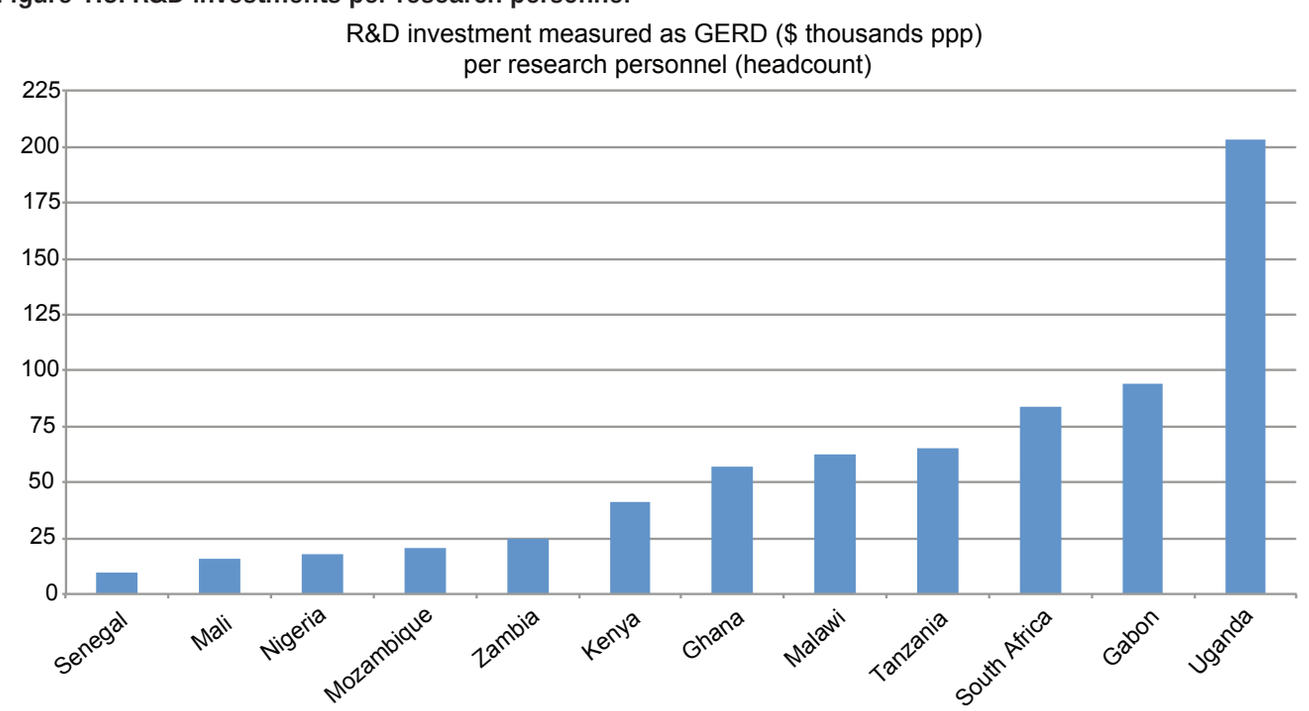
Figure 1.5: Gross expenditure on R&D as a percentage of GDP



Source: UNECA survey of universities

A potential measure of the intensity of R&D is to assess the level of investment per R&D personnel, whether in universities and research centres or private firms. Using the data generated by the NEPAD survey, we estimate that Uganda invested about $200,000 per R&D personnel followed by Senegal, Gabon and South Africa (Figure 1.5). The survey results indicate that investment per R&D personnel is low in many African countries and less than $70,000 per person in two-thirds of the countries surveyed. If salaries and other personnel benefits (pension, education etc.) and utilities are deducted, there may be very little left to directly invest in R&D in such countries.

Figure 1.6: R&D investments per research personnel



Source: AU-NEPAD (2010)

There is thus evidence that while overall investment in R&D is increasing, it is still too small in most countries to significantly fund projects and programmes, acquire adequate physical infrastructures in priority

areas, improve wages of personnel and enable the R&D institutions to perform and yield meaningful outputs. There is also ample evidence of a growing cadre of human capital necessary to undertake research in many countries, although supplementary training of PhD graduates is urgently needed.

1.2 Trends in science and engineering knowledge generation in Africa

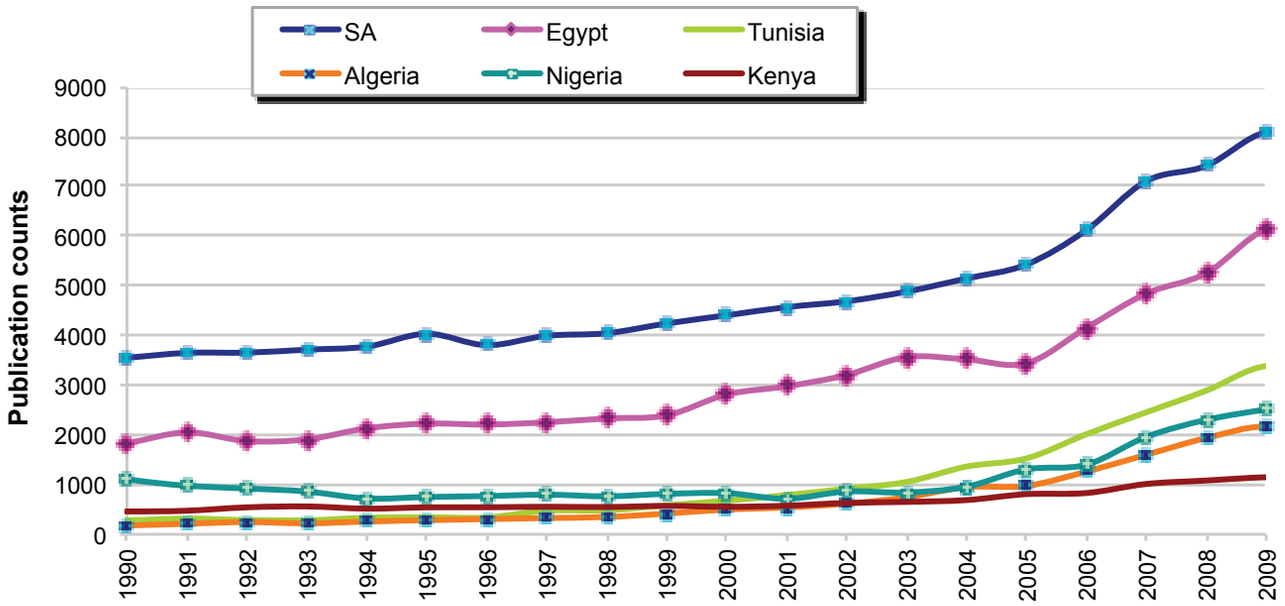
This section discusses Africa's performance in generating knowledge in science and engineering fields and its trends in research collaboration, using quantitative bibliometric data and scientometric analysis. Scientific publication is a necessary condition for communicating research findings and a well-recognized indicator for research performance. The data referred to in this review were obtained from the Institute for Scientific Information (ISI), a recognized leader in documenting scientific information and associated publications.

1.2.1 Science and engineering research performance

The investigation of countries' performances in knowledge production and collaboration patterns was carried out first at the aggregate or macro-levels of the country, and then at the micro-level of the field (subject area). A particular emphasis was given to some major health issues on the continent, mainly malaria, HIV/AIDS and TB research. Other research areas including drug, geoinformatics and ICT are also discussed. Countries were randomly selected among the strong and poor performers in research publishing, from North, South, East, West and Central Africa and among Francophone, Anglophone, Arabic and Lusophone countries. A comparison was made with some developed and developing countries from Europe, Asia and America.
In general, Africa has registered a remarkable increase in its number of scientific publications as shown in Figure 1.7, Figure 1.8 and Figure 1.9. The figures are divided to allow comparison at different levels of overall publication. The overall trend reveals a steady increase in publication rates from 1990-2010. For most countries the rate of increase became much more marked from about 2000 onwards. Only the Democratic Republic of the Congo exhibited a decrease from 2000 onwards.

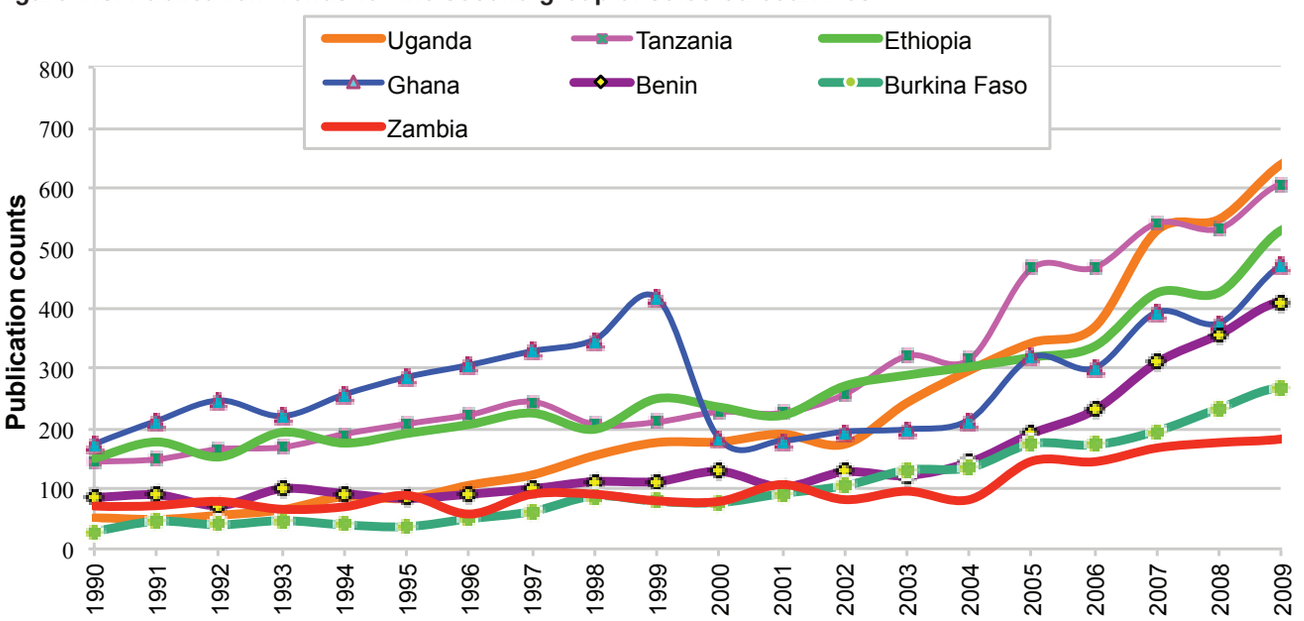
South Africa produced the highest number of papers from 1990 to 2009, followed by Egypt, Tunisia, Algeria and Nigeria. Of these, Tunisia recorded the fastest growth in the number of papers published – from about 300 in 1990 to over 3,000 in 2009. The second and third groups of countries (shown in Figure 1.8 and Figure 1.9) have also shown remarkable growth. In particular, Uganda saw its number of papers increase by more than 1,200 per cent from 1990 to 2009. The return to peace, steady investment in science and technology, expansion of R&D institutions and political support may account for the huge surge in the number of papers published by Uganda. As noted earlier, Uganda is investing heavily in research and had the highest expenditure per R&D personnel (Figure 1.6).

Figure 1.7: Publication trends for the first group of selected countries



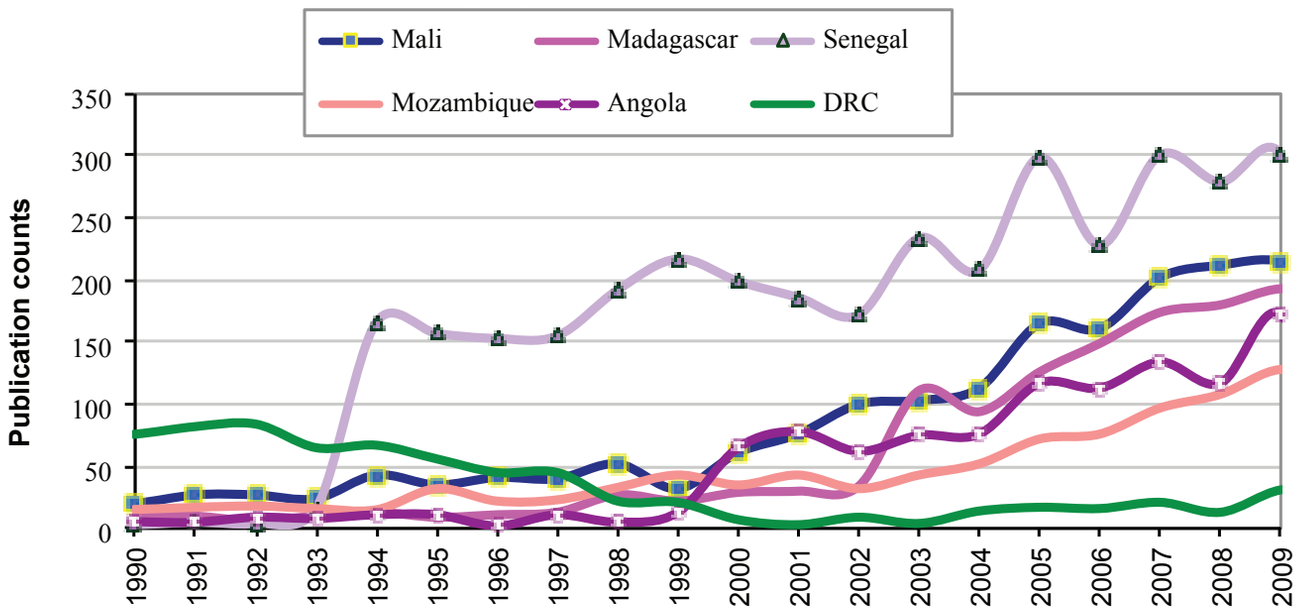
Source: ISI data, UNECA analysis, 2011

Figure 1.8: Publication trends for the second group of selected countries



Source: ISI data, UNECA analysis, 2011

Figure 1.9: Publication trends for third group of selected countries

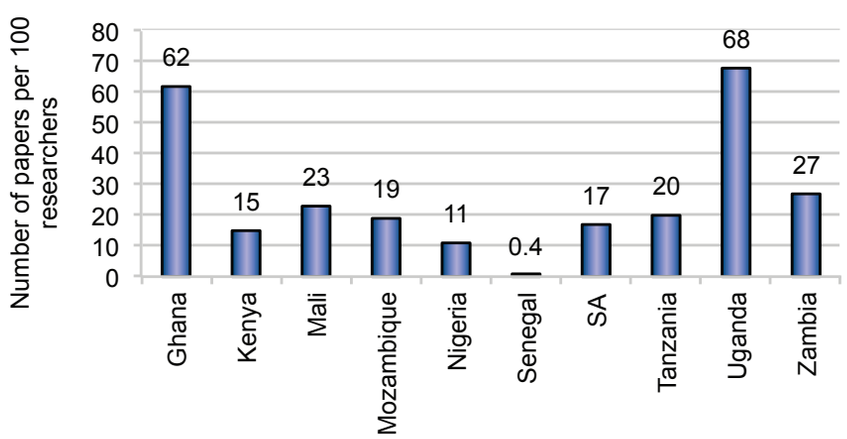


Source: ISI data, UNECA analysis, 2011

If this trend continues over the next few decades, Africa may start to compete internationally as an emerging producer of science, engineering and technology knowledge of global interest. As African economies expand, investment in R&D will also grow, and private sector participation in R&D may further increase to drive knowledge production on the continent.

In order to compare country performance relative to their level of economic development and technological sophistication, one can measure knowledge production against R&D resources invested. One such key resource is the number of R&D researchers that are responsible for most of the publications. As outlined in Figure 1.10, Uganda and Ghana out-perform the other countries in terms of numbers of papers published per researcher by a factor of 3. Overall, 100 African researchers produce about 20 papers a year if one discounts Uganda and Ghana. It is possible that most African countries are not fully exploiting the potential of their researchers. A similar pattern of efficiency in terms of publication per GDP was documented by NEPAD (2010).

Figure 1.10: Research publications per 100 researchers 2007-2008



Source: ISI data, UNECA analysis, 2011

The publication profiles of Egypt, Kenya, Nigeria and South Africa are shown in Table 1.3. They reveal that the most active areas of research include health sciences, engineering, chemistry, biological sciences, physics and astronomy. The prominence of health sciences is in line with the current focus on health and its related challenges (e.g. HIV/AIDS, malaria and tuberculosis, child and maternal health) at the global and regional level. Areas of limited research include mathematics and earth sciences, ICT and veterinary sciences.

There are major differences among the four regional representative countries. For instance, nearly half of all the papers published associated with authors in Kenya are in health sciences, while health sciences account for only about one-fifth of the papers published in Egypt and Nigeria. Similarly, research in agriculture and food sciences is prominent largely in Nigeria and Kenya while research in engineering and physics and astronomy seems to be prominent in Egypt and South Africa.

Table 1.3: Distribution of papers per field as percentage of their totals for selected countries (2000-2009)

country (total number of papers)	Health science	Engineering	Chemistry	Biological Science	Agriculture & Food Science	Physics & Astronomy	Meteorology/ Atmospheric Science	Polymer Science	Materials Science	Mathematics	Environmental science	ICT	Earth Science	Crystallography	Veterinary Science
South Africa (57,856)	30.1	12.6	7.3	2.6	5.4	10.4	0.8	0.6	3.8	2.1	10.9	5.0	6.3	0.1	2.0
Egypt (40,011)	21.6	15.4	15.7	6.5	2.9	13.7	0.2	2.2	5.5	4.0	3.2	6.6	1.7	0.3	0.6
Kenya (7988)	46.4	1.2	2.1	21.0	11.7	0.8	0.8	0.2	0.4	0.1	8.0	0.4	3.9	0.0	3.1
Nigeria (13,662)	23.1	7.2	9.0	20.1	18.0	3.5	0.8	0.5	2.8	1.7	7.0	1.1	3.2	0.1	1.9

Source: ISI data, UNECA analysis, 2011

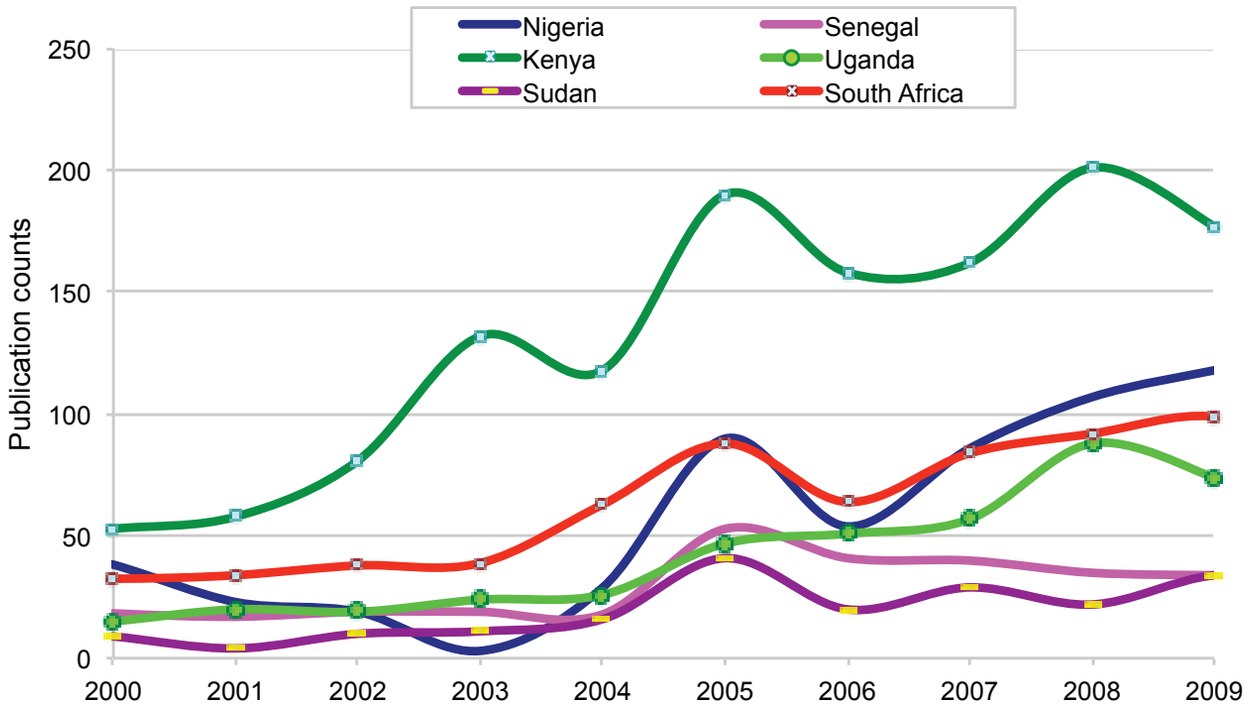
1.2.2 Publication trends in health sciences

In recent times, HIV/AIDS and malaria have been some major areas of international and national research focus. The following analysis aims to provide some insight on the contribution of the top publishing African countries (according to Adams et al, 2010) in these research fields.

As shown in Figure 1.11 and Figure 1.12, the total number of publications on malaria and HIV/AIDS research has grown steadily over the last decade in all the six countries. Kenya is the lead country for malaria, while South Africa leads in HIV/AIDS. For malaria, the number of publications more than tripled for Kenya, Nigeria and Uganda from 2000 to 2009. The number of publications on HIV/AIDS research increased more than 10 times from 2000 to 2009 in the four countries shown in Figure 1.12.

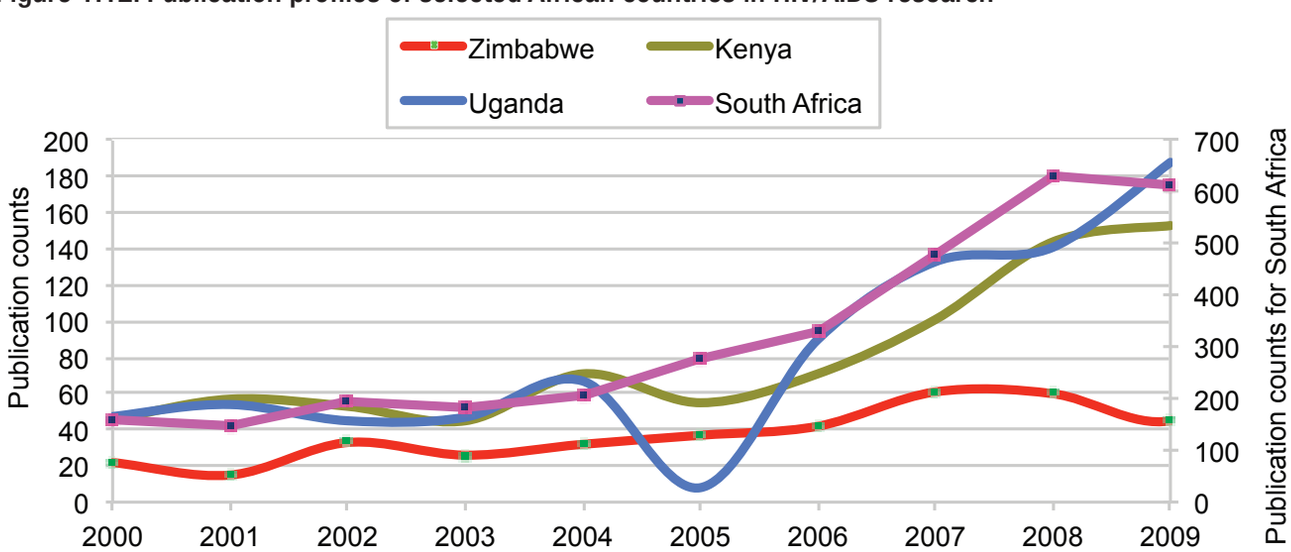
The increase coincides with the numerous international initiatives supporting Malaria, and HIV/AIDS control and research over the past decade. These include the Global Fund to Fight AIDS, Tuberculosis and Malaria; Roll Back Malaria; THE President's malaria initiative; and the President's Emergency Plan for AIDS Relief (PEPFAR). A number of Bill and Melinda Gates Foundation-funded public private partnerships for drugs, vaccines and diagnostics development were also created during this time. They include Medicines for Malaria Venture, Malaria Vaccine Initiative, International AIDS Vaccine Initiative and the Foundation for Innovative New Diagnostics. In addition, there has also been increased bilateral assistance and increased national budgetary support.

Figure 1.11: Publication profiles of selected African countries in Malaria research



Source: ISI data, UNECA analysis, 2011

Figure 1.12: Publication profiles of selected African countries in HIV/AIDS research



Source: ISI data, UNECA analysis, 2011

1.2.3 Africa's collaboration pattern in research science and engineering

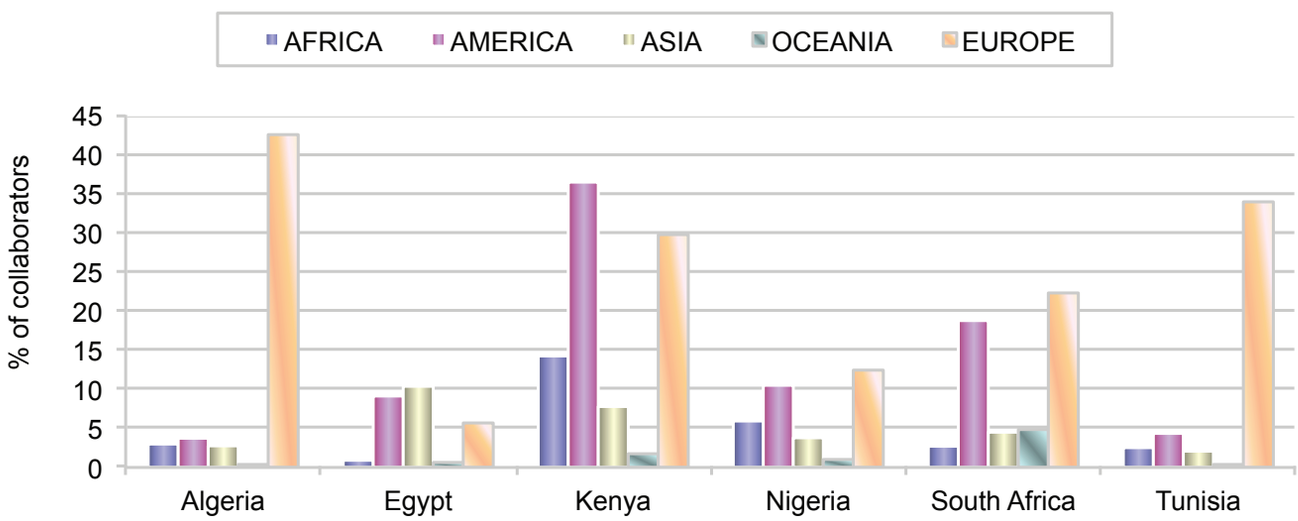
Research and development activities are becoming increasingly complex, costly and risky, and may require accesses to facilities, resources and skills beyond those owned or controlled by a single institution or firm. Networks and strategic alliances have become the mainstay of R&D activity in some of the knowledge and resource-intensive fields such as life sciences and information and communication. The major reasons for collaborative research include: quick access to specialized information; skills and business support; reduction in transaction cost of learning; access to research infrastructures (specialized equipment); and funding, especially in countries with a weak domestic technology base (Lubango and Pouris, 2009; Landry and Amara, 1998; Meneghini, 1996; Menelin and Persson, 1996).

One way of assessing collaborative research outputs taking place in a country is through co-publications (Menelin and Persson, 1996), as it measures both the quality of knowledge generated (i.e. it is worth publishing) and the end product of a research exercise. It can also be used to identify the home countries of collaborators and the role of researchers in collaborative research.

This analysis used an extended Lotka's law (Sobrino, Caldes and Guerrero 2008) for counting co-authors. The percentage of authors for a particular country indicates the frequency of occurrence of a country's scientists in a work (or a paper) being published. The overall per cent of authors in the figures below could thus collectively be greater than 100 per cent, as the per cent of national authors is about 100 per cent and that of co-authors is based on the number of co-authored published works, not on the overall numbers of co-authors.

The analysis of co-authored papers in the top publishing countries on the continent (Algeria, Egypt, Kenya, South Africa and Tunisia from 2000 to 2009) is given in Figure 1.13. A notable fact from this figure is the low level of intra-African collaboration. Almost all collaboration is external to the continent. Europe is the top collaborating partner collectively for these countries, followed by America and Asia. There is significant country to country variation. For example, European collaboration dominates in Tunisia, American collaboration dominates in Kenya and Asian (including the Middle East) collaboration dominates in Egypt.

Figure 1.13: Collaborative research outputs of five top publishing countries in science, engineering and related research



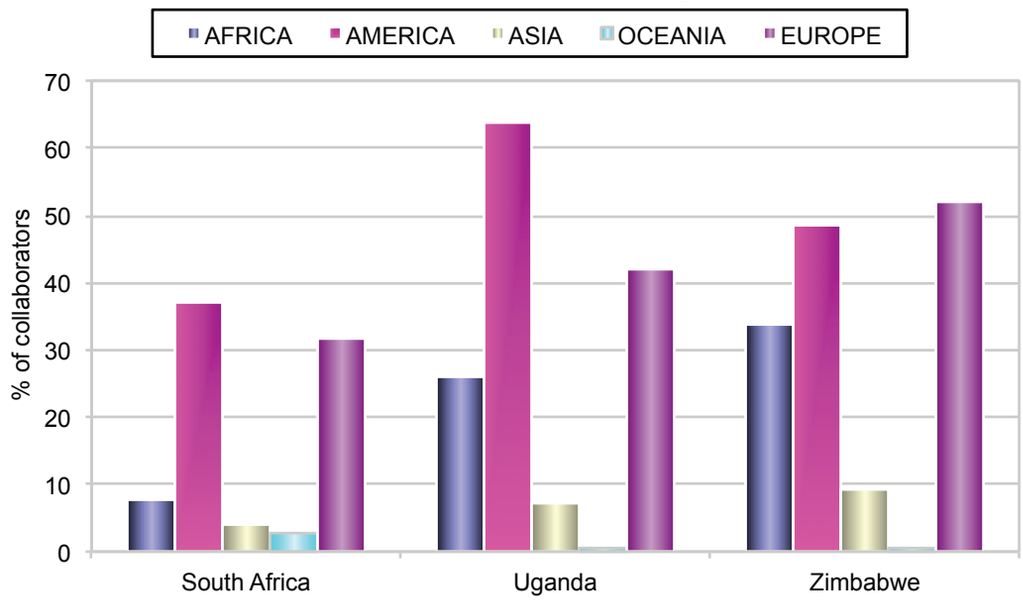
Source: ISI data, UNECA analysis, 2011

It is apparent that historical and cultural links, as well as language, play a key role in determining external collaborations. For example, Francophone countries tend to collaborate with other Francophone countries in and outside the continent (e.g. France, Belgium, and Canada), while Anglophone countries tend to collaborate with other Anglophone countries on the continent and with the USA UK and Germany outside the continent.

The desire to translate the emerging regional economic communities (RECs) into vibrant research networks with superior outputs and outcomes has not fully materialized. However, this is still in the embryonic phase. Most collaborative researchers are still funded or supported by partners outside the continent. More regional and national funding, and international funding directed to African principal investigators, is needed to facilitate the generation of African-led research and innovation.

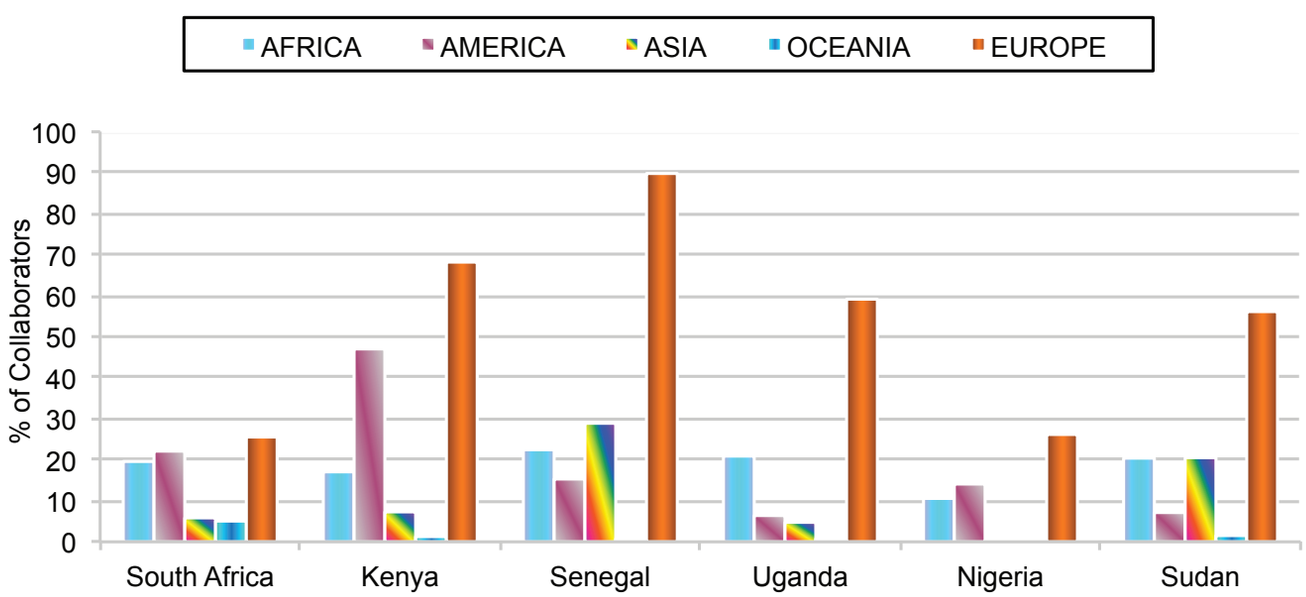
For health research, there is an increasing trend towards collaboration within Africa, but there are still many limitations. Figure 1.14 outlines the collaborative research outputs of top publishing countries in HIV/AIDS research, from 2000 to 2009, based on co-publication. The trend of low intra-African collaboration is again prominent. For South African papers, only 7.72 per cent of collaborators were from Africa. For Ugandan papers, there was a higher figure of 26 per cent, most originating from collaborations with South Africa. For Zimbabwean papers, the figure was 33.78 per cent, again most originating from collaborations with South Africa.

Figure 1.14: Collaborative research outputs of top publishing countries in HIV/AIDS research



Source: ISI data, UNECA analysis, 2011

Figure 1.15: Collaborative research outputs of top publishing countries in malaria research



Source: ISI data, UNECA analysis, 2011

Figure 1.15 outlines the collaborative research output of top publishing countries in malaria research, from 2000 to 2009, based on terms of co-publication. Intra-African collaboration outputs were relatively high for malaria research, up to around 20 per cent for many of the countries selected. However, this is still a lot less than for the European and American collaborations.

The above data illustrates the level of collaboration occurring at the level of individual investigators. A recent publication (Nwaka and others, 2010) strongly illustrates the lack of intra-African collaboration within health research at the institutional level. It found that approximately 95 per cent of institutional collaborative publications involving the top centres in the region had collaborations outside Africa.

1.3 Trends in intellectual property rights

The link between intellectual property rights (IPR), innovation, competition and economic growth has been the subject of many debates. These global debates led to the inclusion of IPR in the global trade rules of the World Trade Organization (WTO) through the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS).[7] The TRIPS agreements established globally agreed minimum standards for the protection and enforcement of IPR. For the first time, IPR became part of the same dispute settlement mechanisms as for other trade issues, should disagreements emerge among WTO members. Inclusion of IPR issues was perceived as possibly limiting the potential of poor countries as IPR infringements could lead to retaliatory actions on country exports of certain products. This is particularly important for developing countries seeking to develop export-led growth and to learn and catch up with leading innovating nations.

There is also an increasing link between university research and patent activity. American legislation in 1980, through the so-called Bayh-Dole of 1980[8] or Patent and Trademark Law Amendments Act, encouraged universities, research centres and industries to own and commercialize outputs from publicly funded research. Since then, variants of this legal framework have been adopted or are being discussed in a number of emerging and developing countries (UNCTAD-ICTSD, 2005).

Two broad categories of IPR are: (a) industrial rights; and (b) copyrights. Industrial rights refer to inventions in all fields and may include industrial design, patents, trademarks, service marks, commercial names and designations. Industrial rights protect the means of transmitting the invention (e.g. the blueprints of the designs, processes, techniques, products, services) and not the knowledge itself. Copyrights refer to rights that protect the exclusive use of literary, artistic and scientific works, including performances of performing artists, phonograms, and broadcasts, by the creator. This review will focus only on some industrial rights to provide an overview of inventive activities on the African continent. It will not cover copyright issues.

1.3.1 Trends in patent applications and registrations

Africa's global share of knowledge generation and ownership remains very small. Based on national reports to WIPO, the number of patent[9] applications worldwide grew from about 600,000 to over 1.9 million from 1980 to 2008, while patents granted increased from about 383,000 to about 759,000 over the same period. In other words, patent applications have nearly tripled, while patents granted have doubled since 1990.

It is difficult to fully assess Africa's patenting activity within the continent. African national data provided for the WIPO database is extremely erratic. For example, data was available for only 10 of the 36 African IP offices in 2006 and four IP offices in 2008. Only nine IP offices had data for 10 or more years for the period 1990-2009.

Given these limited records, it nevertheless appears that the total number of patent applications for Africa has not changed much over the last two decades. The number of patent application increased from about 13,500 in 1995 to about 15,400 in 2007. The total number of patents granted by IP offices in Africa increased from

7 TRIPS agreement came in force on 1 January 1995

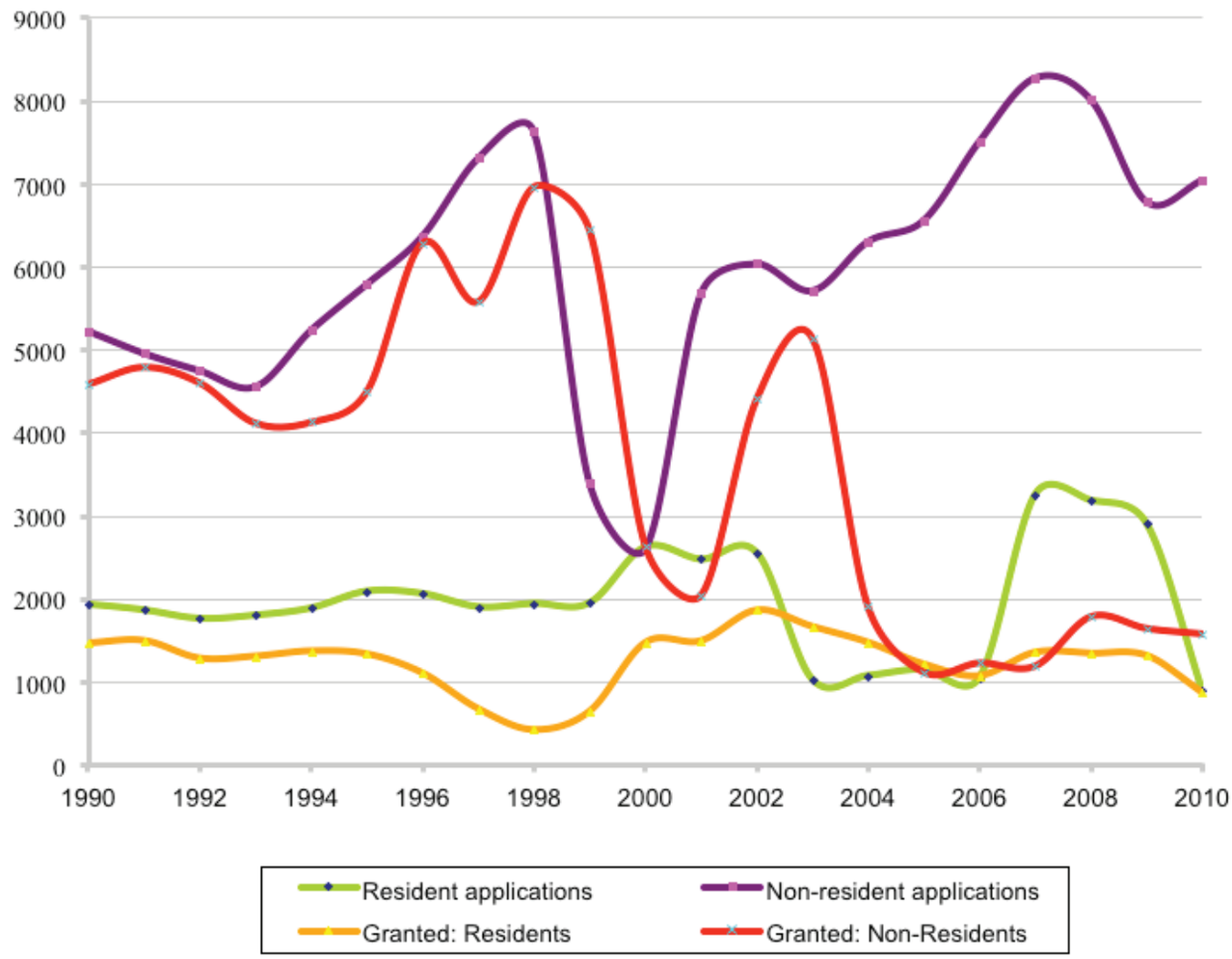
8 Bayh-Dole Act of 1980 or P.L. 96-517. Patent and Trademark Act Amendments of 1980

9 Unless explicitly stated, the term patent as used in this review refers to utility patents (i.e. patents for inventions) and therefore may not include design and plant patents or utility models. WIPO data generally reflect utility patents.

about 5,000 in 1990 to 9,000 in 2008. Over three-quarters of the patent applications and patents granted in Africa were by non-residents.

To gain some insights into trends on the continent, we use data from national offices of seven African countries.[10] Based on the data supplied, there is a small growth in the number of patent applications by both residents and non-residents. However, for these countries, there is a steady decline in the number of patents granted to non-residents, while the number of patents granted to residents has not changed much (see Figure 1.16).

Figure 1.16: Trends in patent application and registrations for seven selected countries



Source: UNECA IP survey

Most of the recorded fall in patents granted to Africa is due to a decline registered in South Africa. For instance, South Africa granted 5,429 patents in 1990. The number had fallen to 3,399 by 2000 and further to 1,468 by 2010. On the contrary, from 1990 to 2010, the number of patents granted by Morocco increased three times from 302 to 915. In Egypt, patent applications increased nearly 2.5 times and patents granted largely remained unchanged from 1990 to 2003. The widening gap between patent applications and patents granted may be due to reduced capacity of the patent offices to meet the increased demand.

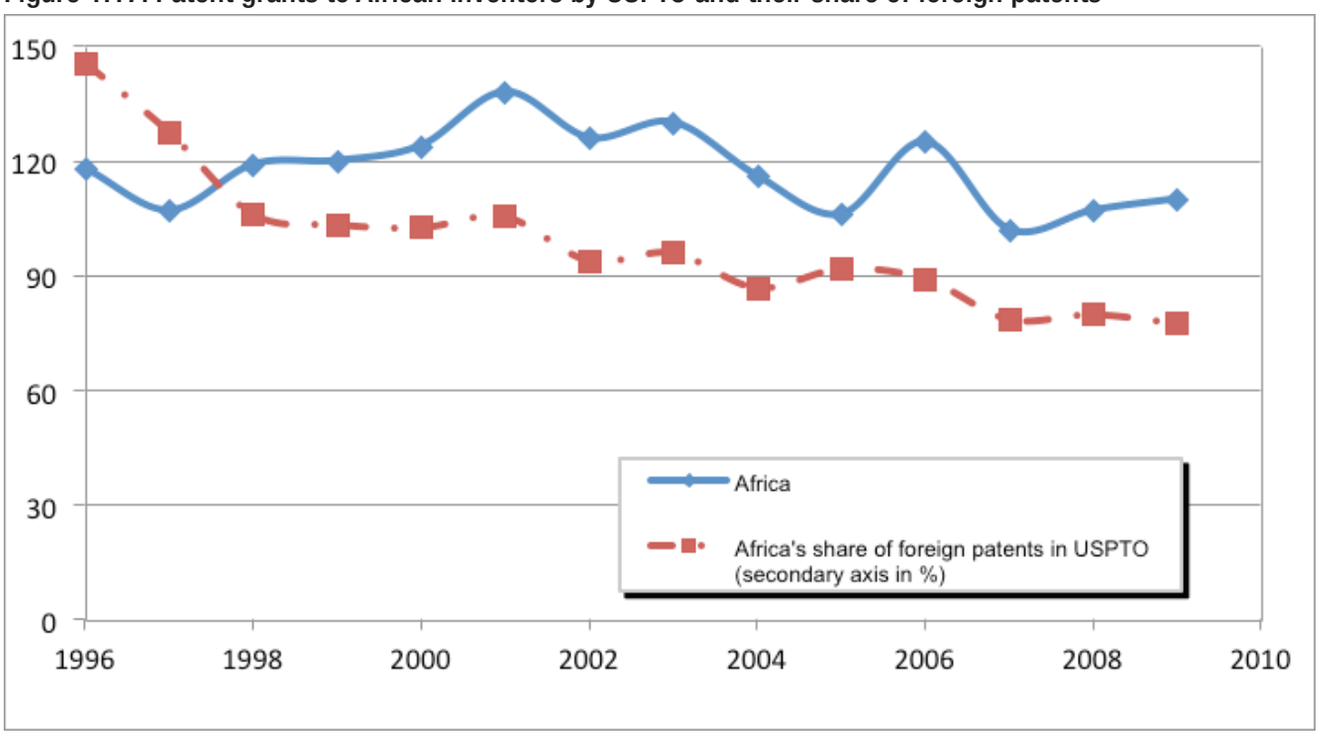
Another source of patent activity in Africa can be obtained through the United States Patents and Trademark Office (USPTO) which is seen as a global repository for knowledge, that inventors believe is worthy of protecting in one of the most competitive, dynamic and innovative markets. Given the cost of seeking patents

10 The seven countries are: Egypt, Ethiopia, Madagascar, Mauritania, Morocco, Seychelles and South Africa

in the United States of America, only knowledge that inventors or owners strongly feel is valuable is likely to be protected through the USPTO.

A graph illustrating actual patents granted to African inventors by the USPTO and their overall percentage of non-US patents from 1997 to 2009 is shown in Figure 1.17. In general, the number of African patents granted by USPTO has remained constant at around 140 per year and Africa's share of foreign patents granted by the USPTO has decreased from around 0.2 per cent to 0.12 per cent. Granted patents are dominated by South Africa (1460) followed by Egypt (77) and Kenya (45). Only four other countries registered more than 10 patents over the 12 year-period, namely Morocco, Nigeria, Zimbabwe and Tunisia.

Figure 1.17: Patent grants to African inventors by USPTO and their share of foreign patents



Source: USPTO

A large proportion of these patents is owned by individuals or universities and public R&D centres. For instance, about 40 per cent of the patents granted to residents in Egypt and 26 per cent of patents to South Africa were individually owned. In contrast, individually owned patents granted to residents of Finland and the Republic of Korea by the USPTO over the same period make up only 3.1 per cent and 2.8 per cent respectively. This underscores the fact that Africa has not yet developed innovative firms that can compare with the likes of Nokia in Finland and Samsung and LG in the Republic of Korea, which account for more than 60 per cent of the patents issued by USPTO to residents in these countries. In general, Africa needs to nurture and develop innovative firms as well as inspire its firms to invest in R&D activities.

1.3.2 Trends in industrial designs

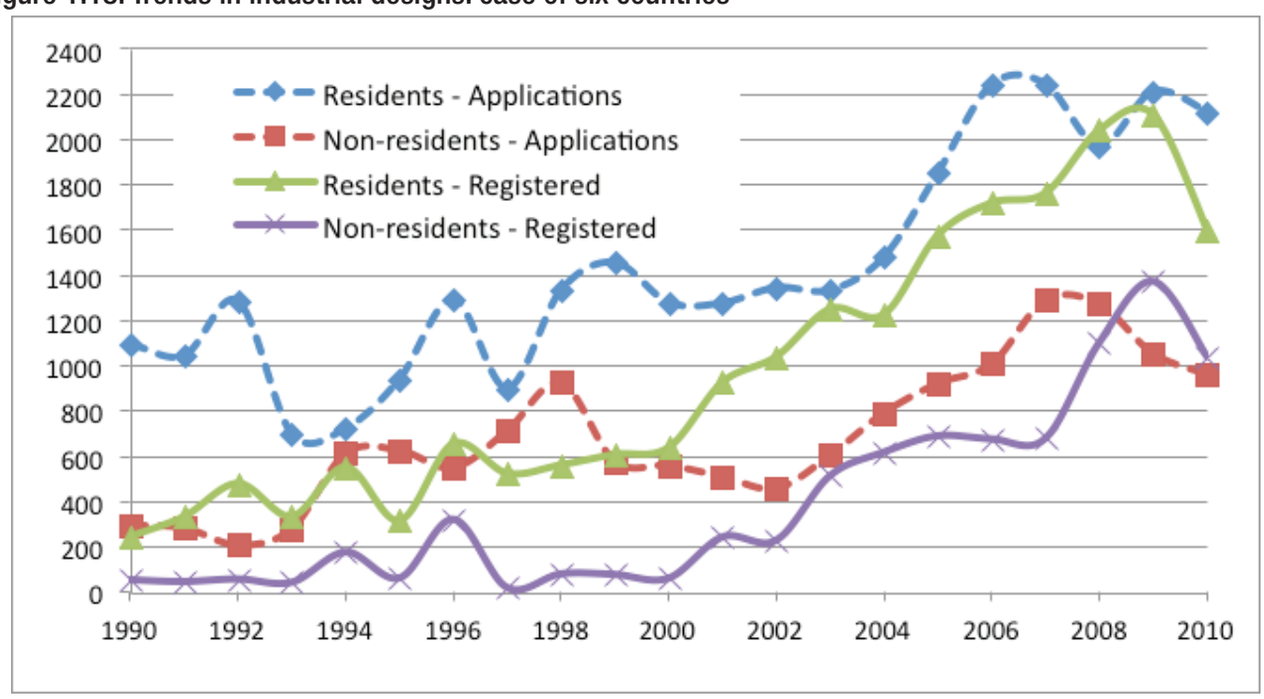
Industrial designs are increasingly becoming an important set of intellectual property rights granted for new or original identifiable shapes, colours and/or lines of an article. Designs constitute a major component of the competitiveness of a product in the market place.

The total number of industrial design applications and registrations under the Hague System grew rapidly. The Hague System provides a simplified application process where a single international application form can cover up to 100 designs for protection in over 70 countries. However, obtaining data on industrial design

applications and registrations is a challenge. Several African countries have not reported data on industrial designs to WIPO in the last decade. These include some of the continent's top innovative countries such as Ghana, Kenya, Nigeria, South Africa and Zimbabwe.

In order to get more informative data, national data from six sample countries[11] have been assessed. The corresponding data is provided in Figure 1.18. Overall, both resident and non-resident applications and designs registered first grew slightly and then very significantly from 2000 to 2010. About 3,300 applications were received in 2010 for these countries and approximately 2,600 were granted. Unlike the case of patents, industrial design registrations have grown faster than applications. In addition, resident applications and registrations are consistently and significantly higher than non-resident applications and registrations.

Figure 1.18: Trends in industrial designs: case of six countries



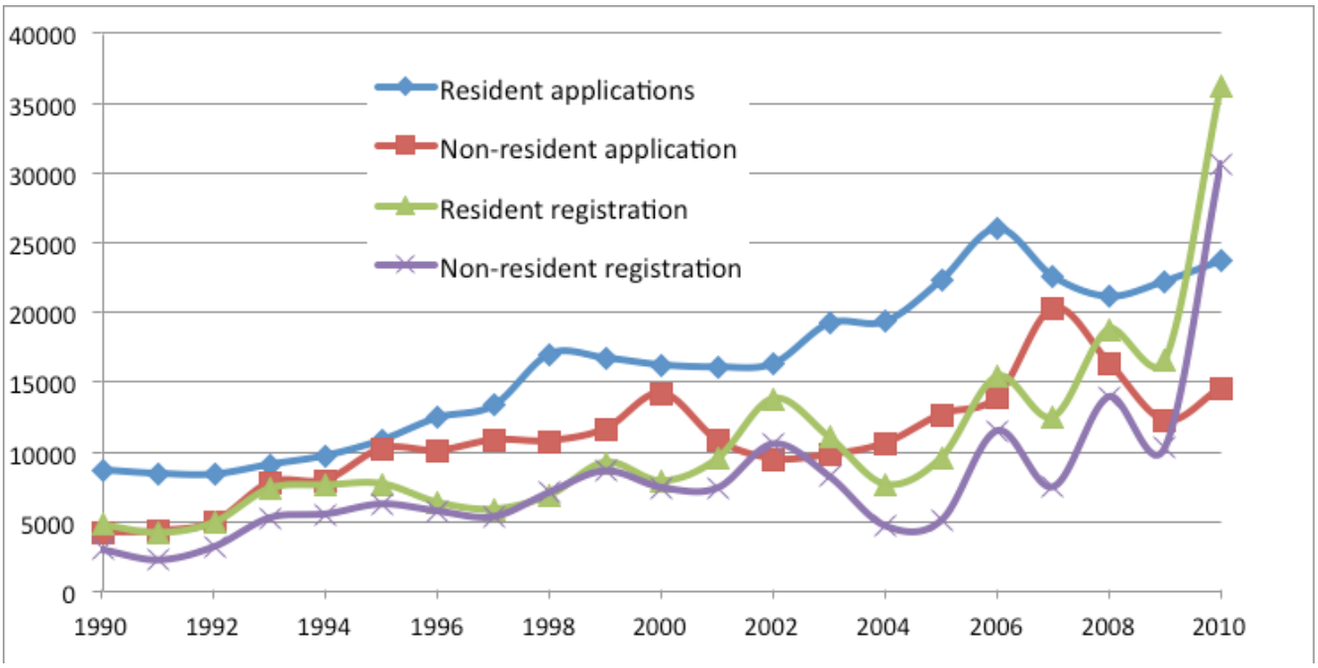
Source: UNECA IP survey

1.3.3 Trends in trademarks

Data for trademarks over a 20-year period for the same six countries is presented in Figure 1.19. Generally, trademark applications and registrations grew rapidly from 1990 to 2010. For instance, resident and non-resident applications rose about three times from 1990 to 2010 while resident and non-resident trademark registrations grew almost seven times (600 per cent) during the same period. Similar to the case of industrial designs, resident applications and registrations of trademarks outnumbered those of non-residents and registrations grew more significantly than applications.

11 Ethiopia, Madagascar, Mauritania, Morocco, Seychelles and South Africa

Figure 1.19: Trends in trademarks for six countries - 1990 to 2010



Source: UNECA IP survey

In summary, the trends highlighted here suggest that there is growing interest to own intellectual property rights in Africa. Nevertheless, lack of data limits our knowledge of the extent to which these trends have led to certain critical outcomes such as increased research and development activities, entry of new products into the African market, increased foreign investment and increased global coverage of IP rights.

Available data on IPR for Africa in most of the international databases is incomplete. The absence of some of Africa's top industrial and prolific R&D performers in such key databases is of particular concern. Industrial designs and trademarks demonstrate a relatively high percentage of approvals compared to applications. The wide gap between patent applications and patents granted may indicate the added complexity of the patent review process, limitations in the processing capacity of patents in the national offices and changes in the requirements for patent grants.

1.4 Africa's performance in technology acquisition

It is generally accepted that science, technology and innovation play a central role in the economic and social transformation of countries. Therefore the process of acquiring and applying new and improved knowledge has been, and remains, central to the development of all countries. While the advanced countries operate at the frontiers of technology development, lagging nations have to rapidly catch up and learn new and improved processes in order to improve both their capacity to utilize knowledge and their quality of life. The application of new knowledge in productive activities and institutional arrangements has been a key driver of much of the improvement in quality of life around the globe.

The limited use of new and improved processes in Africa accounts for a significant share of the challenges the continent continues to face. In the area of health, for instance, the continent has limited capacity to develop and produce drugs, vaccines and diagnostic and medical devices. Similarly, there is a high cost of transporting goods and services to markets across the continent due to the limited investment in, and application of improved technologies to, the design of roads, railway lines, airports and seaports as well as in related support services (immigration, border control, etc.).

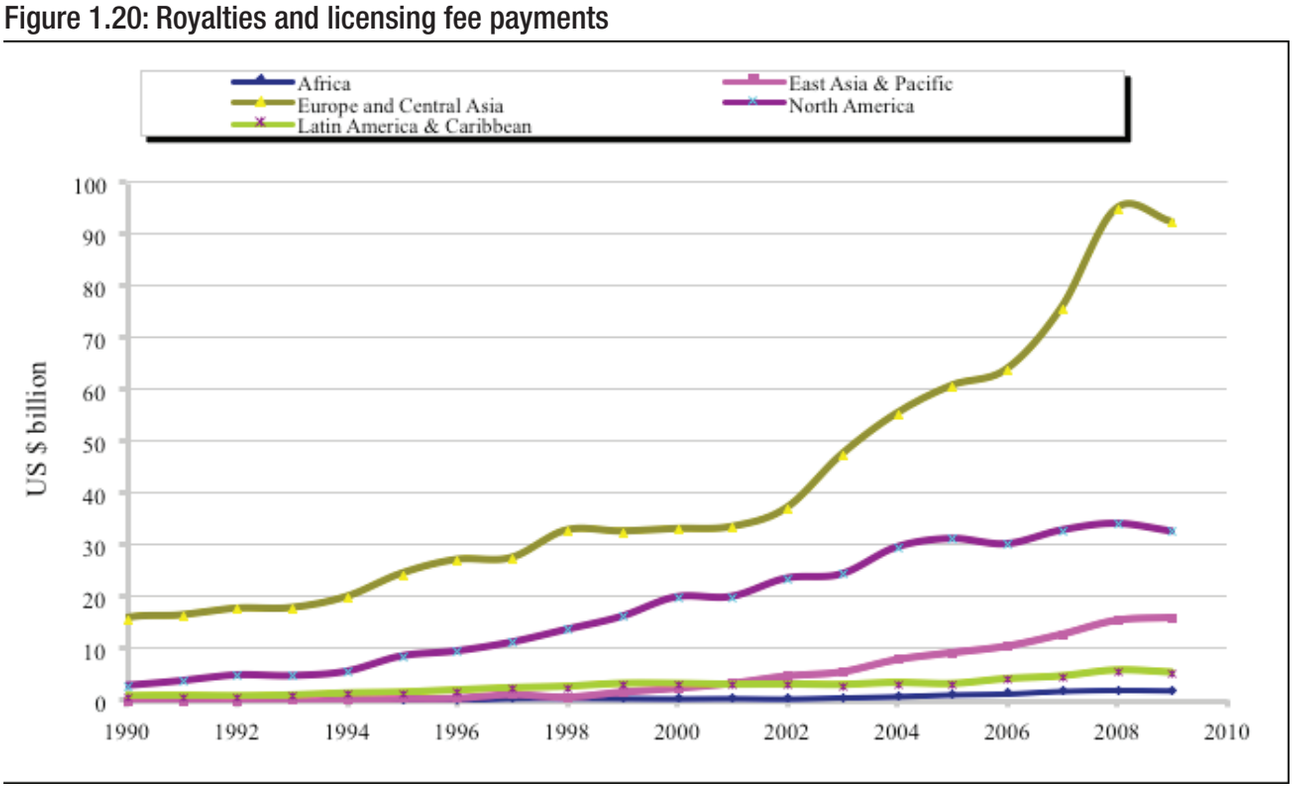
1.4.1 Royalties and licensing fees

Royalties and license fees are commonly defined as "payments and receipts between parties for the authorized use of intangible, non-produced, non-financial assets and proprietary rights, and for the use, through licensing agreements, of produced originals of prototypes" according to the World Development Indicators database classification. Intangible assets and proprietary rights, as defined above, may include patents, copyrights, trademarks, industrial designs, industrial processes and business methods. Produced original prototype works may include films, music and manuscripts. At the international level, such royalties and licensing fee payments may be between both national residents and non-residents.

Royalties and licensing fees provide some evidence of the degree of innovation within an economy. Not surprisingly, most of the royalty and licensing fee payments globally are between advanced economies. OECD countries account for over 80 per cent of royalty and licensing fee payments and receipts globally. There are three main reasons why countries that are technologically advanced are also the major importers of technology. First, the process of technology development cannot successfully take place without accessing technology owned by others. Secondly, advanced countries tend to operate at the frontiers of technology development and have strong intellectual property rules. Third, most of the transnational corporations (TNCs) promoting innovation are from developed countries. Furthermore, affiliates of TNCs outside the country of origin pay royalties and licensing fees to their parent firms for technologies that they have acquired and are using.

As shown in Figure 1.20, it is observed that East Asia and the Pacific registered the fastest growth in royalties and licensing fee payments of over 2000 per cent from 1990 to 2009, followed by Europe and Central Asia (949 per cent) and Africa (937 per cent). Africa's royalty and licensing fee payments rose from a little over $250 million to about $2.45 billion in 2008 before dropping marginally to $2.37 billion in 2009 following the financial crisis. In 2009, East Asia and the Pacific accounted for 8.7 per cent of the global share of royalty and licensing payments, up from 1 per cent in 1990.

Figure 1.20: Royalties and licensing fee payments



Source: World Development Indicators, UNECA analysis, 2011

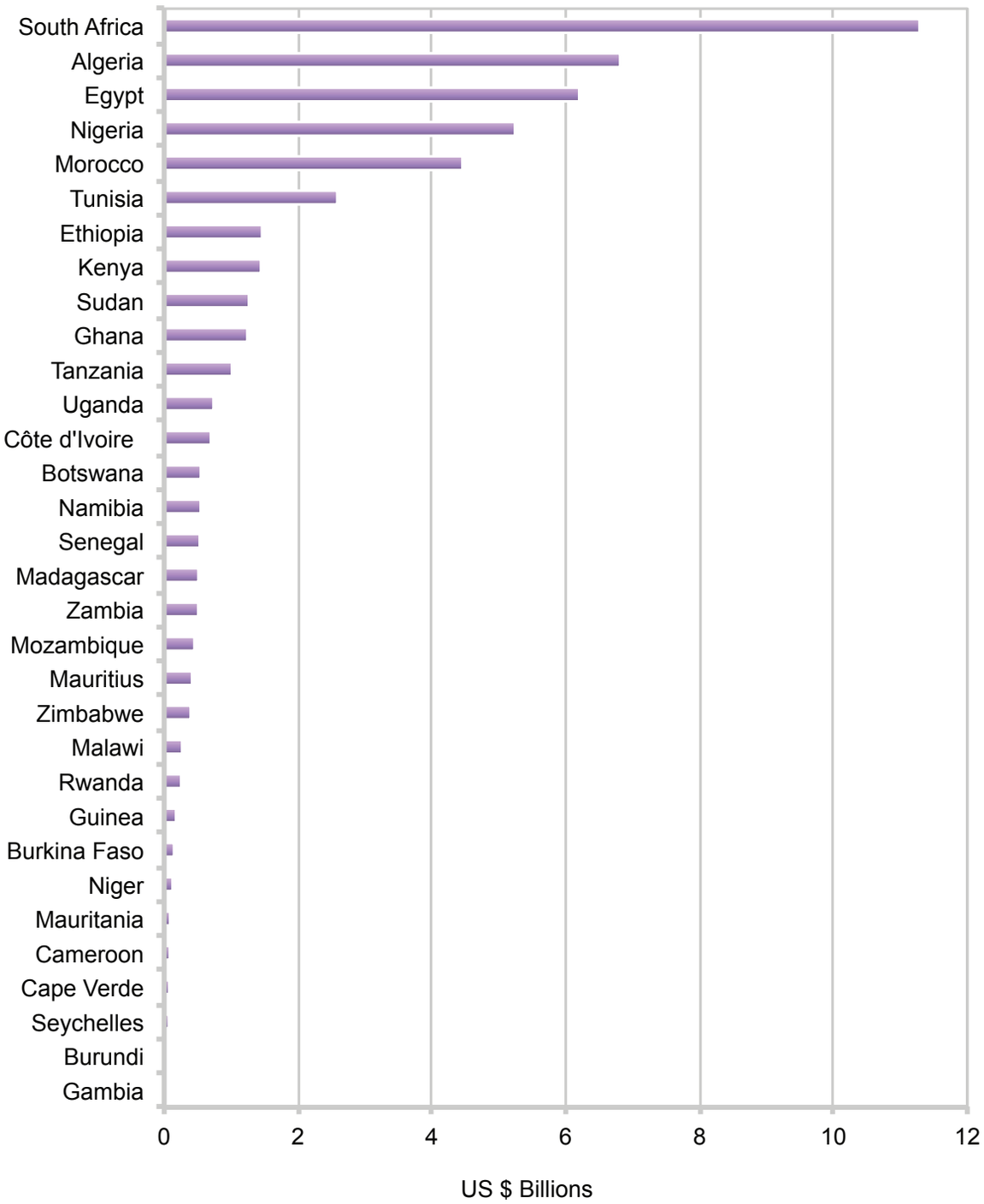
Data availability, reliability and quality remain a major challenge within Africa. The royalty and licensing fee payments reported by Angola, Niger, Tanzania and Zambia, among others, do not reflect the development trends in these countries. Although data on individual African countries is poor, South Africa ($1.6 billion) accounts for nearly 70 per cent of Africa's total payments of royalties and licensing fees reported in 2009. The other major importers of foreign technologies include Egypt ($284 million), Nigeria ($208 million) and Swaziland ($116 million). Of these, Nigeria, South Africa and Swaziland have recorded a fast growth in royalties and licensing fees since 1990 while Egypt's payments have generally stagnated.

1.4.2 Trade in capital goods imports

Capital goods may be defined as high value and durable agricultural, industrial and commercial machinery or tools, used in the production or delivery of services. Some studies have argued that imports of capital goods are a good indicator for technology transfer or passing on of R&D benefits (technology spillovers) from the exporting countries to the importing countries (Kelly, 1998). It is important to stress that the technological sophistication or content of capital goods may vary widely even within the same class of machines (e.g., engines may have varying outputs, performance and applications) and, as a result, their ability to serve as conduits for technology transfer may vary (Navaretti and others, 2003).

Africa has performed well in acquisition of capital goods in recent years. Following years of stagnation, imports of capital goods have grown faster in Africa than in any other region of the world. In value terms, capital goods imported by African countries increased from about $7.3 billion in 1995 to $54.0 billion in 2008, representing an over 500-per cent increase in capital goods imports over the period (see Figure 1.21). Data for 2009 is still incomplete, but countries such as South Africa, Nigeria and Morocco reported reduced imports in 2009, presumably due to a knock-on effect of the global financial crisis.

Figure 1.21: Imports of capital goods by selected African countries for 2009



Source: UNCOMTRADE, 2011

1.5 Concluding remarks

there has been a massive increase (massification) in student participation in higher education and in the number of higher education institutions in Africa. A major challenge is to ensure that with this increase in quantity, the quality of education is maintained. In this regard, there is a need to increase the number of academic staff and researchers with higher degrees, especially PhDs, so that both teaching and home-grown research and innovation can continue to develop. The NEPAD report on African Innovation Outlook for 2010 and its accompanying statistics is to be commended and needs to be published regularly with updated and improved data.

There has been a dramatic increase in the number of scientific publications coming from within Africa, across all countries. Health research, building on a major input of international, regional and national resources linked to MDG targets has provided a particularly strong impetus to this expansion for a number of countries. There is however a wide variation in the level of research output between countries and there should be a sustained effort, not only to help the top countries to continue to develop and compete internationally, but to support the poorer performing countries so that they too can join the ranks of innovating economies. There is a need to build on the bilateral extra-African collaborations that have assisted development to date and create more intra-regional research partnerships and innovation networks for sustainable regional growth.

In contrast to the increase in scientific publications, there has been only a limited extension of regional research output for innovation linked to industrial and economic applications. While there has been some increase in industrial designs and trademarks, there has been virtually no increase in the number of industrial patents being registered. Industrial patents have formed the basis of growth for many emerging economies globally, notably in East Asia and the Pacific. The intellectual property infrastructure within Africa, with the exception of one or two countries, including notably South Africa, remains poor and requires attention.

Despite limited growth overall in the initiation of innovation-driven business from within Africa, a study of technology acquisition shows a major increase in knowledge-based business activity. This has been developed both through royalty payments to access knowledge and innovation on the one hand, and through the import of capital goods and equipment on the other. There is however a significant resource and capacity gap between different countries on the continent.

The challenge in the coming decade is to build on the increase in higher education and research and link this to technical and business-associated innovation so that innovation and technological development is not just imported, but self-generated within the continent and can assist in economic development and export-led growth.

References

Adams, J., King, C. and Hook, D. (2010). Global Research Report: Africa, Thomson and Reuters.

AU–NEPAD (2010). African Innovation Outlook 2010, African Union–NEPAD, Pretoria, South Africa.

Bloom, D., Canning, D. and Chan, K. (2005). Higher Education and Economic Development in Africa, Harvard University. Available from http://siteresources.worldbank.org/EDUCATION/Resources/278200-1099079877269/547664-1099079956815/HigherEd_Econ_Growth_Africa.pdf.

Cyranoski, D., Gilbert, N., Ledford H., Nayar, A. and Yahia M. (2011). Education: The PhD factory. Nature, 472 (7343), 276-279.

Kelly, W. (1998). Are international R&D spillovers trade related? Analysis of spillovers among randomly matched trade partners. CERP Working paper No. 2815. Available from http://www.nber.org/papers/w6065.pdf.

Landry, R. and Amara, N. (1998). The impact of transaction costs on the institutional structuration of collaborative academic research, Research Policy, 27 (9), 901-913.

Letseka, M. and Maile, S. (2008). High university drop-out rates: a threat to South Africa's future, HSRC policy brief. March ed. Pretoria: Human Sciences Research Council.

Lubango L.M. and Pouris A. (2009). Is patenting activity impeding the academic performance of South African University researchers? Technology in Society, 31 (3), 315-324.

Melin, G. and Persson, O. (1996). Studying research collaboration using co-authorships, Scientometrics, 36 (6), 363-377.

Meneghini, R. (1996). The key role of collaborative work in the growth of Brazilian science in the last ten years, Scientometrics, 35 (3), 367-373.

Moyer, E.J. (2007). An Educated View of Universities, Research Africa, March 20.

Navaretti, G.B., Schiff, M. and Soloaga, I. (2003). The knowledge-content of machines: North-South trade and technology diffusion, Flowenla Discussion Paper 22. Available from http://www.migration-research.org/EastWest/dokumente/Flowenla22.pdf.

Nwaka, S., Ilunga, T. B., Da Silva, J. S., Verde, R. E., Hackley, D. and others (2010). Developing ANDI: A Novel Approach to Health Product R&D in Africa. PLoS Med 7(6): e1000293. doi:10.1371/journal.pmed.1000293.

Sobrino, M.I.M., Caldes, A.I.P., and Guerrero A.P. (2008). Lokta Law applied to the scientific production of information science area, BJIS, v.2, n.1, p.16-30.

Tettey, W. J. (2006). Staff retention in African universities: Elements of a sustainable strategy, World Bank.

UNCTAD (2005). Resource Book on TRIPS and Development, UNCTAD-ICTSD, Cambridge University Press.

UNECA (2010). Implementing the World Summit on the Information Society Action Lines in Africa. Analysis of Country Reports.

UNESCO (2010). UNESCO Science Report 2010, The Current Status of Science around the World, UNESCO Publishing, Paris, France.

Zhao, L. (2011). China Attracting International Students, EAI Background Brief No. 680, East Asian Institute. National University of Singapore.

CHAPTER 2

Trends in technology application

2.0 Overview

Over the last decade, Africa has made unprecedented progress in the acquisition, use and development of ICTs, especially those related to mobile and wireless and geospatial (location-based) technologies. More people in Africa have access to telecommunication technologies in the last decade than in the previous century. ICT is now a driver of socio-economic development in several African countries.[12]

This chapter presents the trends and status of ICT developments and their contributions to development in Africa. It addresses the trends and status of ICT access and usage, the status of the ICT industry, software and content development, including products and services development, and its contribution to economic and social development in Africa.

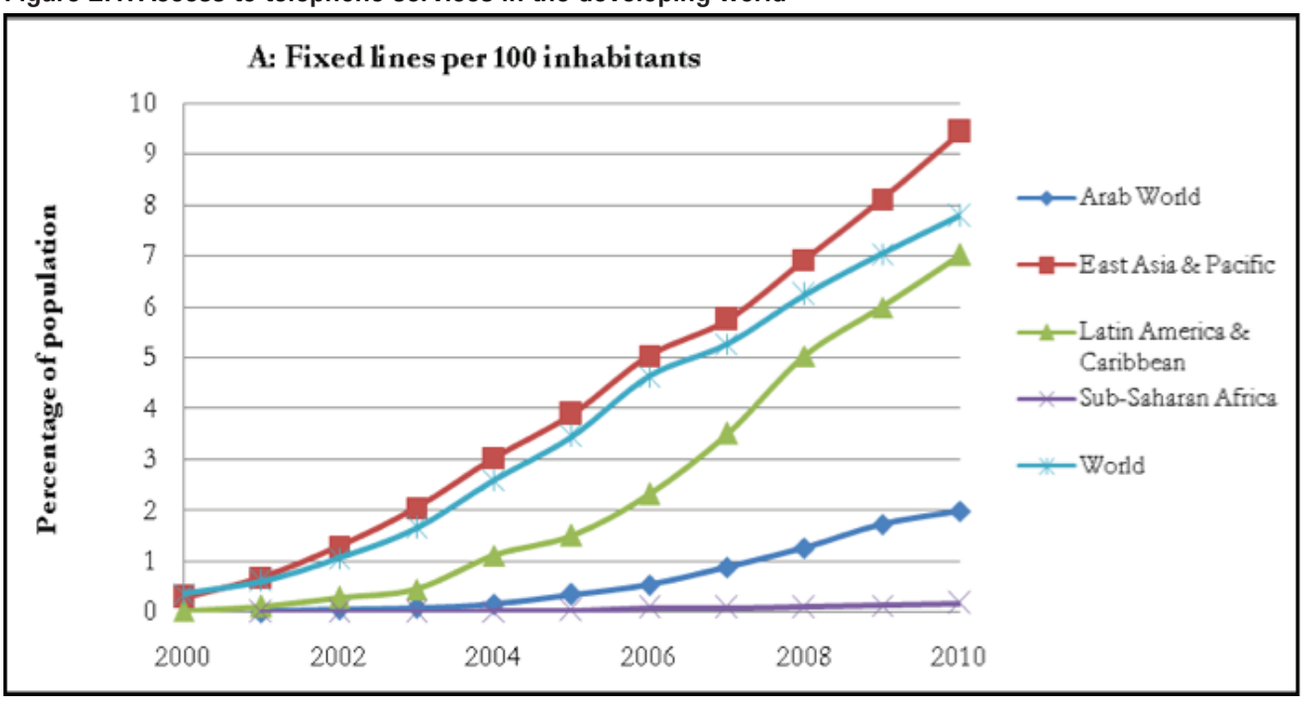
2.1 Technology access and application in Africa

2.1.1 Recent trends in telephone services access

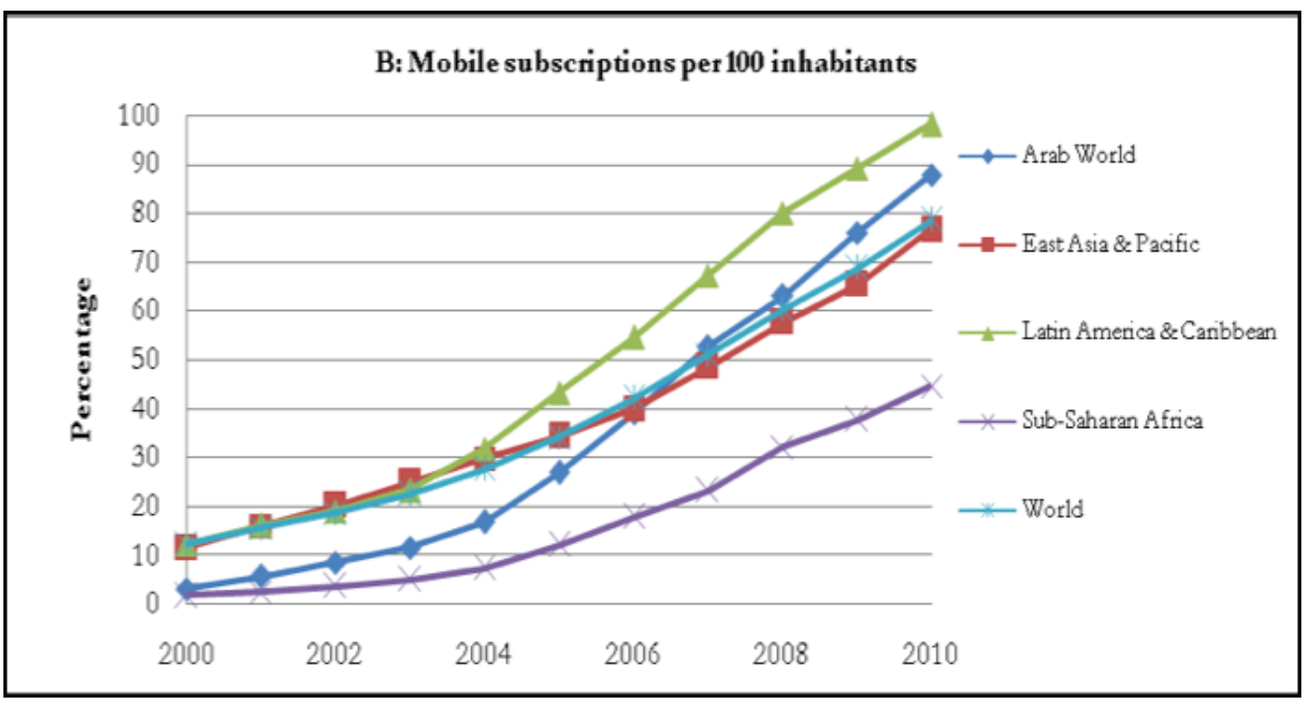
Africa has witnessed a fast penetration of telephone technologies and increased access to ICT services in the last ten years. Figure 2.1 illustrates the increased coverage in mobile subscriptions compared to fixed lines in developing countries, including Africa. In 2010, global coverage of land lines was only 2 per cent, compared to a global level of 80 per cent for mobile coverage. Access to fixed phone lines in Africa remains very low at less than 0.2 per cent. Even in the few African countries that have privatized the fixed line network, there was no expansion in the network and no significant improvement in labour efficiency or in reduction in tariffs (Gasmi and others, 2011). However, Africa has registered a fast growth in mobile phone subscriptions, standing at 44.7 per cent in 2010. The rate of increase in Africa, 26-fold, from 1.7 per cent to 44.7 per cent from 2000 to 2010, is second only to the Arab world's 29-fold increase over the same period. Unlike fixed lines, the liberalization of the mobile phone sector has resulted in mobile network infrastructure expansion in Africa.

12 Egypt (2010), Egypt, (2011); and Mauritius (2010)

Figure 2.1: Access to telephone services in the developing world



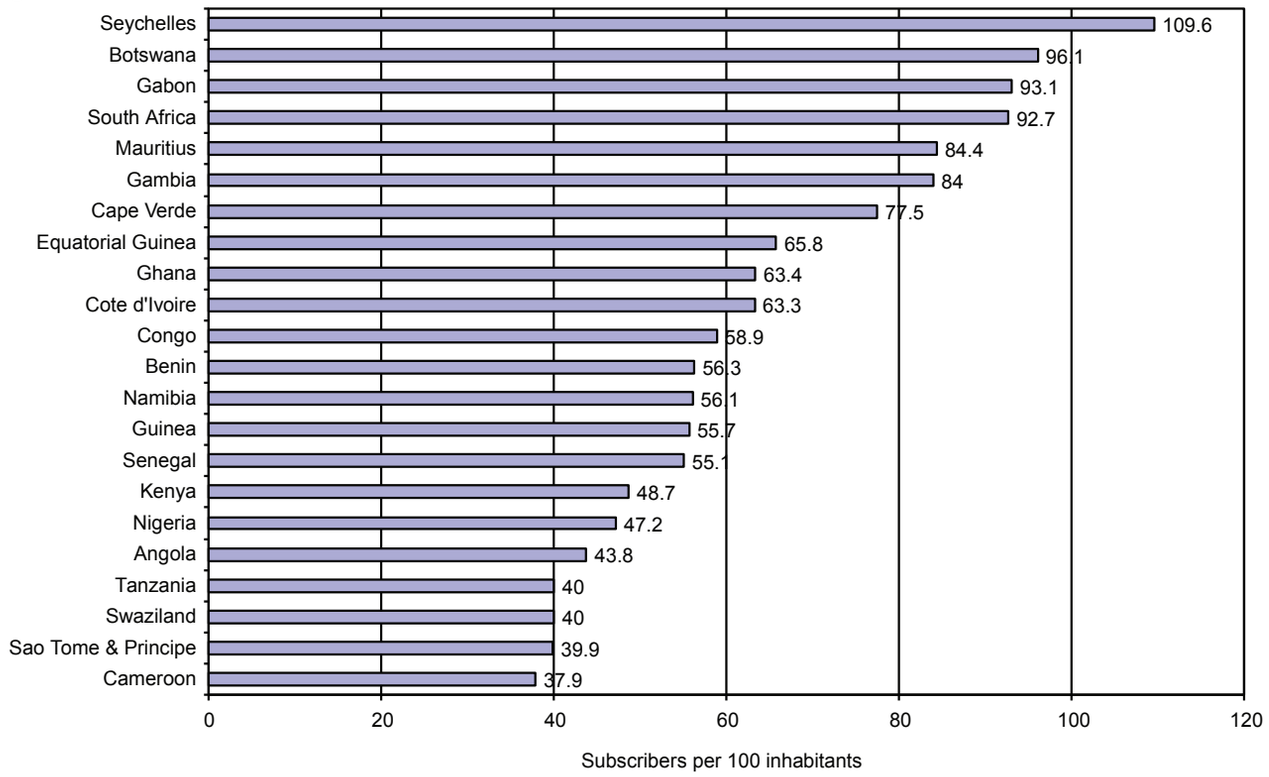
Source: World Development Indicators database, UNECA analysis, 2011



Source: World Development Indicators database, UNECA analysis, 2011

By 2010, 90 per cent of Africa's urban population and 48 per cent of its rural population lived within the reach of a mobile network. By September 2010, Africa surpassed Latin America to become the world's second largest mobile market in monetary terms, after the Asia and Pacific region (GSMA, 2011). However, there are major differences in mobile phone penetration at the national level as shown in Figure 2.2, with a penetration rate ranging from 38 per cent in Cameroon to 110 per cent in the Seychelles in 2009.

Figure 2.2: Mobile cellular subscribers per 100 inhabitants in 2009



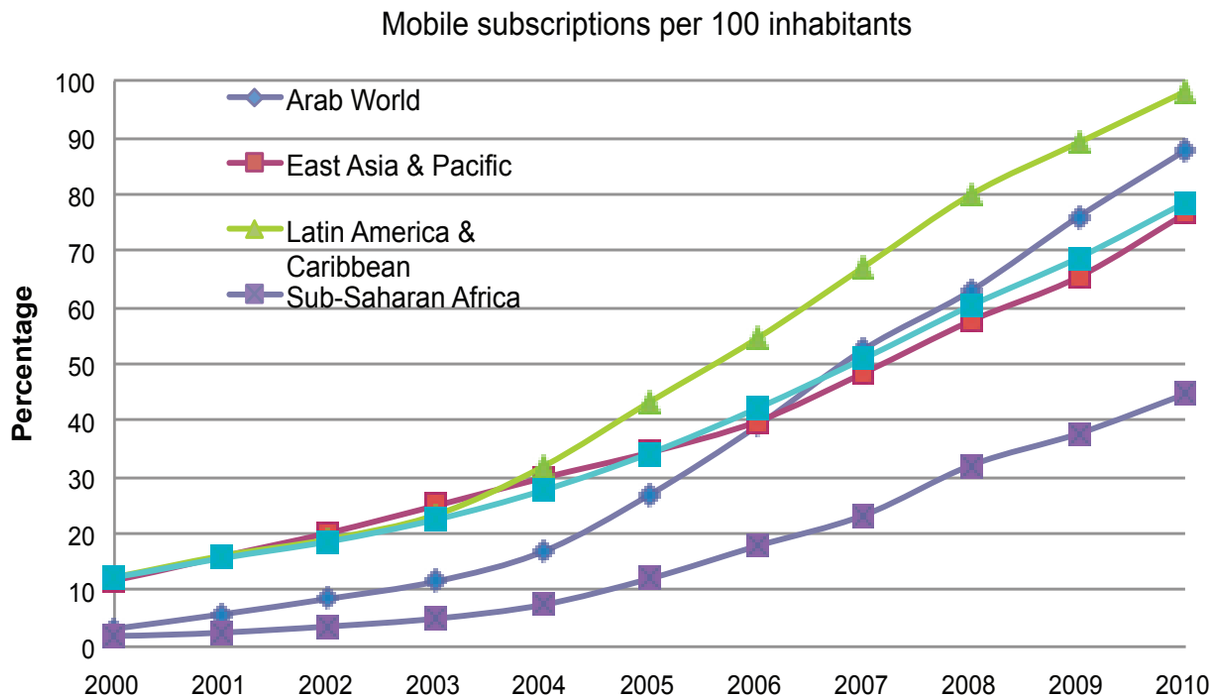
Source: World Development Indicators database, 2011

2.1.2 Internet Access

The Internet is perhaps one of the most profound and transformational technologies of the 20th Century. Estimates suggest that the Internet now accounts for about 3.4 per cent of GDP in mature economies and about $8 trillion worth of electronic transactions occur annually (Manyika and Roxburgh, 2011). The Internet has changed the way countries, business corporations and individuals organize and manage their economic, social, technological, cultural and political activities. It is not surprising that internet penetration has been growing very fast in the last decade, reaching 30 per cent of the world population in 2010. Although sub-Saharan Africa remains the region with the lowest internet access at 10.9 per cent, internet penetration grew about 22 times from 2000 to 2010, faster than that of East Asia and the Pacific and Latin America and the Caribbean (Figure 2.3).

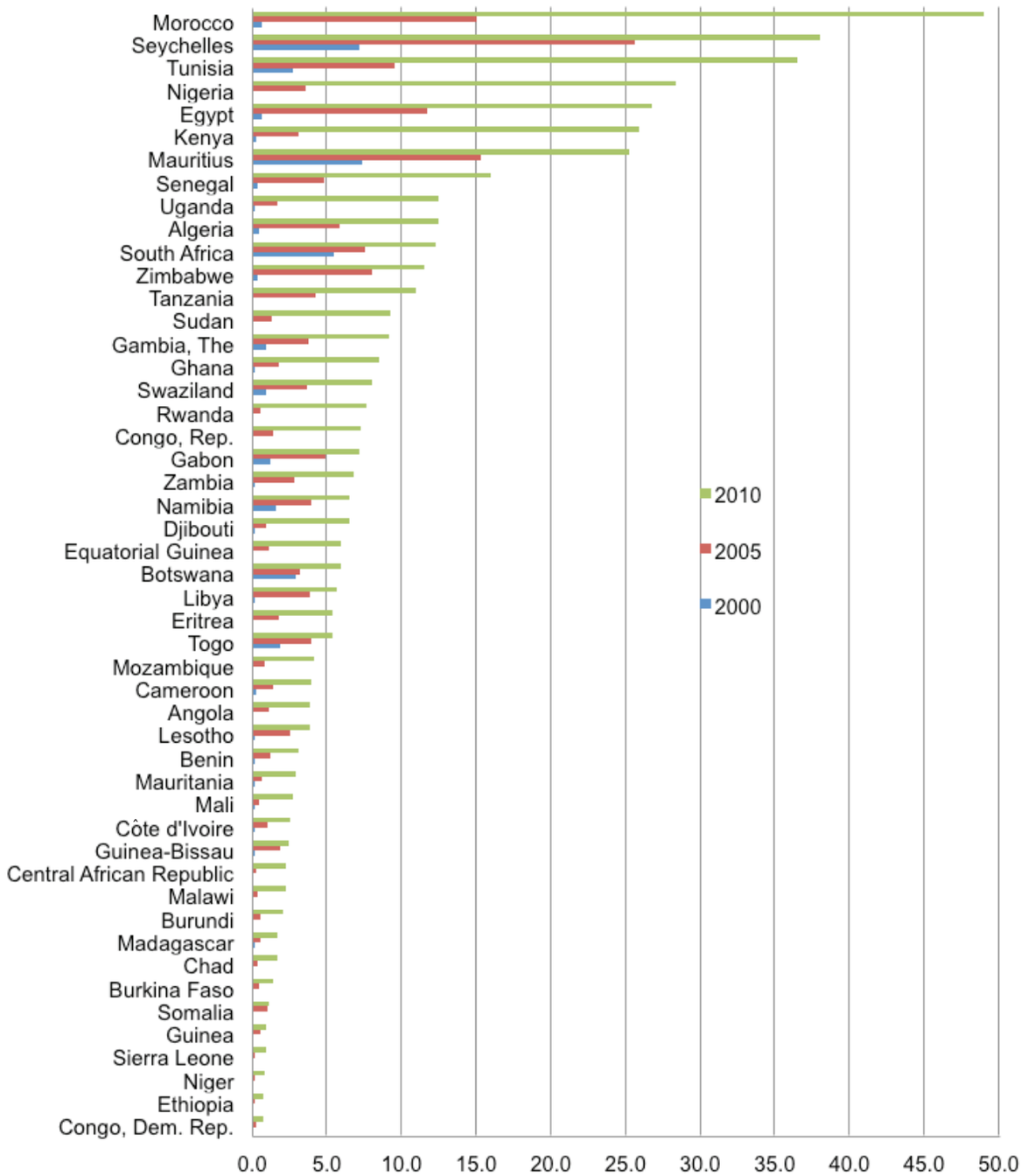
There are wide variations in the rate of internet penetration among African countries (Figure 2.4). There are at least 7 countries with internet penetration of more than 25 per cent (i.e. users per 100 inhabitants) and about 12 countries with less than 2.5 per cent.

Figure 2.3: Global trends in internet penetration



Source: World Development Indicators database, 2011

Figure 2.4: National trends in mobile penetration in africa (user per 100 inhabitants)



Source: World Development Indicators database, UNECA analysis, 2011

Broadband internet (internet with a greater information-carrying capacity)[13] has been growing rapidly in both developed and developing countries. Developing countries' subscriptions accounted for 45 per cent of global subscriptions in 2010.

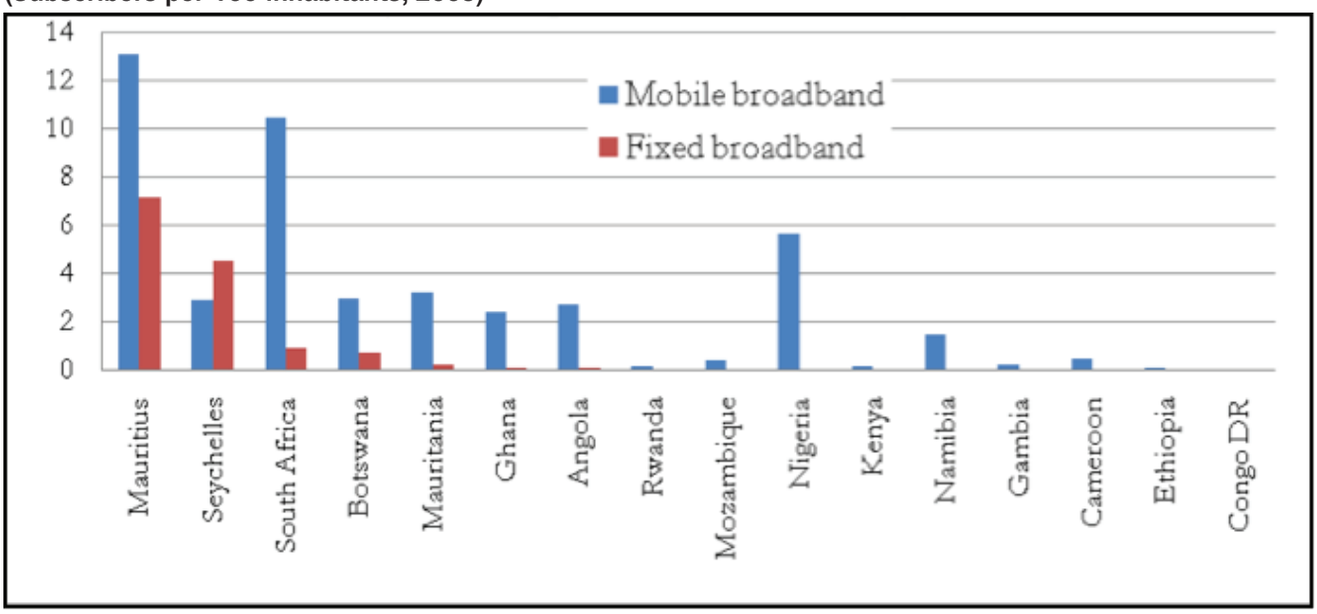
Broadband subscription differs widely at the national level, as shown in Figure 2.5. Africa's fixed broadband penetration rate is less than 1 per cent. The low penetration rate illustrates the inadequacy of infrastructure for high-speed and high-capacity internet delivery of countries on the continent in general.

Wireless broadband internet access is growing faster than the fixed broadband, mainly driven by the advancement in mobile phone technologies. Almost all mobile phone providers in Africa now offer broadband

13 http://en.wikipedia.org/wiki/Broadband

services for both prepaid and post-paid subscribers. The capacity and speed is increasing; and while costs are falling, they do remain relatively high. By the beginning of 2010, about 95 per cent of the 19 million broadband subscribers in Africa accessed broadband via wireless technologies (Williams and others, 2011). However, the subscriber base is concentrated in a few countries. Eighty one per cent of sub-Saharan Africa's total broadband subscribers, i.e. about 15.7 million subscribers, are concentrated in Nigeria and South Africa alone.

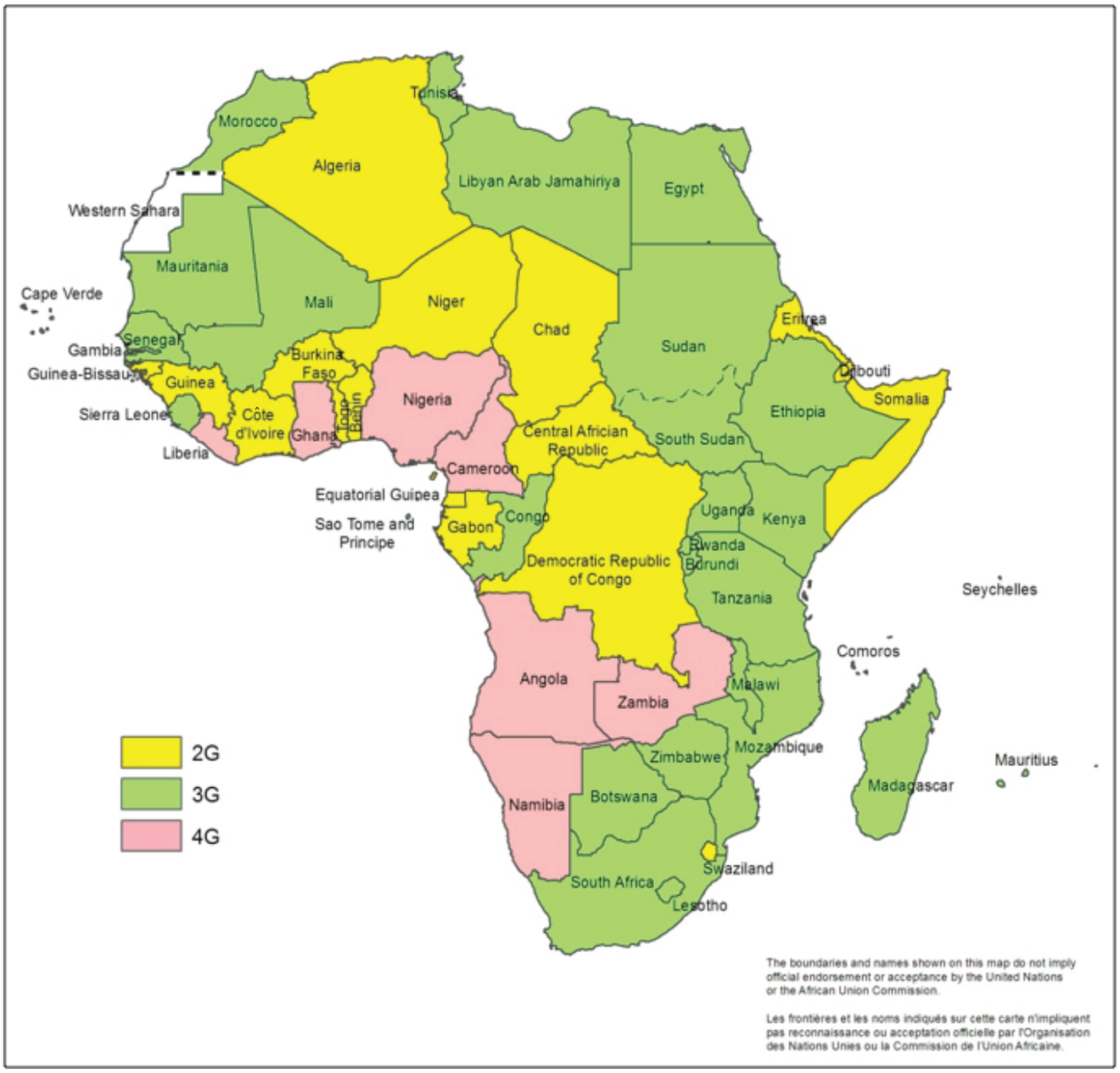
Figure 2.5: Comparison of fixed and mobile broadband penetration in selected African countries (Subscribers per 100 inhabitants, 2009)



Source: World Development Indicators database, UNECA analysis

In addition, most internet service providers and mobile phone companies are offering wireless internet. In the last few years, the number of mobile phone companies offering 2G, 3G and 4G services (Figure 2.6) has substantially increased. The demand for improved mobile services saw investments in the ICT sector increase from $8.1 billion in 2005 to almost $70 billion in 2010.

Figure 2.6: 2G, 3G and 4G Coverage in Africa (July 2012)



Source: GSMA – African Mobile Observatory, 2011 and national websites of operators

2.1.3 Social media penetration

The Internet has also provided a platform for a variety of services, of which social media has become an important tool that allows people to interact with each other much more extensively than was previously the case.[14] Social media empowers individuals, firms and institutions to share and exchange, inform, collaborate across disciplines and borders and receive feedback from a target population in ways that were previously not possible.

Africa has not been left of this revolution, most probably due to its youth population[15]. Social networking firms such Facebook, Google+, LinkedIn, Twitter and YouTube have seen the number of users in Africa grow rapidly. For instance, Africa's level of Facebook penetration, at 3 per cent, is lower than that of the world average, at 10.3 per cent. However, it is growing much faster than in any other region (See Table 2.1).

14 http://www.scribd.com/doc/69309864/KPCB-Internet-Trends-2011
15 http://www.un.org/ecosocdev/geninfo/afrec/vol24no4/social-media-boom.html

Table 2.1: Facebook usage and internet statistics (June 30, 2011)

Region	Facebook Users Aug. 31, 2010	Facebook Users June 30, 2011	Facebook Growth (per cent) (10 Months)	Facebook Penetration (per cent)
Asia	93,584,580	152,957,480	63	3.9
Africa	17,607,440	30,665,460	74	3.0
Europe	162,104,640	208,907,040	29	25.6
Latin America	68,189,920	115,288,940	69	20.7
North America	149,054,040	167,999,540	13	48.4
Middle East	11,698,120	16,125,180	38	7.5
The Caribbean	3,925,060	5,903,520	50	14.3
Oceania/Australia	11,596,660	12,881,560	11	36.4
Total	517,760,460	710,728,720	37	10.3

Source: http://www.scribd.com/doc/69309864/KPCB-Internet-Trends-2011

The penetration of social media varies widely. For instance, six countries in African are ranked in the top 50 countries in the world in terms of number of users of Facebook in 2012 (see table 2.2 for details). Unlike in other regions, more than 15 per cent of people online in Africa are currently using Facebook, compared to 11 per cent in Asia. Two other social networking websites, Twitter and YouTube, rank among the most visited websites in most African countries[16]. However, care needs to be taken as the numbers mask the size of the population.

Table 2.2: Top ten African countries by number Facebook users and rank

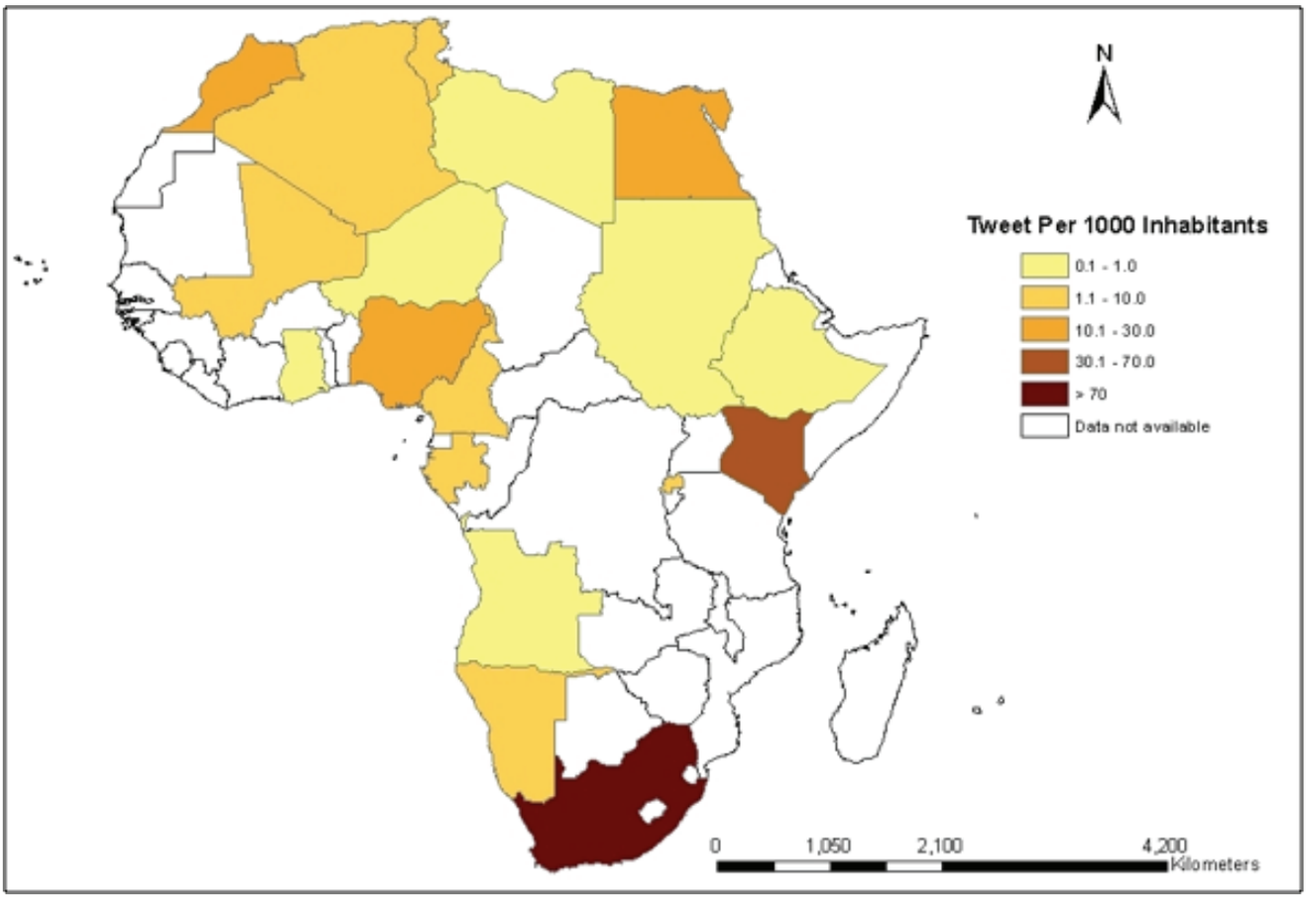
Country	No of Users	Global Rank (out of 213 countries)
Egypt	1,1781800	20
Nigeria	6,566,040	31
South Africa	6,434,220	32
Morocco	4,925,300	36
Algeria	3,849,180	43
Tunisia	3,242,320	48
Kenya	1,923,260	64
Ghana	1,651,640	69
Democratic Republic of Congo	880,780	85
Ethiopia	818,620	88

Source: http://www.socialbakers.com/facebook-statistics/

A detailed analysis of twitter use in Africa revealed a similar picture in terms of use. In absolute terms, South Africa, Kenya, Nigeria and Egypt were the only four African countries that registered more than 1 million tweets in the last quarter of 2011. As a proportion of the population, South Africa, Kenya and Morocco were the only countries that registered more that 20 tweets per 1000 inhabitants. Interestingly, 57 per cent of the Tweets recorded were made from mobile phones and about 60 percent of Africa's tweeters were aged 20 to 29. Considering that about 340 million tweets are recorded per day, Africa's 11.5 million tweets in 3 months represent less than 0.05 per cent of global tweets.

16 http://www.socialbakers.com/facebook-statistics/

Figure 2.7: The distribution of three months' geo-located tweets from Africa

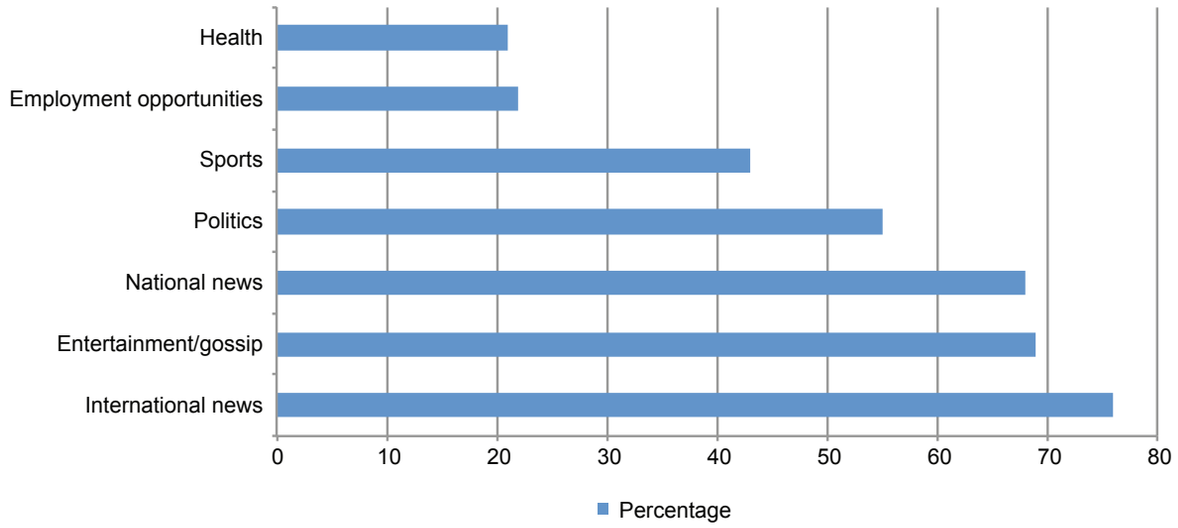


Source: www.portland-communications.com

The growth of social media is providing many opportunities, given the large numbers of users. Platforms such as Facebook (800 million users), LinkedIn (175 million users) and Twitter (175 million active accounts) are attracting activists, businesses, politicians and social service providers, among others, who are increasing their presence on these platforms in order to reach potential voters, clients, customers and consumers. This trend is creating a rich digital environment that is driving the growth of social media. As shown in Figure 2.8, a survey of 500 major users of Twitter in Africa suggests that this platform is a major source of information on a number of subjects[17].

17 www.portland-communications.com

Figure 2.8: Twitter as main source of information



Source: Portland-communications

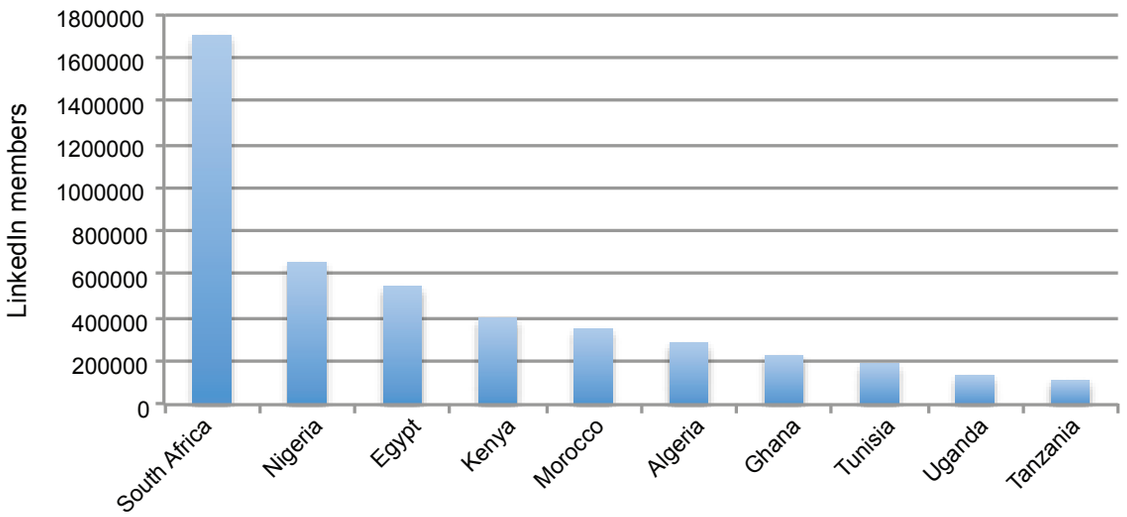
Some social network platforms, such as LinkedIn, are used largely to reach a broad range of partners, professionals, consumers and individuals with common interests. . LinkedIn has emerged as an important tool for hiring staff, searching for jobs, marketing, collaboration and outreach, among others. Unlike Facebook, Twitter or You Tube, LinkedIn enables individuals to build their own network of professionals based on similar interests. Individuals can raise questions and topics of interest to members of their networks , share information and mobilize interests. LinkedIn has become a powerful platform for mobilizing other professionals to provide ideas, advice and support as well as collaborate on issues of common interest.

The use of LinkedIn on the continent is growing very fast although its share is remains low (3.2 per cent). For example, Africa posted a growth of 26.4 per cent in the first six months of 2011, second only to Latin America which posted a 34.6 per cent in memberships over that period. Currently, 80 per cent of users reside in the United States, India, the United Kingdom, Brazil, Canada, the Netherlands, France, Australia, Italy and Spain)[18]. However, Africa's share of LinkedIn users stands at 3.2 per cent.

Currently, LinkedIn is estimated to have over 5.7 million users on the continent, with South Africa, Nigeria and Egypt leading Africa's LinkedIn rankings[19]. The majority of LinkedIn users are male (58.5 per cent) and aged between 25 and 54 years (70 per cent).

18 http://www.digitalbuzzblog.com/linkedin-demographics-statistics-stats-2011/
19 http://www.cp-africa.com/2012/02/29/south-africa-nigeria-and-egypt-lead-africas-linkedin-rankings/

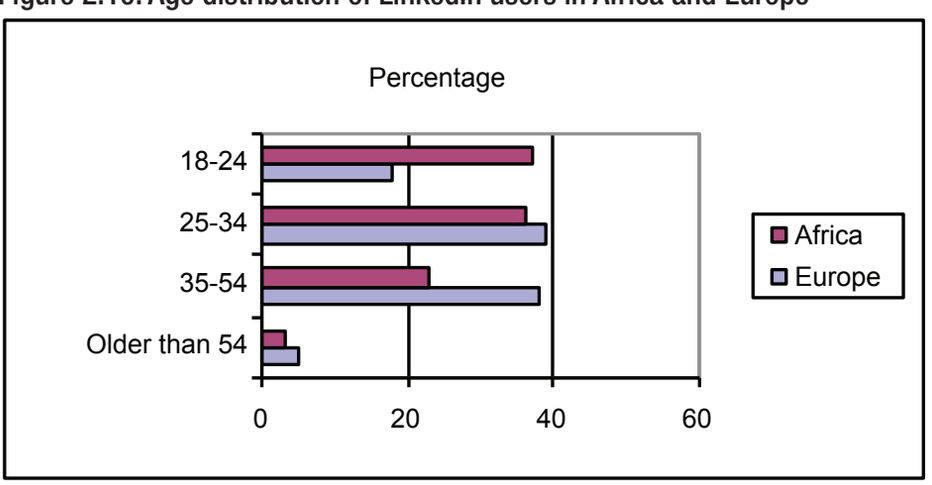
Figure 2.9: Top ten ranking of African countries on LinkedIn



Source: www.cp-africa.com

Africa, Asia and Latin America represent the highest concentrations of members under the age of 34 (more than 70 per cent). As shown in Figure 2.10, the proportion of LinkedIn users under the age of 24 in Africa is twice higher than that of Europe while the proportion of users above the age of 34 is much higher in Europe than in Africa. The demographic of users in Africa mirrors that of Asia and Latin America while that of Europe is similar to that of North America.

Figure 2.10: Age distribution of LinkedIn users in Africa and Europe



Source: http://www.slideshare.net/amover/linkedin-demographics-statistics-jan-2012

In terms of sectors, the majority of users work in or have skills related to high technology industries followed by finance. In developed countries, users from high technology sectors account for over 20 per cent, while in Africa, high technology sectors account for about 17 per cent of all LinkedIn users. This has significant impact, as the continent's younger population, uses this social media tool, which hosts over 20 million students and recent college graduates as at May 2012.

African leaders embrace social media

By 2011, almost all African heads of State and Government were on one platform of social media or another. On Facebook alone, the Presidents of Nigeria (790,000 followers), Tanzania (45,000), Algeria (25,000) and the Republic of the Congo (8,200) are among some of the top politicians with official websites in 2011.

Goodluck Jonathan, the President of Nigeria, was perhaps the most popular on the Internet among African leaders in 2011 as he actively used his Facebook page to address the nation on major events. The choice to announce his candidacy via Facebook has remained a reference point in the use of social media in politics in Africa and beyond.

Other leaders are using social media to gather opinions and post messages to the nation at large. For instance, Abdelaziz Bouteflika, Algeria's President, used his Facebook to gather opinions from citizens as to whether they were satisfied with the formation of the new Government. Similarly, Jakaya Kikwete, the Tanzanian President, posts several key messages to the nation through his Facebook page. About one third of African leaders have unofficial Facebook pages created on their behalf by interest groups, while others have community pages on Facebook, created as a placeholder, courtesy of Wikipedia, for cases when no user-generated page exists. On average, the number of fans of a given leader rose 24 per cent over the previous quarter[20].

Table 2.3: Examples of African leaders on Facebook and Twitter

Country	President (or other title)	Facebook type	Facebook fans	Twitter followers[a]
Benin	Thomas Yayi Boni	Official	7,563	373
Nigeria	Goodluck Jonathan	Official	790,225	35,727
Rwanda	Paul Kagame	Unofficial	23,341	63,047
South Africa	Jacob G. Zuma	Unofficial	20,847	125,364
Tanzania	Jakaya Kikwete	Official	45,381	22,910
Zimbabwe	Morgan Tsangirai	Official	77,418	3,638

Source: www.oafrica.com and http://www.itnewsafrica.com/2012/06/top-five-african-presidents-to-follow-on-twitter/

Some African leaders use twitter in governance. Rwandan President Paul Kagame is an active Twitter user and responds openly to issues relating to the state of governance in his country. President Kagame has also featured on YouTube's Worldview, answering questions about Rwanda and life after the genocide. South African President Jacob Zuma's state of the nation address trended on Twitter because he had asked citizens to pose questions online while he prepared his speech. His use of questions from social media platforms turned his state of the nation address into an online event[21].

This trend reflects the general growing use of social media in Africa. The use of social media by Governments in Africa is likely to grow. Governments and leaders may wish to ensure that such adoption of social media in governance is planned, fair, engaging, and transparent[22].

There is no doubt that African leaders are embracing social media.

Africa's social media innovation

Africa is also developing its own social networking tools. For example, MXit (a free online mobile instant messenger and social network) has more than twice the number of users of Facebook in South Africa.[23] Other home-grown tools include YouTube imitations, professional networks, such as Linkedafrica.com, and crowd-sourcing applications such as Wonzomai ("citizen reporting").

Major Internet companies are showing a special interest in Africa's expanding pool of Internet users. Facebook has launched Swahili, Hausa and Zulu versions. Similarly, Google has started testing a new service for Swahili speakers in East and Central Africa, tentatively called Baraza (i.e. "the meeting place" in Swahili), which will allow people to interact and share knowledge on local and regional issues.

20 http://www.oafrica.com/statistics/updated-african-leaders-on-facebook-march-2011/
21 Magro, Michael J. (2012). A review of Social Media Use in E-Government. Administrative Sciences, 2012, 2, 148-161.
22 Dadashzadeh, M. Social media in government: From eGovernment to eGovernance. J. Bus. Econ. Res. 2010, 8, 81–86.
23 With about 10 million or more active unique users, the network easily trumps Facebook's 3.9 million users in South Africa. See http://thenextweb.com/africa/2011/06/14/why-mobile-social-network-mxit-is-twice-as-big-as-facebook-in-south-africa

Overall, social media is making a difference in Africa despite the limited internet connections. The role played by Facebook and Twitter in the Arab Spring in Tunisia and Egypt highlights the potential of social media in mobilizing and organizing the public.[24] These developments will most likely have enormous social, political and economic impacts on the continent, creating increased levels of accountability and transparency and resulting in a positive change if appropriately harnessed.

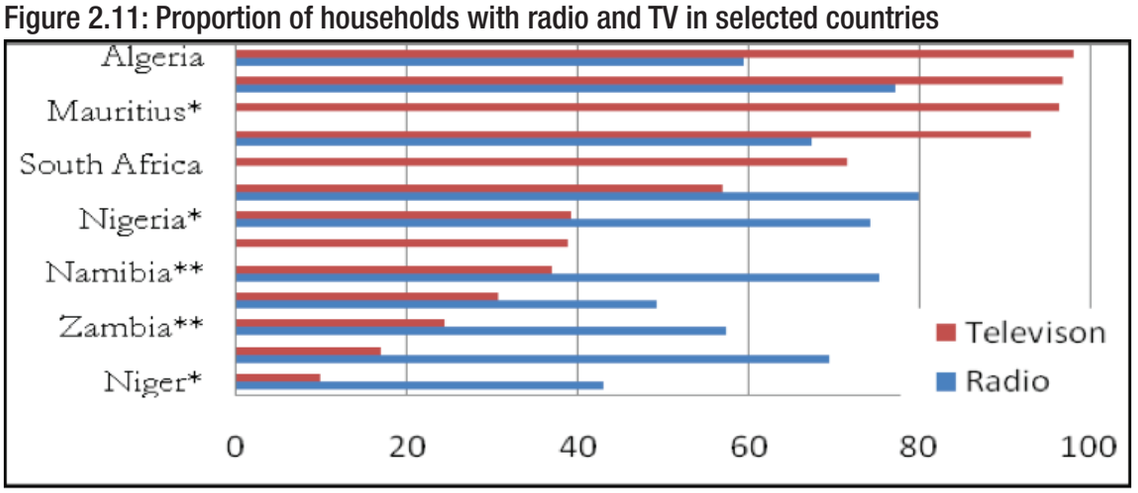
Expansion of radio and television

Radio and television (TV) remain the most dominant electronic mass media in Africa, with the penetration rate much higher than that of fixed phone lines, mobile phones and the Internet in Africa. Unlike other ICT tools, radios and TVs are generally owned per household. In rural communities, one radio and/or TV could cater for more than one household, making them perfect tools for social networking and information sharing.

As shown in Figure 2.11, TV penetration is much higher in relatively wealthier African countries such as Algeria, Egypt, Mauritius, Morocco and South Africa, while radio penetration is higher in general than TV in lower income countries such as Niger, Burkina Faso and Zambia. According to Dataxis Intelligence, television household penetration in Africa will increase from the current level of 30 per cent to 50 per cent in 2015. This will account for more than 123 million TV households.[25]

Africa has yet to embrace the convergence between traditional media and digital media, which could offer interactive services such as film, music and games and have a significant impact on the growth of the media industry on the continent. For instance, streaming TV and movies to mobile phones can benefit the media industry, such as Nollywood, Nigeria's film industry, which has an average production of 200 films per month.[26] The African cable giant, DSTV, already streams some of its programmes to smart phones almost everywhere in Africa.[27] The increased availability of 3G and next generation enabled services and handsets, and the migration to digital television, will give a boost to mobile media services.

Figure 2.11: Proportion of households with radio and TV in selected countries



Note: ** Refers to 2007 data, * refers to 2008 data and no star refers to 2009 data
Source: ITU, UNECA WSIS questionnaire, 2008

24 See Africa Renewal, December 2010
25 See http://dataxisnews.com
26 http://en.wikipedia.org/wiki/Cinema_of_Nigeria
27 http://go.dstvmobile.com/NokiaN8/howtoget.html

2.1.5 Trends in communication infrastructure development

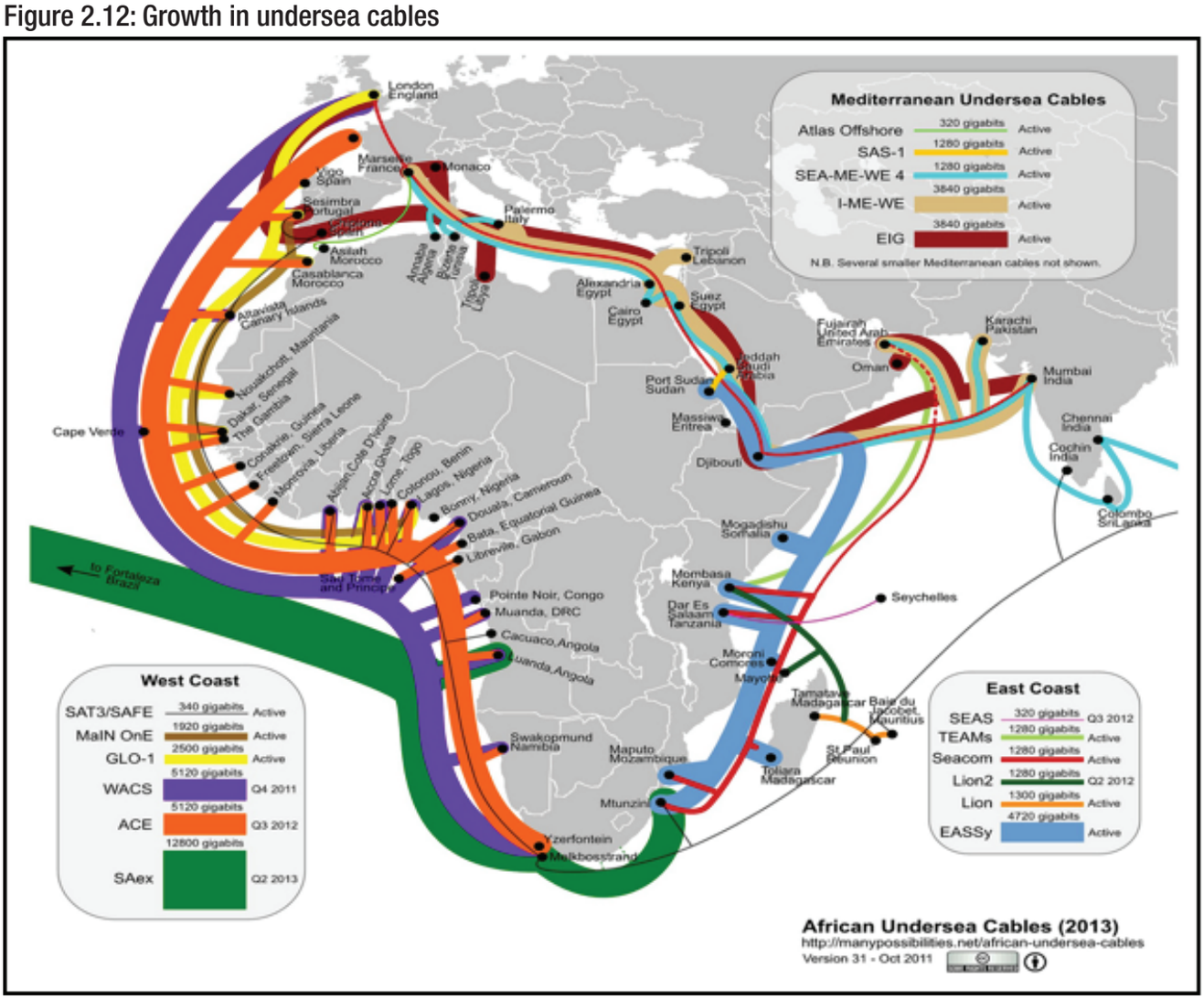
2.1.5.1 Backbone network infrastructure

The telecommunication infrastructure in Africa has evolved as technology has changed and customer demand to new services has grown. The established infrastructure determines the type of services available to customers and the quality and dynamics of the competition among service providers. Telecommunication infrastructure consists of interconnected networks that carry different types of information traffic. In this context, two major divisions of "fixed" and "mobile" networks have been established, based on the categories distinguishing fixed-line networks and wireless networks that began to emerge in the 1980s.

2.1.5.2 Submarine and terrestrial transmission networks

The recent deployment of fibre optic cable links across Africa, as shown in Figure 2.12, has increased bandwidth availability and reduced dependence on expensive satellite links. This has resulted in a significant improvement in services and reduction in the cost of Internet and communication services. As of 2011, the 13 submarine cables with landing points in sub-Saharan Africa have a total design capacity of 14.0 Tbps.[28] The capacity is expected to reach 25.8 Tbps by end of 2012.

Figure 2.12: Growth in undersea cables



Source: http://manypossibilities.net/african-undersea-cables/, date accessed 2012

28 Tbps = Tera bytes per second (1000 Gigabytes)

In order to deliver the benefits of this capacity to customers, Africa's private and public sector players have been investing heavily in terrestrial transmission networks. In 2009, Africa had only 465,659 km of terrestrial high capacity transmission networks. This figure had increased to 676,739 km by September 2011. Estimates suggest that about 138 km of new fibre networks entered into service per day in the last 12 months. In other words, 313.2 million people (36.3 per cent) were within reach of operational fibre node by mid-2011 compared to 259.3 million people (30.8 per cent) in June 2010.

However, there was a north-south divide in terms of usage between countries in North Africa (Algeria, Egypt, Libya, Morocco, Tunisia and Western Sahara), which consumed 60 per cent of the bandwidth, i.e. 312 Gigabits, and the rest of the continent, which consumed only 208 Gigabits as of end 2010.

2.2 Development of geospatial science and technology in Africa

2.2.1 Overview

Geographic Information System (GIS) is a tool that allows users to create, edit and analyze spatial data, and visualize the results of these operations. GIS has three major components: (a) a database system to store both geospatial and thematic data; (b) a capacity to spatially model or analyse the data; and (c) visualization capabilities. Geospatial Information Technology (GIT), also known as "Geomatics", includes three technology systems: GPS (global positioning systems), GIS (geographical information systems), and RS (remote sensing). GIS is one of the core occupational fields within the overall geospatial technology industry.

Due to developments in the ICT sector, geospatial technology innovation is evolving at a fast rate and current geospatial innovation is being driven more and more by users. Consumer-oriented geospatial web tools such as Google Maps, Google Earth and Microsoft Virtual Earth are continuously adding new functionalities. It is also noteworthy that space technology capabilities are improving in Africa. Many African countries are participating in a variety of space technology initiatives, such as the encouraging evolution of an African Resource Management Satellites (ARMS) constellation programme, which will help the continent achieve its own space science and technology agenda.

Geospatial information technology (GIT) is becoming known worldwide as an information development tool in an economy. Given that 80 per cent of public and private planning and decision making processes use geospatial data[29], it becomes obvious that geospatial science and technologies are increasingly taking centre stage in the knowledge-based economy. A number of sectors can significantly benefit from access to geospatial information and services. These include travel and tourism, navigation, traffic, communications, utilities, transportation, national defence, agriculture, emergencies and public security, public health, location/mobile services, environmental modelling and management, water resource management, climate change, land administration, petroleum and solid minerals, and the emerging needs of e-commerce.

GIS plays an important role in ensuring that all products and processes can be located, the beneficiaries identified, and the markets, infrastructure, elements, utilities, etc. mapped. Such information is useful in planning and managing specific activities or events, mapping risks and determining the best way to move (people, products, and services) from source to destination. This has made products such as Google maps critical in locating businesses (e.g. hotels, manufacturers, schools, hospitals etc.) and navigating or planning unfamiliar routes (e.g. pedestrians and drivers moving from one side of town to another). There are a number of specialized and intergovernmental institutions at the continental and regional level in Africa with geo-

29 Østensen O. (2001) "The Expanding Agenda of Geographic Information Systems", ISO Bulletin, July 2001, www.iso.ch/iso/en/commcentre/pdf/geographic0107.pdf

spatial information technology capabilities. These institutions provide a structure and the basis of essential building blocks for geospatial technology uptake in Africa.

2.2.2 Technological drivers of GIS

The current rise in the adoption and use of geospatial information and geospatial technology has been driven by rapid development in technology for the acquisition, storage, analysis and presentation of geographic data. High resolution aerial photographic imagery will not be possible without significant development in camera and sensor technologies. As a result, ground resolution increased from approximately 79 meters in 1972 to about 10 metres in 1986 and 0.25 metres in 2009 (Armstrong, 2001). Firms such as Geo-Eye and Digital Globe (satellite imagery) and GeoVantage (aerial photographic imagery) offer high resolution ground images of about 0.25 metres for commercial purposes.[30]

These developments open up new applications for GIS in a variety of areas. For instance, the French wine makers in the city of Bordeaux receive a CD of infrared satellite imagery of their plots taken by satellites from 800 kilometres up in the sky shot between 15 and 20 days before the grapes change colour. In partnership with the Wine Cooperative Institute (WCI)[31], a subsidiary of Astrium Services offers to provide an instant overall view of vineyards. The satellite maps help farmers assess the uniformity of the ripening process as it takes place in a specific plot of land. Farmers can quickly decide which zones to harvest first. This has helped them increase the amount of grapes put in their premium production as well as improve their growing practices. The users pay about $100 per acre per year for the service.[32]

It has also become possible to undertake routine acquisition of remotely sensed imagery captured by airborne systems or satellites. Commercial aircraft mounted with specially designed cameras can capture large amounts of data as they fly around a number of locations of interest. Such data is useful for industries such as insurance companies, local government institutions, natural resource management agencies, tax authorities and State agencies.[33]

Geospatial technology and communication technology developments such as positioning systems, database technology, open standards, Internet development, wireless communication and network infrastructures (wired and mobile) had important roles to play in the development of the geospatial industry. Many of these technologies enable the industry to develop products.

Significant amounts of data are now captured on the ground from motor vehicles, mobile phones and other ground based-tools. Since mobile phone users are increasing in Africa and many of these phones are now coming with geospatial solutions such as GPS applications and street maps, it is expected that mobile devices will increasingly become an important medium for acquisition, communication, management and location-based services (Olajide, 2009).

The end of the last decade witnessed an explosion in wireless mobile communication infrastructure which led to the development of mobile mapping technologies. These technologies range from simple land-based systems to more sophisticated, real-time multitasking and multi-sensor devices, such as charge-coupled device (CCD) cameras, Light Detection and Ranging (LiDAR) and hyperspectral/multispectral scanners, aimed at automatic data acquisition for geoinformatics; thematic mapping, land classification, terrain modelling, emergency response and domestic or internal security.

30 Satellite Imaging Corporation, http://www.satimagingcorp.com/satellite-sensors/geoeye-2.html
31 http://www.icv.fr/documents/Services/SpotMAG_juin08_oenoview.pdf (Accessed July 2012)
32 http://worldcrunch.com/french-winemakers-use-satellites-and-infrared-spy-their-own-crop/3580 (Accessed July 2012)
33 INTERGRAPH. Imagine Objective: the Future of Feature Extraction, Update and Change Mapping. http://geospatial.intergraph.com/Libraries/Brochures/IMAGINE_Objective_Brochure.sflb.ashx, accessed on 12 July 2012.

There is an increase in the ways data are visualized, from a physical mapping environment to a digital view that demonstrates how the user would experience a location; for instance, street views in Google Earth. The creation of geospatially accurate 3D city models and flythrough software that allow users to view a journey are areas that are expected to grow. Geospatial data is critical for helping to supplement 3D views of other geo-coded information to provide; for example, 3D business intelligence, supported by feeds from semi-structured data from mobile devices, geotagging of existing enterprise structured data, and tapping into new streams of location-aware unstructured data[34].

Traditional GIS software was designed with a single-user model. This approach is inadequate for multi-user groups addressing complex scientific and public policy challenges. Moreover, the complexity of geodata requires multiple concurrent processing workflows. Geospatial web services within a Spatial Data Infrastructure (SDI) framework therefore represent a main interest in geospatial information technology by provide access to spatial data and GIS functionalities through the Internet. This is leading to increased use of network-distributed parallel processing or 'grid computing' with improvements in data sharing and knowledge sharing through interoperable systems and common standards.

In an increasingly connected world, volunteered information generated via crowd sourcing and other broad social platforms will become more and more important. The need and demand for this kind of information will possibly challenge traditional approaches to geospatial data generation and maintenance.

2.2.3 Examples of GIS applications in decision making in Africa

Currently, GIS is used in virtually all disciplines that require geospatial data to execute their tasks or solve their problems. Some of the applications of GIS are in areas of climate change, disaster risk, food security, water resource, energy, population dynamics and urbanization, poverty reduction, and (HIV, Malaria, TB, etc.) and utilities. A few cases of applications in Africa are provided in the sections below.

2.2.3.1 The case of rural electrification in Zambia

Zambia has a relatively small population of 13.5 million dispersed over an area of 752,612 square km.[35] Provision of modern energy sources to the public is a major challenge. Therefore, the need to prioritize locations to be provided with electricity, identify potential sources and distance to power stations and identify the presence of economic activity in areas becomes important. During the development of the Zambia Electricity Master Plan in 2005, Zambia and its partners turned to GIS. Using the open-source GIS application DIVA-GIS, a large amount of data was collected, analysed and visualized for the different energy options or mixes.

The data used included flow rates of rivers, rainfall received, known and potential mini/micro hydro locations, sunshine hours, wind speeds, known potential wind power sites, existing power stations, agriculture and forest wastes and existing hot spring sites, among others. This data was then overlaid with population density, economic activity, public sector institutions (e.g., schools, hospitals, municipalities) as well as potential for new or improved resource-based activities such as irrigated agriculture, forest products and food processing. This information can easily be visualized to support decision-making.

2.2.3.2 Mapping post-election violence in Kenya

Following the 2008 disputed presidential elections in Kenya and the violence that hit the country thereafter, a web-based mapping of violent incidents reported via mobile phone SMS quickly attracted about 45,000

34 GSDI (2001). Developing Spatial Data Infrastructure: The SDI Cookbook. GSDI

35 For example, New Delhi's 16.7 million residents live on 1,484 square km

users in Kenya. The platform, called Ushahidi[36], is built as a tool to easily crowdsource information using multiple channels, including SMS, email, Twitter and the web. The platform was used to map xenophobic attacks in South Africa in 2008, monitor elections in Burundi, India, Mexico and Sudan, warn drivers about snow-covered roads, map clean-up efforts during a blizzard in Washington DC and to monitor the BP oil spill in the Gulf of Mexico. Ushahidi has transformed itself into a not-for-profit technology firm that offers GIS-based services.

2.2.3.3 GIS-based firms in Africa

In September 2010, Ushaidi, won the global Nokia Growth Economy Venture Challenge for developing the most innovative mobile solution aimed at improving the lives of people in the developing world.[37] This is a Cinderella story as the company was developed to track the Kenyan post-election violence and has since been used in virtually every human crisis or weather catastrophe in the world.[38]

Buffalo GIS is another open source software providing web-enabled, multi-tiered, enterprise-based GIS. It was designed and developed in South Africa by DataWorld Inc. Buffalo GIS is an open source, agnostic, spatial data delivery platform that provides a wizard-based friendly user interface to setup a spatial data infrastructure. The platform is rapidly expanding through community development support and is a reliable alternative to some widely established commercial GIS systems such as Intergraph MGE/MGA or ArcGIS.

2.2.4 Communication satellite deployments

Satellites play an important role in communication, earth observation and tracking, monitoring and control, as well as in the management of various activities and events. A few African countries such as Egypt and Morocco have their own communication satellites. The RASCOM project, a pan-African satellite communications system providing continental coverage for the exchange of radio and television programmes is also expected to improve communication infrastructure.

In Africa, satellites were traditionally the tools for voice networks, to handle international telecommunications traffic. Submarine fibre-optic network infrastructure has now become the technology of choice for high-volume traffic. However, links carrying lower volumes of traffic could remain wireless or use satellite technology.

In this context, it is estimated that 508,000 square kilometres of terrestrial backbone infrastructure (microwave and fibre-optic cables)[39] operating in sub-Saharan Africa are serving around three-quarters of the region's communications users, while the other one-quarter of the region's users utilize satellites for backbone connectivity.[40]

2.2.5 Earth observation satellites deployments

There is growing interest by several countries in developing capacity for space research and development. Countries such as South Africa, Algeria, Nigeria and Egypt have already launched their own satellites in space. Today, there are several African-owned operational earth observation satellites in orbit; AlSat-1 (belonging to Algeria), NigeriaSat-1, NigeriaSat-2 and NigeriaSat-X (belonging to Nigeria) and EgyptSat-1 (belonging to Egypt). Among the pioneers, South Africa rolled out the legal and institutional infrastructure for a space

36 www.ushahidi.com
37 http://www.callingallinnovators.com/venture_challenge.aspx
38 http://www.ushahidi.com/about-us/newsroom/in-the-news
39 The metrics used to measure the extent of backbone networks is typically length (in kilometers) and capacity (megabits per second, or Mbps). Microwave and fibre networks can be measured this way, but measuring the length of satellite links is not a relevant statistic.
40 Ibid 9

programme in 1994. In 1999, South Africa launched its first satellite, SUNSAT, which was built by post-graduate engineering students at the University of Stellenbosch and has the capacity to record images of vegetation, plant vigour and stress, biomass, water bodies, silt in the water, roads and bare soil, among others. A second South African micro earth observation satellite, SumbandilaSat, was launched in 2009, designed and initially managed by students and researchers at Stellenbosch University. The Department of Science and Technology commissioned the work to build, launch and commission the spacecraft.

Algeria and Nigeria also have their own space agencies. In 1999, the Federal Government of Nigeria approved the Nigerian Space Policy and the implementation of a space programme through the establishment of a National Space Research and Development Agency (NASRDA). The space policy has a programme tailored towards the development of space, science and technology in Nigeria, through R&D, as well as capacity-building in the fields of science, engineering, space law and administration for sustainable national development. Nigeria launched its first satellite, NigeriaSat-1, into orbit in September 2003. NigeriaSat-2 and NigeriaSat-X were launched on 17 August 2011. The satellites were built by engineers from Nigeria's National Space Research and Development Agency (NASRDA) under the supervision of Surrey Satellite Technology Ltd (SSTL, UK). Two joint NASRDA-SSTL teams are working in parallel in Abuja and Guildford in the UK to commission NigeriaSat-X and NigeriaSat-2.

Since developing countries have severe resource constraints, South Africa's space programme identified the need to involve bilateral and multilateral partnerships to assist in its revival. South Africa has negotiated with Algeria, Kenya, and Nigeria to create the African Resource Management Constellation (ARMC) to pool imagery and other remote sensing data from all their microsatellites. These four countries are cooperating for a satellites constellation dedicated to the monitoring and management of African resources and the environment.

2.2.6 Global navigation satellite systems

Modern surveying and geodesy have benefited enormously from the introduction of the Global Positioning System (GPS) which originated in the USA and is currently one of four similar systems generically known as Global Navigation Satellite Systems (GNSS). Apart from GPS, GNSS includes the fully operational Russian GLONASS, the European Galileo and Chinese Compass/Beidou systems. All African countries have started embracing the use and applications of GNSS technologies, particularly the Global Positioning System (GPS), in various geoinformation applications, services and products.

A sparse continuous operating reference stations (CORS) GNSS network has been established and is managed by some African States, the International GNSS Service (IGS) and other partners. This network has at least one station in 19 African countries.[41] Other countries, such as Cameroon and Niger, are expected to establish CORS soon.

A recent survey of GPS sites indicates 116 GPS base stations so far in Africa (Figure 2.13). A total of 43 stations are currently broadcasting data that can be used for computing of position solutions and analysis. The data from the established CORS is already being received by the Hartebeesthoek Radio Astronomy Observatory data Centre in South Africa and by the IGS.

It is now possible to survey and map across vast areas of Africa with incredible accuracy. Given the right conditions, equipment and data processing methods, accuracies of less than a few centimetres over a few hundred kilometres can be achieved on a regular basis. The realization of the African Geodetic Reference Frame, (AFREF)[42] has vast potential for geoinformation applications such as mapping, surveying, natural hazards

41 Algeria, Egypt, Mozambique, Ghana, Kenya, Benin, Morocco, South Africa, Namibia, Zambia, Côte d'Ivoire, Malawi, Angola, Mauritius, S. Tomé e Príncipe, Uganda, Cape Verde, and Nigeria.

42 www.uneca.org

mitigation, earth sciences etc. AFREF, when fully implemented, will consist of a network of continuous permanent GPS stations such that a user anywhere in Africa would have free access to GPS data and products, from at most 1000 km from such stations.

Figure 2.13: Location of GNSS reference stations in Africa

Source: African Geodetic Reference Frame workshop, Feb 2010

2.2.7 Human resource development in geospatial information technology

The field of geospatial technology is growing very fast and African countries have started to put in place various mechanisms to build the necessary infrastructure and human resources. The number of universities offering undergraduate and post-graduate degrees in geospatial-related fields is on the rise. This trend is likely to be sustained as career opportunities continue to rise both in industry and Government.

Departments of Geomatic Engineering have emerged in universities such as Kwame Nkrumah University of Science and Technology (Ghana), Jomo Kenyatta University of Agriculture and Technology (Kenya), Makerere University (Uganda), University of Cape Town (South Africa) and University of Zambia (Zambia), Ahmadu Bello University (Nigeria), just to mention a few. Other universities, such as University of Nairobi (Kenya) and Stellenbosch University (South Africa), have taken a further step to include space technology and research. A good proportion of the departments are located in the schools of engineering and/or technology.

However, with recent progress in geovisualization, there is an increase in customer-focused evolution towards spatially-enabled and locally centered services. Thus, spatial literacy will not only be about learning GIS in schools. Rather, it will be about creating spatial awareness, navigational abilities and an understanding that most of today's issues have a significant spatial aspect.

In this regard, a number of specialized courses are offered by different regional centres such as the Regional Centre for Training in Aerospace Surveys (RECTAS) located at Ile-Ife, Nigeria and the Regional Centre for Mapping and Resource Development (RCMRD) located at Nairobi, Kenya, the Centre Régional Africain des Sciences et Technologies de l'Espace (CRASTE-LF) located in Rabat, Morocco and the African Regional Centre for Space Science and Technology Education in English (ARCSSTE-E), located in Ile-Ife, Nigeria and the African Organization for Cartography and Remote Sensing, located in Algeria.

RECTAS offers long-term programmes in Geoinformation Production and Management. Student enrolment for 2009-2011 was 133 at the technician, technologist and postgraduate diploma level, and 26 at the Master of Science level. Short-term training programmes, seminars and workshops are provided at the Centre under its consultancy and advisory services. Between 2009 and 2011, 80 trainees from state governments, ministries and mapping agencies attended short courses in Geo-information and Environmental Management (GEM), Digital Cartography and Information Extraction, and Remote Sensing and GIS Applications.

The capacity building activities at RCMRD are mainly short courses in resource survey, mapping, remote sensing, GIS and natural resource assessment and management. To date the Centre has trained over 3,000 technical officers from its member States and other African countries. It has also implemented numerous projects on behalf of its member States and development partners.

2.2.8 Trends in GIS publications of selected countries

Another indirect measure of the manpower and investment in GIS can be deduced from trends in research performance. Tracking publications in GIS can indirectly tell whether countries are investing in and performing GIS-related R&D of international interest. One such indirect measure is peer-reviewed publications. Since this field is relatively young, this section looks at the trend in Egypt, Kenya and South Africa.

The number of publications in GIS grew by 61.5 per cent between the periods 2000-2004 and 2005-2009 for Kenya and by about 32.6 per cent for South Africa over the same period (Table 2.4). The growth rate is within the growth rate registered by the United States but falls far short of that registered by China in the same period.

Table 2.4: Publications of four selected countries in GIS

Period	2000-2004	2005-2009	Growth rate (per cent)
Kenya	26	42	61.5
South Africa	49	65	32.6
China	313	796	154.3
USA	1462	2184	39.4

Source: ISI data base, UNECA Analysis, 2011

The number of papers published in the field of remote sensing has generally increased, despite the fact that Africa is coming from a very low base. For instance, South Africa posted a growth rate of 207 per cent - similar to that of China - and far higher than that of the United States (see Table 2.5 for details). This trend suggests that Africa is investing in research that meets international standards and interest.

Table 2.5: Publication trends in remote sensing for selected countries

Period	2000-2004	2005-2009	Growth rates (as a per cent)
Egypt	13	28	115.4
Kenya	13	23	76.9
South Africa	28	86	207.1
China	421	1388	229.7
USA	2887	4188	45.1

Source: ISI data base, UNECA Analysis, 2011

2.2.9 Emerging trends in Geospatial Information Technology

Observing the new trends and changes to business logics involving geospatial information, and also looking at expected technological progress, the main drivers of the market trends in the GIS industry are classified in three categories: data, tools and applications.

Regarding data, the growing availability and use of dynamic geoinformation, such as real-time traffic conditions, weather data and river water levels, has led to the development of location-based services. Location-based services exploit the location of the device to provide personalised services to the user of the device. However, location-based services need highly accurate geoinformation, obtained primarily from high-resolution ortho-rectified satellite imagery and aerial photography using the new map-building technologies that have become available. The future trend is moving to dynamically offered scalable solutions that support key open standards in reading, possessing and analysing large collections of file-based imagery through web services accessible to virtually any client.

Regarding tools, as technology continues to evolve, web services like Google Earth and Microsoft Virtual Earth will all individuals to become more involved with the creation, maintenance and distribution of their own geospatial information. Web mapping or mash-up map services allow the integration and creation of new web-based maps. These will continue to introduce more people into daily experiences and perception of spatially enabled services. In turn, this will expand opportunities for the development of innovation, research and operational services, which can support economic growth.

Regarding applications, the translation of complex cycles of data acquisition and bringing their processing, analysis, visualization and decision-making potential into real time monitoring and management has become a reality. With popular applications such as Google Earth and community mapping, the GIS industry is moving from analyzing and presenting discrete data sets towards working with streams of spatially enabled data (e.g. real-time location-based mobile services).

Positioning technologies are pervasively making our societies mobile in every aspect. Individual, environmental and business "objects" change across an ubiquitous positioning infrastructure and will be a key enabler for novel GIT applications. We expect to see a rapidly evolving market for geospatial solutions since we are approaching the final convergence of GIS, mobile location-based services and enterprise information technology into one integrated system. This convergence will spawn new markets and solutions that will drive growth in the future. If African expertise and enterprise in the relevant areas are developed, Africa can be a generator and seller of innovation and products in this area.

2.3 Software and content development

2.3.1 Status of software development in Africa

The software industry in Africa is just emerging and lacks large firms that match the likes of Microsoft, Infosys and SPSS. However, South Africa, Morocco, Egypt, Mauritius, Kenya and Tunisia are strategically positioning themselves as preferred destinations in IT offshoring services (Gereffi and Fernandez-Stark, 2010). It is argued that, for Africa, software production is the best entry point into the IT production complex. Compared to hardware production, software production has much lower entry barriers because it is less capital-intensive, more labour-intensive, with a lower rate of obsolescence, and (at least for certain types of software) it has far fewer economies of scale (Heeks, 1996).

There are a few success stories in Africa's software industry for producing globally competitive solutions for both local and international markets. In Tunisia, for example, software firms recorded an average growth of 16 per cent from 2005 to 2010. Export turnover constantly rose from 20 per cent in 2001 to over 40 per cent in 2008. As at early 2010, Tunisia had over 600 software firms (Tunisia, 2009).

The recent mobile revolution in Africa has also opened up a new window for innovation and a market for software development. Foreign and local enterprises are today spearheading the development of new applications in areas such as mobile money and mobile insurance in view of the large parts of the population that are un-banked and uninsured. Safaricom's M-PESA, the first mobile money transfer service developed in Africa, is well known and reported. As shown in Table 2.6, almost all mobile service providers in Eastern, Central and Southern Africa are now developing their own mobile money application (UNCTAD, 2011b).

Table 2.6: Applications developed for mobile money systems

Type of Activity/Service	Enterprises
Mobile money integration platform	Airtel (formerly Zain), Essar Telecom (Yu Cash), MobiKash, MobiPay, Safaricom (M-Pesa), Tangaza Limited, Orange Telecom (Orange Money)
M-money integration platform	Cellulant, CoreTEC, Craft Silicon, Intrepid Data Systems, KopoKopo, Tangazoetu Limited, The Software Group, Zege Technologies, Web Tribe Limited
M-money e-commerce processing	ePay Kenya, PesaPal, Symbiotic Media Consortium, Tristar
Management Information Systems integrated with mobile money	Flexus Technologies
International remittances via local mobile money channel	Beyonic, Western Union/Safaricom
ATM infrastructure integrated with mobile money	Paynet Group, KCB Kenya, Equity Bank

Source: UNCTAD, 2011

These developments are empowering other sectors such as education, health and finance. A number of private firms and not-for-profit organizations are supporting or developing software for various industries and social organizations and activities. A number of them are developing globally competitive software packages for the international market. Terms such as m-commerce, m-health, m-learning, and m-agriculture, among others, represent a convergence between internet and mobile applications. These services are becoming the key growth areas revolutionizing Africa's financial sector, where hundreds of millions of people are unable to access traditional banking services or do not have a bank account (UNECA, 2009).

For example, on the M-PESA platform alone, 14 million users in Kenya are now able to conduct basic banking activities, creating more than 28,000 jobs and generating a flow of $300 million person-to-person transactions each month (about 10 per cent of Kenya's annual GDP). Similar services now available in many African countries include Wizzit and MTN Mobile Banking in South-Africa, Airtel Money in Kenya, Democratic Republic of the Congo and Zambia, Telma in Madagascar, MobilPawa, NMB and e-Fulusi Africa in Tanzania and m-Birr in Ethiopia (Gereffi and Fernandez-Stark, 2010).

In agriculture, mobile technologies have enabled smallholder farmers to access timely information on inputs, prices, market, good cultivation practices, improved crop varieties, pest and disease management. They can improve smallholder access to information and transactions related to inputs like seeds, fertilizers, pesticides as well as outputs.

Manobi service, for instance, offers market trading information and water management for farmers and rescue for fishermen, using Mobile cellular telephony technology and GIS and Satellite Tracking System in Senegal and South Africa (Gakuru, Winters and Stepman, 2009). Similar marketing information systems seek to foster regional trading and market integration. For instance, E-Soko, founded in Ghana as TradeNet

in 2005, offers current market data via SMS and the web and is now active in 15 African countries (including Ghana, Nigeria, Mozambique, Burundi, Zambia, Mali, Ivory Coast, Madagascar, Rwanda, Kenya, Burkina Faso, Sudan, Malawi, Tanzania and Uganda).[43] A Bill and Melinda Gates Foundation-supported system "has established m-Agri: a mobile phone voice-based farmer helpline" which is currently being implemented to provide demand-driven agricultural information in Burkina Faso, Ghana, Kenya, Mali, Mozambique, Tanzania, Malawi, Niger, Nigeria, Rwanda, Uganda and Zambia.

In Niger, the mobile phone rollout on grain markets reduced grain price dispersion across markets by a minimum of 6.4 per cent and reduced intra-annual price variation by 10 per cent (Aker, 2008). In Kenya, the DrumNet project, on farmers' welfare, which used food security status and access to medical health services as proxies of welfare, improved farmers' incomes from the sale of their crops and produced more food from their farms than those of their counterparts (Okello, 2010).

In the health sector, mobile health applications have shown tremendous potential from a wide range of initiatives implemented across the continent. A study commissioned by the World Health Organization (WHO) revealed that round 75 per cent of African countries are involved in m-Health activities. In Kenya, a mobile application called RapidSMS is used by more than a hundred community health workers to monitor more than ten thousand children under the age of five. This platform is also used in Rwanda by community health workers to inform health centres about emergency obstetric and infant cases, enabling the centres to offer advice or call for an ambulance if necessary. Similarly, the Treatment and Research Centre on AIDS (TRAC) of Rwanda designed an m-application to collect, store, retrieve, display and disseminate critical health information, as well as manage drug distribution and patient information related to care and treatment of HIV/AIDS. This initiative was awarded the 2007 Technology in Government Award (TIGA) of UNECA.

In Botswana, a mobile-based malaria surveillance and mapping programme is used to gather and upload real-time malaria data. In Ghana, the Mobile Midwife initiative provides antenatal and neonatal care among the rural poor; while in Ethiopia, UNECA has been supporting a research programme with the Addis Ababa University to develop an e-Health mobile application based on an Ethiopian script keyboard for smart phones.

In the area of education, the number of m-learning applications is steadily growing and this has also enhanced the students' desire to pursue specific subjects such as mathematics, science and health. For example, Dr. Math on MXIT in South Africa is an m-learning application to provide tutorial help in mathematics to over 5,500 pupils. A Nokia/MXIT is designed to improve high school mathematics score through drill-and-practice quizzes and the m-Ubuntu initiative connects South African teachers with coaches in the United States and England (GSMA, 2010).

In Tanzania and South-Africa, Bridge is providing teachers in primary schools with access to a variety of digital video content in mathematics, science, English and life skills, for use in their classrooms. Teachers connect their mobile phones to a television set and transmit educational materials to their students.[44]

2.3.2 Free and open source software in Africa

Free and Open Source Software (FOSS) are programmes whose licenses give users the freedom to run the programme for any purpose, study and modify the programme and redistribute copies of either the original or modified programme without having to pay royalties to previous developers.[45] This makes localization of the software to a specific language, cultural context, convention and market requirement possible. There are

43 See Startup Watch: Esoko Ltd: Powering an agric revolution. http://afrinnovator.com/blog/tag/accra/feed
44 Ibid 28
45 See http://en.wikibooks.org/wiki/FOSS_A_General_Introduction/Introduction

also financial benefits, as the total cost of ownership, which includes direct software cost (purchase, maintenance, support), indirect software costs (license administration, audit), staffing (project management, systems engineering, administration, etc.), support (install, troubleshoot, casual learning, training) and downtime, may be lower for open-source than commercial software (Opoku-Mensah, and Chekol 2010).
In its efforts to promote FOSS, ECA, at its Third Meeting of the Committee on Development Information (CODI-III) held in May 2003, adopted a resolution[46] requesting, inter alia, member States to adopt free and open source software as an important tool in promoting ICT and good governance. In the same year, the Free and Open Source Software Foundation for Africa (FOSSFA) was officially launched in Geneva, at the Second Meeting of the Preparatory Committee of the World Summit on the Information Society (WSIS). FOSSFA promotes the use and adoption of FOSS in Africa. It also organizes the bi-annual African Conference on FOSS and the Digital Commons – IDLELO[47], which is a forum where stakeholders exchange information, evaluate policies, build capacity and test emerging solutions.

There are major barriers to the uptake of FOSS in Africa. These include the lack of awareness, lack of teaching of FOSS in schools and lack of national policies to support FOSS (Sowe, 2011). Despite these challenges, FOSS is making a major impact on m-applications and e-applications.

Indeed, one FOSS-based software firm is the Kenyan firm, Ushaidi, which, in September 2010, won the global Nokia Growth Economy Venture Challenge for developing the most innovative mobile solution aimed at improving the lives of people in the developing world.[48] This is a Cinderella story as the company was developed to track the Kenyan post-election violence and has since been used in virtually every human crisis or weather catastrophe in the world.[49]

In the geospatial sector, Buffalo GIS is another open source software providing web-enabled, multi-tiered, enterprise-based GIS. It was designed and developed in South Africa by DataWorld Inc. Buffalo GIS is an open source, agnostic, spatial data delivery platform that provides a wizard-based user-friendly interface to setup a spatial data infrastructure. The platform is rapidly expanding through community development support and is a reliable alternative to some widely established commercial GIS systems such as Intergraph MGE/MGA or ArcGIS.

In conclusion, the software industry clearly offers opportunities for African countries. It is both an area that opens up access to major technologies of benefit to Africa and to which the continent can contribute and generate innovation-led business opportunities. Entry into software development requires relatively small levels of capital investment and infrastructure and the returns can be significant. To realize these opportunities however, Governments need to be proactive in the promotion of local industry by taking steps, for example, to stimulate software exports, subsidize telecommunications, support the establishment of research institutes and relevant university programmes, offer tax and financial incentives, reduce trade barriers, plan and coordinate industry efforts, market software activities collectively and pass and enforce copyright laws.

2.4 Human resource development in the ICT sector

The ECA WSIS survey (2010) revealed that there were over 200 tertiary-level institutions offering ICT programmes in 21 African countries (UNECA, 2010).[50] The number of students benefiting from these campus-based programmes, as well as from online and blended learning programmes, can be counted already in

46 http://repository.uneca.org/codist/sites/default/files/Report per cent20of per cent20the per cent20Third per cent20Meeting per cent20of per cent20the per cent20Committee per cent20on per cent20Development per cent20Information.pdf
47 http://www.idlelo.net
48 http://www.callingallinnovators.com/venture_challenge.aspx
49 http://www.ushahidi.com/about-us/newsroom/in-the-news
50 Note that it was a study sample of 11 selected countries

hundreds of thousands. Moreover, there are major cross-border services like the African Virtual University, which further promote ICT programmes and activities. The upward trend is clear and gaining momentum.

One of the most important factors in building up the ICT base of a country is through training of ICT specialists at different levels of the education system in fields such as engineering, physics, computer sciences, geography and mathematics. In a recent ECA survey[51] of a sample of African universities on student intake and graduation over the period 1999-2010, it was observed that there was rapid growth, especially from 1999 to 2004.

Specifically, the number of new entrants in BSc degree studies in Engineering and ICT rose by slightly over 30 per cent over the period 2005 to 2010 in eight universities surveyed.[52] By comparison, enrolment figures into Masters programmes (for all science-related disciplines) over the same period practically remained on the same level, while Engineering student enrolment showed a slight growth of about 10 per cent from 2005 to 2011. For PhD programmes, the intake increased by about 50 per cent over the same period.

Teacher education remains a bottleneck when rapid and profound pedagogical paradigm change is required in the emerging knowledge societies. Africa's teacher education institutions in general, with very few exceptions, are not providing schools with sufficient numbers of teachers with proper knowledge, society skills and ICT teaching qualifications. Until this situation changes, the responsibility to acquire the necessary skills and competences will remain with national and local education authorities, schools and individual teachers in service (UNECA and IICBA, 2011).

At the secondary school level, Africa has registered marked expansion in recent years according to UNESCO, but is still lagging behind all other regions in the world (UNESCO, 2011). The readiness and capacity of mass secondary education to provide ICT-literate students for tertiary education remains inadequate. This is not only because of the lack of ICT-trained teachers, but because of missing and inadequate infrastructure, digital learning materials and access to networks.

Fortunately, various forms and types of technical and vocational education and training (TVET) institutions have emerged to fill in the gap. The technical skills developed through these institutions enhance youth employment in jobs related to the knowledge economy (Oketch, 2007). These institutions offer basic user skills as well as technical skills to install, repair, manage and upgrade network (UNCTAD, 2011a). However, the quality of the education in the mushrooming technical colleges remains a source of concern.

There is also a concern that as these are mainly commercial educational institutions, they are highly demand driven and tap primarily on more affluent segments of the society for their courses. It is of significance that a substantial number of technology and innovation hubs have been set up primarily to incubate innovations and innovative companies. These offer high-level ICT learning environments for the most technically talented African youths.

2.4.1 Human resource development in Geospatial Information Technology

The field of GIS is growing very fast and African countries have started to put in place various mechanisms to build the necessary infrastructure and human resources. The number of universities offering undergraduate and post-graduate degrees in GIS-related fields is on the rise and this trend is likely to continue as career opportunities continue to rise both in industry and government.

51 See ECA STI sample survey of 2011 published first in this report 2012.

52 Presumably, there are also students studying subjects directly related to the emergence of the knowledge economy, heavily integrated with ICTs in media studies (social media) for instance and in some of science programmes related to computational data analysis (in biomedicine, biotechnology, economics, environmental study programmes, geology, geography, linguistics, astronomy etc.). However, it has not been possible to quantify this in figures.

Departments of Geomatic Engineering have emerged in universities such as Kwame Nkrumah University of Science and Technology (Ghana), Jomo Kenyatta University of Agriculture and Technology (Kenya), Makerere University (Uganda), University of Cape Town (South Africa) and University of Zambia (Zambia), Ahmadu Bello University (Nigeria) just to mention a few. Other universities such as University of Nairobi (Kenya) and Stellenbosch University (South Africa) have taken a further step to include space and GIs. A good proportion of the departments are located in the schools of engineering and/or technology.
However, with recent progress in geovisualization, there is an increase in customer-focused evolution towards spatially-enabled and locally centered services. Thus, spatial literacy will not only be about learning GIS in schools, but rather, creating spatial awareness, navigational abilities and an understanding that most of today's issues have a significant spatial aspect.

In this regard, a number of specialized courses are offered by different regional centres such as the Regional Centre for Training in Aerospace Surveys (RECTAS) in Ile-Ife, Nigeria and the Regional Centre for Mapping and Resource Development (RCMRD) in Nairobi, the Centre Régional Africain des Sciences et Technologies de l'Espace (CRASTE-LF) in Rabat, and the African Regional Centre for Space Science and Technology Education in English (ARCSSTE-E) in Ile-Ife, Nigeria as well as the African Organization for Cartography and Remote Sensing in Algeria.

Box 2.1: RECTAS Fellowship programme

RECTAS offers long-term programmes in Geoinformation Production and Management. Student enrolment for 2009-2011 was 133 at the technician, technologist and postgraduate diploma level, and 26 at the Master of Science level. Short-term training programmes, seminars and workshops are provided at the Centre under consultancy and advisory services. From 2009 to 2011, 80 trainees from state governments, ministries and mapping agencies attended short courses in Geoinformation and Environmental Management (GEM), Digital Cartography and Information Extraction, and Remote Sensing and GIS Applications.

Capacity building activities at RCMRD are mainly short courses in resource survey, mapping, remote sensing, GIS and natural resource assessment and management. To date the Centre has trained over 3,000 technical officers from its member States and other African countries. It has also implemented numerous projects on behalf of its member States and development partners.

2.4.2 Concluding remarks

It has been noted that African university education favours non-technical subjects. For example, in the mid-1990s, South Africa produced five to six times more university graduates in humanities and social sciences than in natural sciences and engineering, whereas the ratio in Korea was around 1:1.5. There is a need to invest more in science and technology education, including ICT, and to refocus university education and the education sector in general, to offer more technical courses (Chang, 2002). This includes investment in space and satellite-related training programmes that can help build ICT capacity.

African countries need to give substantial and sustained policy priority to incorporate ICTs throughout their educational systems. There is a need to:

- Set up a systemic ongoing teacher education programme addressing both in-service and initial teacher education at all levels and sectors of education;
- Ensure development and provision of materials that comply, not only with national ICT curricula and the needs of different subjects across the curricula, but also cultural and linguistic needs;

- Continuously monitor and evaluate progress made, taking corrective measures whenever necessary and ensuring that the entire education system in respective countries is technologically enhanced in a balanced and sustainable manner.

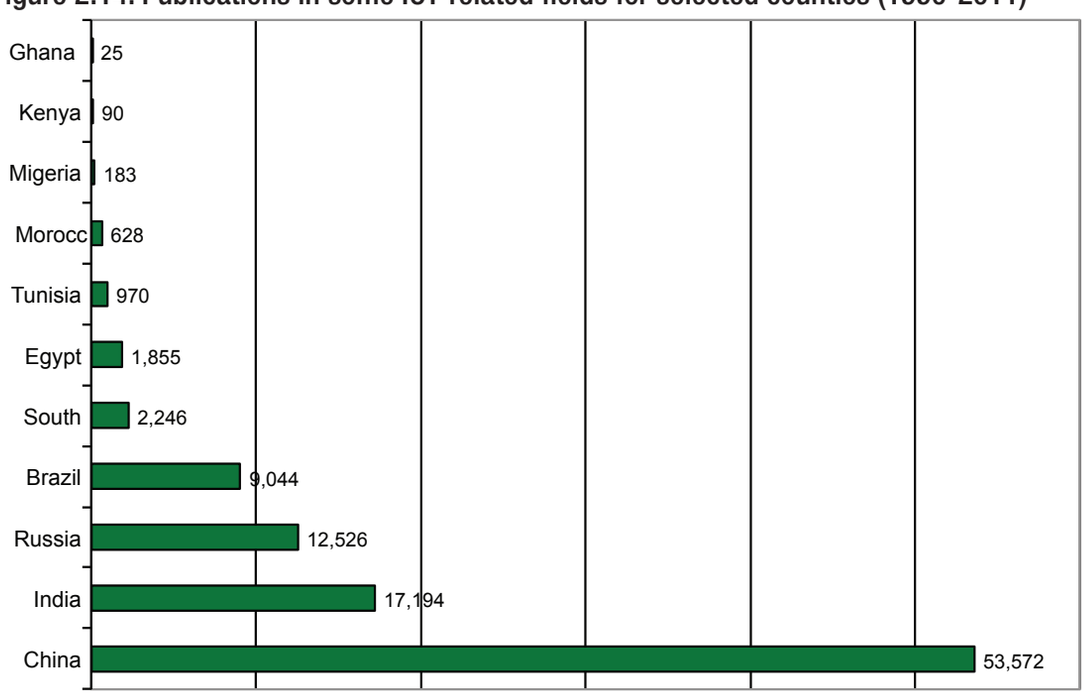
2.5 Research and development in ICT

Sustaining the fast pace of innovation in ICT requires high levels of R&D. Investment in R&D drives a robust pipeline of next-generation products and services. It sustains the performance of domestic ICT firms and contributes to the development of new technologies, which may develop into entirely new industries that create substantive employment. An indirect way of assessing R&D performance is through some of the expected outputs such as papers, patents and firms generated (Ezel and Andes, 2010).

2.5.1 Trends in ICT publications and patents (applications/grants)

In general, the numbers of papers published in areas related to ICT and GIS by African countries has increased over the last decade but remains lower than in other regions. As shown in Figure 2.14, the total number of papers published in ICT-related subjects in Africa's top publishing countries[53] remains low in comparison to the emerging economies of Brazil, Russia, India and China.[54] For instance, Brazil published about four times more papers than South Africa over the period 1990-2011.

Figure 2.14: Publications in some ICT-related fields for selected counties (1990-2011)



Source: ISI data, UNECA analysis, 2011

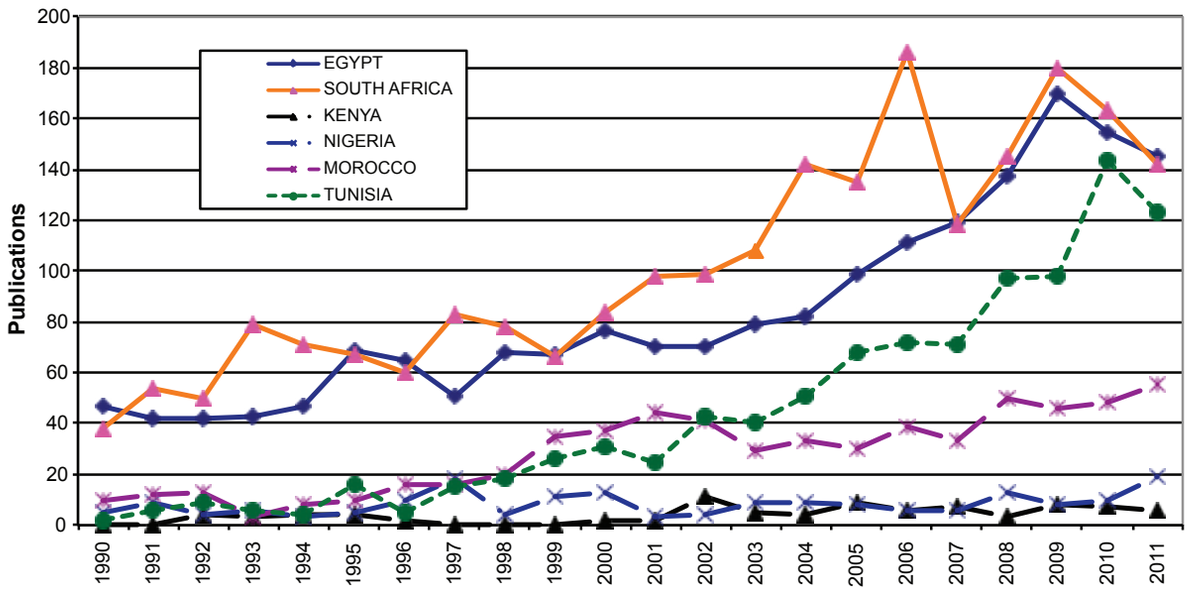
At the continental level, Egypt, South Africa and Tunisia have experienced significant growth in the number of ICT related papers published over the last decade (see Figure 2.15). Egypt, South Africa and Tunisia

53 In this report the ICT-related papers and publications are defined to belong to the following subject areas: computer sciences, telecommunications, automation control systems, remote sensing, imaging science photographic, technology, informational science library science and communication.

54 Brazil Russia, India, China and South Africa are often referred to as BRICS countries.

recorded an average growth rate of 6.7 per cent, 1.1 per cent and 12.8 per cent respectively over the period 2001-2011.[55]

Figure 2.15: Publications in some ICT-related fields for selected African countries (1990-2011)



Source: ISI data, UNECA analysis, 2011

Patent applications data was only available for South Africa. The number of ICT-related patent applications for South Africa from 2003 to 2007 is shown in Table 2.7. China is significantly way ahead of Brazil, India and South Africa in ICT-related patent applications. However, it is noteworthy that in comparison to India, South Africa performs better in: (a) audio-visual technology, (b) IT methods, and (c) electrical machinery, apparatus and energy.

Table 2.7: Patent applications by technological fields in emerging economies (2003-2007)

Field of Technology	Brazil	China	India	South Africa
Electrical machinery, apparatus, energy	1,018	26,803	179	366
Audio-visual technology	476	16,739	98	210
Telecommunications	397	32,098	302	187
Digital communication	149	31,679	304	85
Basic communication processes	43	3,169	154	13
Computer technology	400	28,691	1118	288
IT methods for management	164	2,784	146	224
Semiconductors	43	12,377	61	36

Source: WIPO Database, 2010

2.5.2 Innovation and entrepreneurship infrastructure

Technology parks and incubators are key R&D and entrepreneurship infrastructures for attracting investment, especially for countries seeking to become global leaders in technology development. The race to establish technology parks in Africa seems to be guided by a fundamental need to enhance innovative capabilities and technological entrepreneurship. Some examples of the types of technology parks developed in selected African countries to utilize and promote ICT activity are shown in Table 2.8 (Tavares, 2009).

55 Calculations are based on data from Web of Knowledge, accessed in November 2011

In Tunisia, the Government worked closely with public and private sectors (which include companies such as Microsoft, HP, Tunisie Telecom, Orange, BFPME, ACP and Tuninvest) in the development of Tunisia's ICT industry through promotion of innovation and entrepreneurship. Multiple programmes have been developed and implemented. These have helped hundreds of entrepreneurs to create new enterprises with local technological expertise. These initiatives have made Tunisia a new destination for partnership, business opportunities and investment in the ICT sector.[56]

Egypt's Ministry of Communications and Information Technology is strategically promoting R&D in the ICT industry and promoting ICT application in other sectors. Egypt has established R&D centres of excellence to promote collaboration between academic and industrial institutions at local and international levels (Egypt, 2006).

Table 2.8: Some of the technology parks in Africa

Country	Name of technology park	Focus areas	Established
South Africa	Technopark Stellenbosch (TS)	The focus sectors are the following: advanced engineering (mining technology and mineral processing), agro-food, energy, healthcare and medicine and ICT	1987
Egypt	Smart Village	To make an attractive business environment with modern high tech facilities (i.e. fibre optic network, multi-source power supply, district cooling and heating redundant network plant), effective coaching and management services for national and foreign ventures.	2003
Mauritius	The Ebene Cybercity	The Business Park provides a high quality environment to live and work in ICT fields. The aim is to position Mauritius as a regional centre of excellence for ICT outsourcing	2001
Tunisia	Elgazala Pole of Communication Technologies	Host innovating companies in the field of ICT and develop synergy between industry, research and higher education, and promote innovative ideas and international cooperation network.	2003
Morocco	Casablanca Technopark	Aims to promote and support ICT-based activities in Morocco focusing mostly on incubation and consultancy services to the public and private sector.	2001

Source: Tavares, R., (2009), Science and technology parks: An overview of the ongoing initiatives in Africa

According to Katlic[57], 22 technology hubs have been recorded since 2009, of which seven are based in Kenya, five in South Africa, three in Uganda, two in Nigeria, and the rest dispersed over a number of countries including Botswana, Cameroon, Ethiopia, Côte d'Ivoire, Liberia, Senegal and Tanzania.

In order to support private sector participation, the Information for Development (infoDev) programme of the World Bank set up mobile innovation labs or mLabs in Kenya and South Africa in 2010. The programme has also set up eight mobile social networking hubs in Nairobi, Dar-es-Salaam and Kampala.[58] Nairobi also hosts one of Nokia's 13 global research centres (the first on the continent).[59] Open innovation initiatives are also gaining momentum, especially the so-called Living Labs, which seek to enhance participatory African ICT innovation.[60]

2.6 Contribution of ICT to development

The contribution of ICT to economic development in Africa is documented in numerous case studies (see also Indjikian and Siegel, 2005). It has a major impact on the continent through jobs created and the provi-

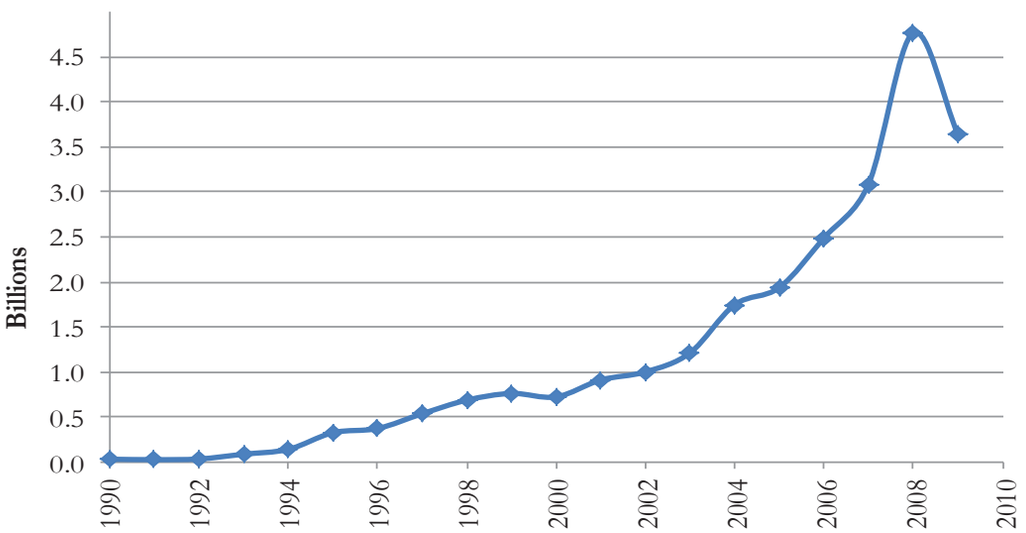
56 http://mictunis.micnetwork.org/
57 http://www.oAfrica.com
58 http://www.infodev.org/en/Topic.28.html
59 http://research.nokia.com/locations#nairobi
60 See for example http://safipa.com/newsletter/safipa-publication

sion of applications and services that have changed the economic, political, social and cultural life of Africa, including through trade diversification.

2.6.1 Trade in ICT goods and services

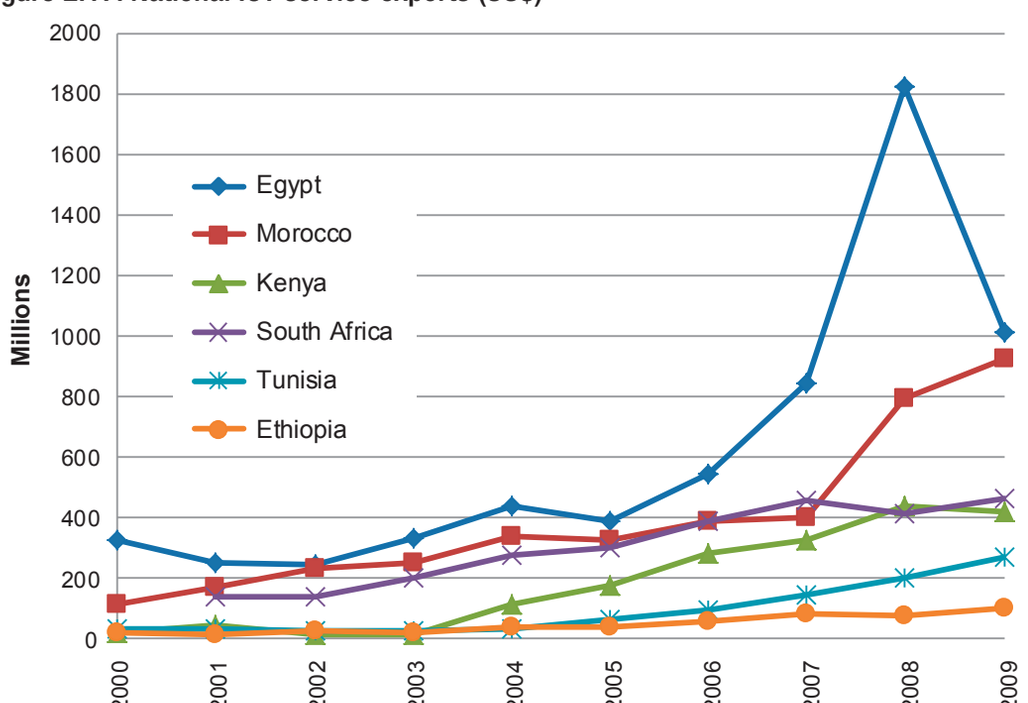
The ICT trade in African countries has grown rapidly since 1996. Africa earned about $4.5 billion from ICT exports in 2008 (see Figure 2.16 and Figure 2.12) compared to the $2.2 billion it earned from exports of cotton in the same year (UNCTAD, 2011b). For a number of countries, ICT service exports have become an important source of foreign exchange, employment, technological learning and diversification of the economy.

Figure 2.16: Africa-ICT service exports (US$)



Source: WDI, UNECA, 2011

Figure 2.17: National ICT service exports (US$)



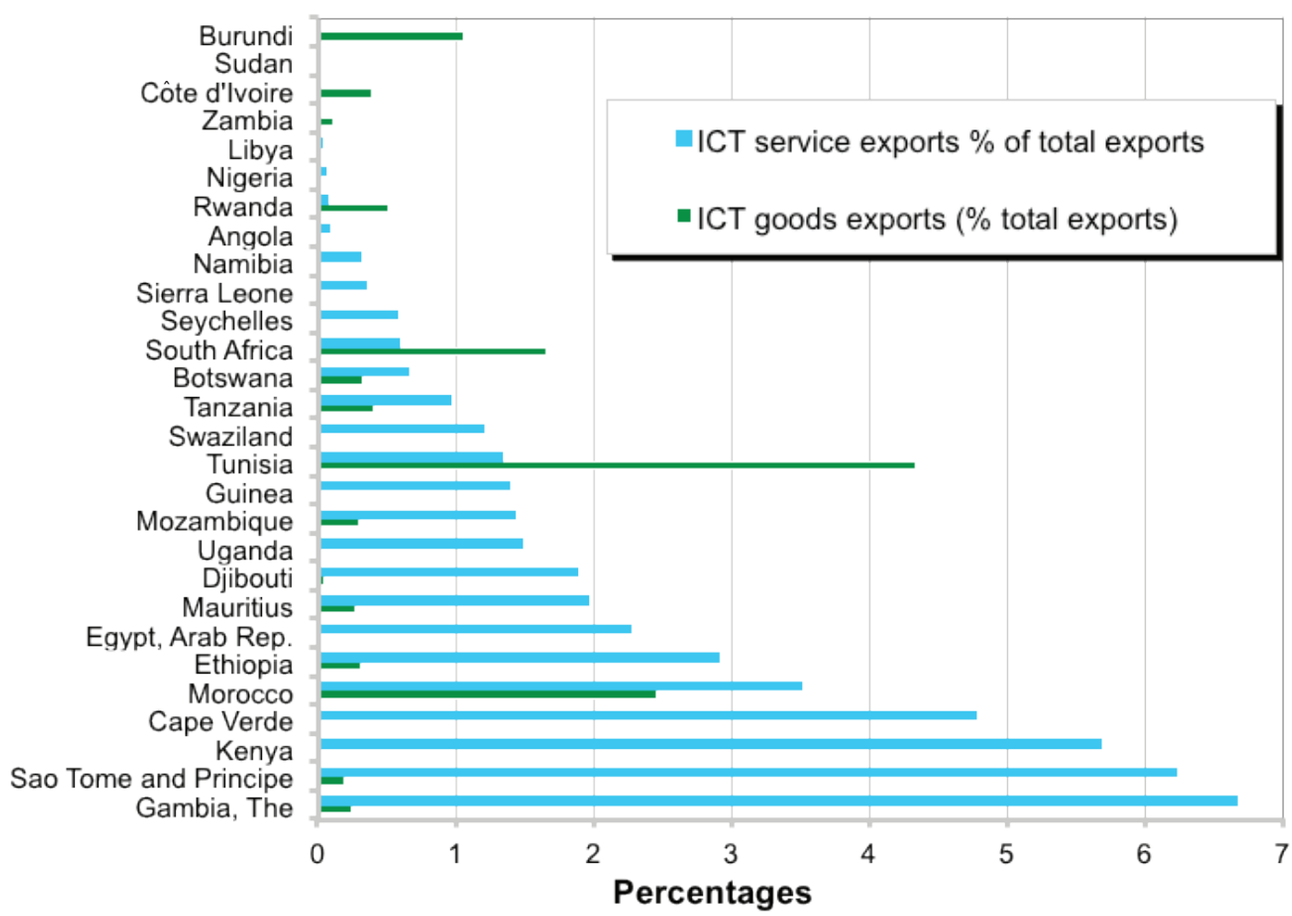
Source: WDI, UNECA, 2011

Despite the significant growth in the exports of traditional sectors across the continent, ICT exports, measured as a percentage of total exports, have significantly increased. For example, as a proportion of total exports, ICT service exports increased from less that 0.1 per cent in 1990 to about 1.5 per cent of total exports in 2009, while that of ICT goods grew from 0 per cent in 1990 to about 0.4 per cent in 2009. With significant investment in ICT R&D and infrastructure, it is possible for Africa to utilize ICT as an engine of economic growth.

At the national level (see Figure 2.17), ICT service exports constitute a significant proportion of the total exports of The Gambia, Sao Tome and Principe, Kenya, Cape Verde and Morocco while ICT goods exports constitute a significant proportion of the total exports of Tunisia, Morocco and South Africa. In terms of imports, countries such as Djibouti, South Africa, Rwanda, Burundi and Ethiopia spend a good proportion of their total imports on ICT services. African countries are increasingly being recognized as emerging outsourcing destinations by European firms due to the location advantages of close proximity to Europe and the vast pool of skilled talent and competitive costs. From 2004 to 2010, Egypt's exports grew from $150 million to $1.1 billion with an average annual growth rate of 90 per cent, driven by increased off-shoring business in Egypt (Egypt, 2010).

According to the AT Kearney Off-shoring Index which tracks the global outsourcing landscape in 50 countries, Egypt is ranked number 3 and other countries in the list include Tunisia, Ghana, Senegal, Mauritius, Morocco and South Africa, in order of attractiveness (Kearney, 2011). In Mauritius, exports of ICT services stood at 34.4 per cent over the period 2004-2008, and increased by 40.4 per cent over the period 2007-2008 (Mauritius, 2010).

Figure 2.18: ICT goods/service exports as a per cent of overall exports in selected African countries (2009)

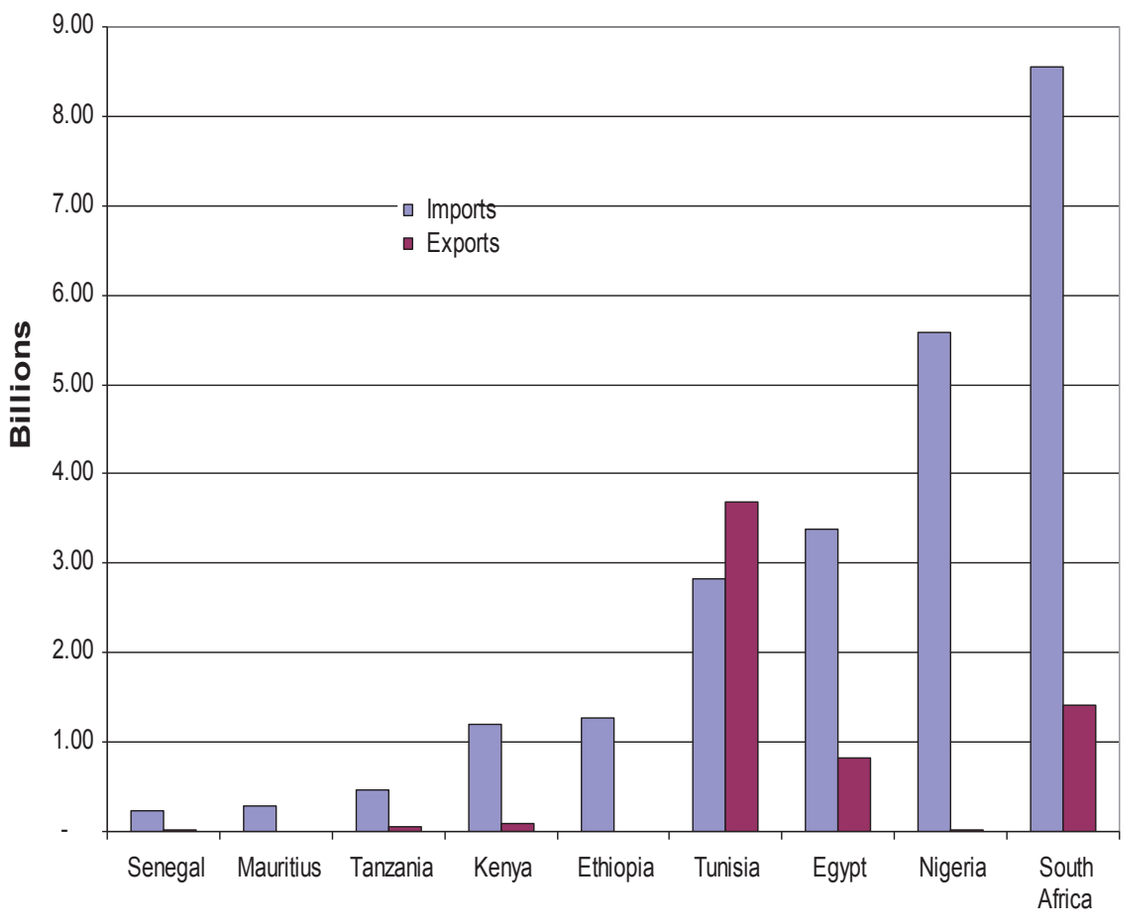


Source: WDI, UNECA, 2011

Despite this progress, computer hardware and software imports are very high and local hardware production is primarily limited to final assembly. Between 2007 and 2010, Africa's imports of ICT hardware had increased from about $10 billion to about $22 billion while ICT hardware exports had remained unchanged at about $2billion. This reveals the absence of real efforts to enhance technological initiatives to promote production and development of hardware technologies in the region.

At the national level, as shown in Figure 2.19, ICT hardware imports significantly exceeded exports with the only exception being Tunisia, where exports exceeded imports in 2010. This was mainly due to the Tunisian Government's efforts in promoting hardware and software development, sales and application development and targeting both local and international markets. Tunisia had set a target of generating 25 per cent of all new jobs in the ICT sector in the 2000-2006 period. Within the first four years, annual employment creation of 20,000 in the ICT sector was achieved. With a young population, mostly bilingual or trilingual (French, Arabic, English, Spanish or Italian) and an optimal geographical location between Europe, Africa and the Middle East, Tunisia is ideally located to play this role (World Bank, 2002).

Figure 2.19: ICT hardware imports and exports ($) of selected African countries (2010)



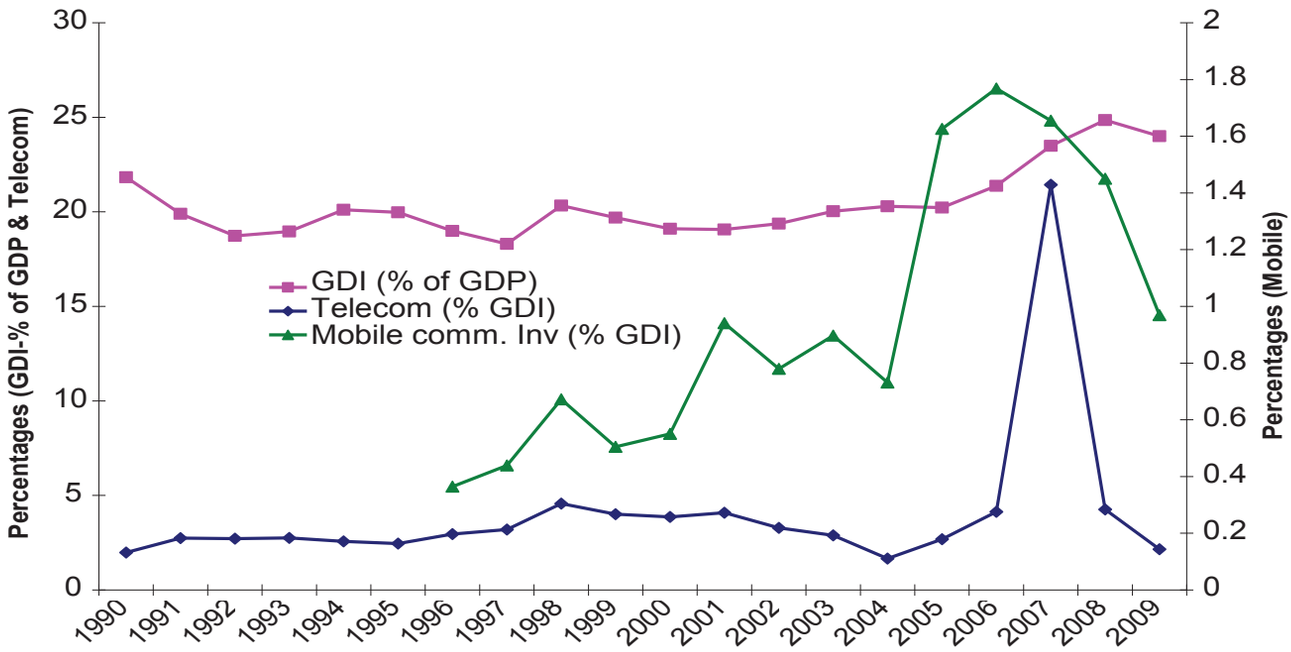
Source: UNECA based on COMTRADE 2011

2.6.2 Investment and public expenditure in ICT

Despite the recent growth in the ICT sector on the continent, investment in ICTs remains low among African countries, as compared to investment in other sectors. Figure 2.14 shows that telecoms investment, as a ratio of gross domestic investment (GDI), increased notably after 2004, peaking in 2007. This was due, in part, to a significant increase in telecom investment through the mobile sector. The significant decline after 2007 could be associated with the overall decrease in Foreign Direct Investment (FDI) inflows to Africa as a

result of the global economic and financial crisis during that time. FDI inflows to Africa fell by 36 per cent in 2009, after six consecutive years of growth, which reflects the drop in telecommunications investment during the period 2007-2009 [61].

Figure 2.20: ICT investments in Africa (1990-2009)[62]



Source: WDI, UNECA Analysis, 2011

In terms of the expenditure on ICTs by different countries, Table 2.9 reveals that Senegal invested more public funds in ICT, measured as a percentage of GDP than the other countries over the period for which data was available. This has been attributed to strong political interest being championed by the country's former president, which has led to significant increases in ICT investments in social sectors, e-government services and infrastructure, such as broadband networks.

Table 2.9: ICT expenditure (per cent of GDP) in selected African countries

Country Name	2003	2004	2005	2006	2007
Senegal	7.6	8.6	9.8	11.0	10.8
South Africa	8.2	8.1	9.4	9.7	9.7
Morocco	6.1	7.2	8.0	8.0	8.3
Kenya	5.6	5.5	6.3	7.0	7.4
Tunisia	4.6	5.1	5.3	5.7	6.0
Egypt, Arab Rep.	4.3	5.1	5.6	5.7	5.8
Cameroon	4.4	4.6	4.6	4.8	5.0
Nigeria	4.3	4.1	4.1	3.4	3.4
Algeria	2.5	2.5	2.7	2.6	2.5
Africa	5.6	5.9	6.5	6.4	6.4

Source: World Development Indicators

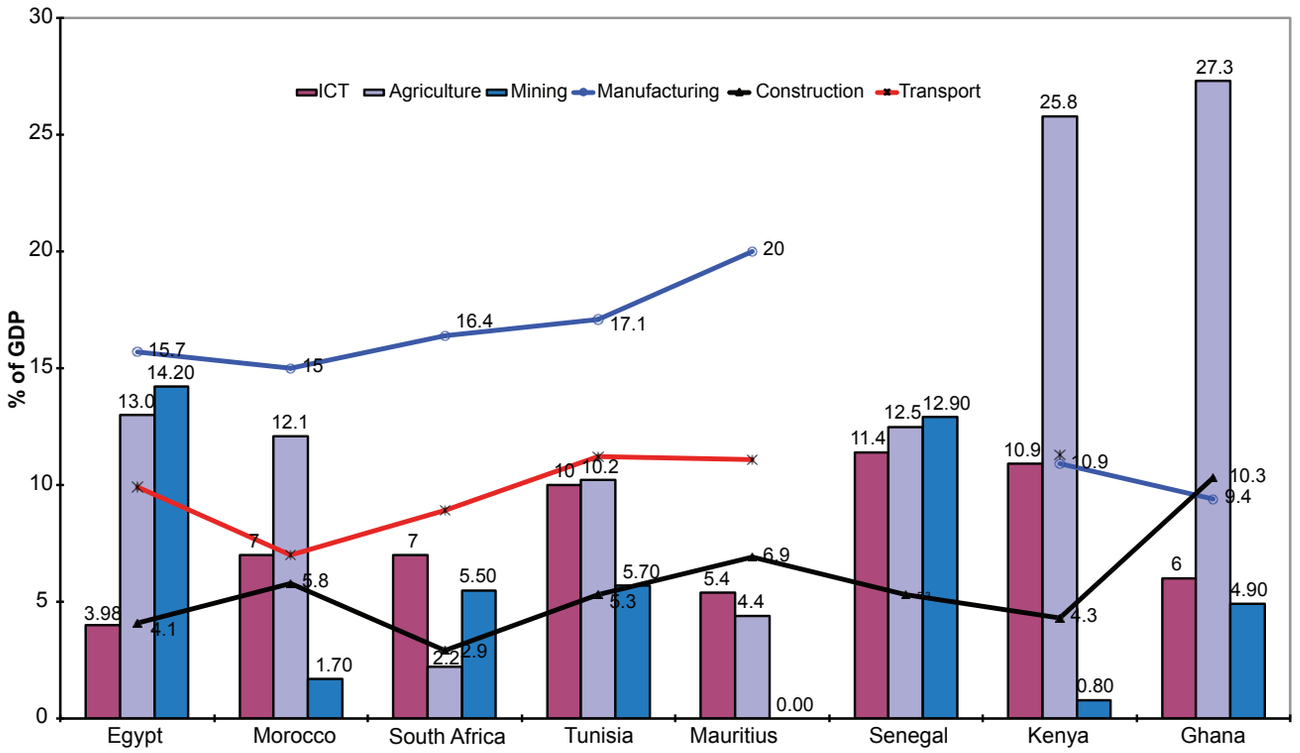
61 See Policy brief no. 4, October 2010. FDI in Africa, Published by the United Nations Office of the Special Advisor on Africa (OSAA) and the NEPAD-OECD Africa Investment Initiative.

62 GDP is the gross domestic product, GDI is the gross domestic investment, telecom is the telecommunications investment and mobile communication is the investment in mobile communications.

2.6.3 ICT contribution to GDP growth

In recent years, the ICT sector has grown significantly in many countries, notably in Kenya[63], Mauritius[64] and Egypt.[65] These developments have led to the ICT sector contributing immensely to the GDP of several countries[66], as shown in Figure 2.21.

Figure 2.21: Contribution of ICT to GDP in comparison with other sectors (2008-2009).



Source: Countries' statistical offices and websites, and WDI

For example, the ICT sector has contributed relatively more than the mining and construction sectors in South Africa, Morocco, Tunisia, Kenya and Ghana, and more than the agriculture sector in South Africa and Mauritius.

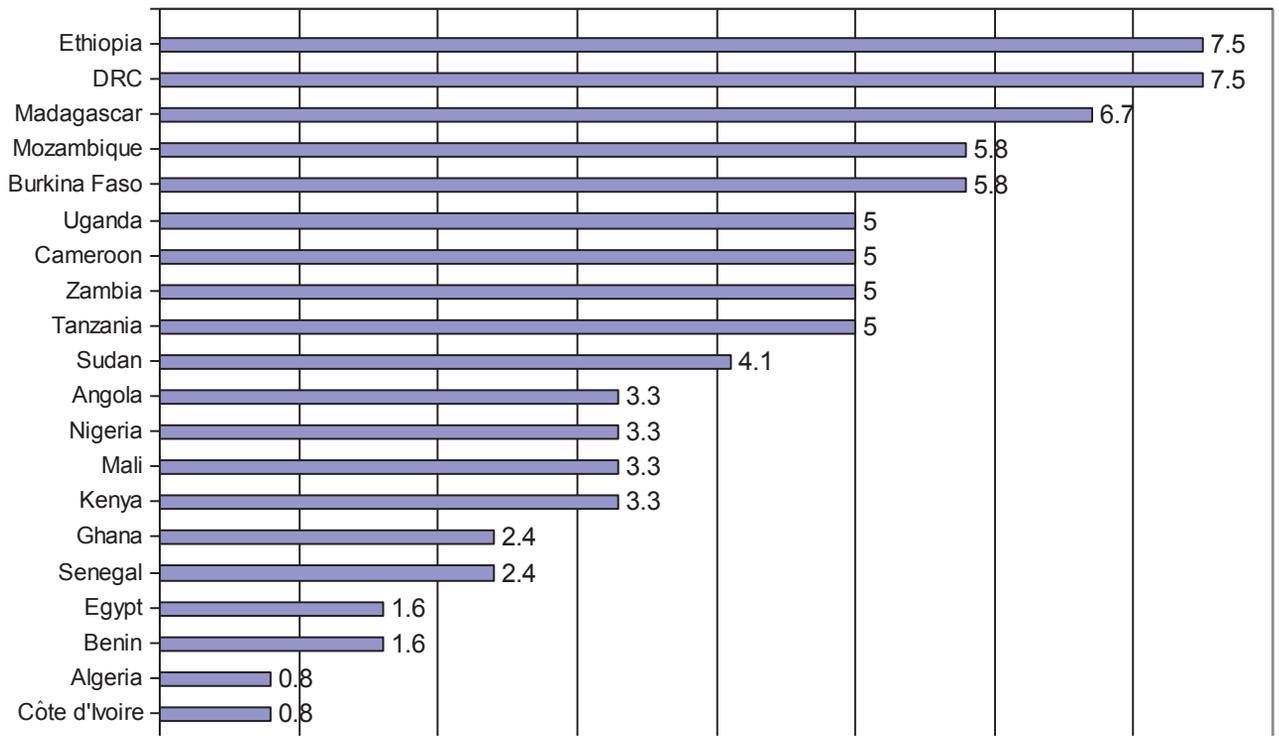
2.6.3.1 The contribution of mobile telephone industry to GDP

The mobile industry has made significant economic contributions, both directly and indirectly, to the GDP growth of many African countries. The uptake of mobile services across Africa in recent years has resulted in total revenues of approximately $53 billion, which equates to a direct contribution of 3.0 per cent to total GDP (GSMA, 2011).

Figure 2.22 shows that Ethiopia and the Democratic Republic of the Congo led other African countries with regards to the mobile sector's contribution to GDP, with Algeria and Cote d'Ivoire having the lowest. It may imply that the mobile sector's contribution, as a percentage of GDP, may be greater in poorer countries. This also suggests that access to mobile technology is seen as an "essential" commodity. The analysis involved 25 African countries which contain 91 per cent of the continent's mobile connections.[67]

63 Calculations based on data obtained from Kenya National Bureau of Statistics
64 (Mauritius, 2010)
65 (Egypt, 2010)
66 Note that the selection if countries was based on the availability of data.
67 Ibid

Figure 2.22: Direct contribution of mobile industry to GDP-2010 (per cent)

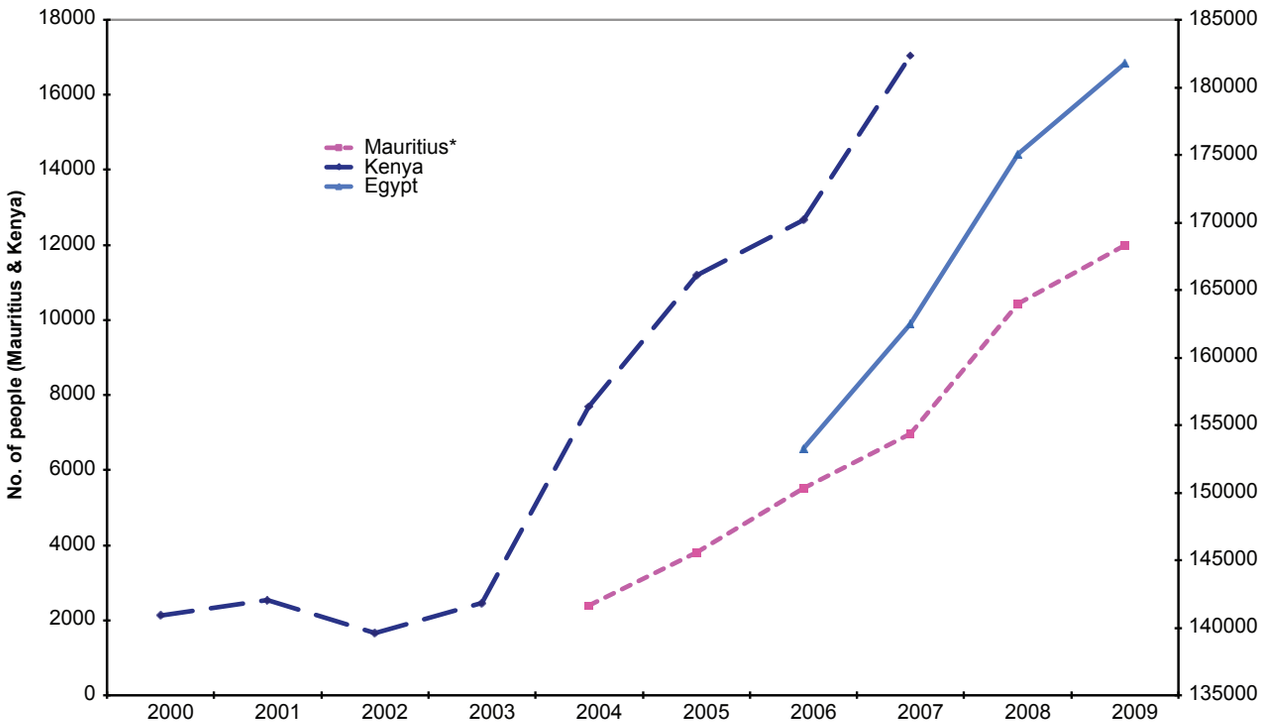


Source: GSMA (2011)

2.6.4 ICT contribution to employment

The ICT sector contributes significantly to employment in many African countries. It has been noted that for Africa's diversified economies, as well as many of its transition economies, most of the new jobs have been created in the service sector, which mainly include retail and wholesale, banking, telecommunications, business services and construction industries (McKinsey Global Institute, 2011). These service industries are also key users and employers of ICTs, which in turn has led to a significant increase in employment in the ICT sector. African countries have experienced significant growth in employment in the ICT sector (Figure 2.23). A greater percentage is employed in the mobile sector, which accounted for approximately 1.4 per cent of the total African workforce suggesting a total employment of 5.8 million people (GSMA, 2011).

Figure 2.23: ICT employment trends in Kenya, Mauritius and Egypt



Source: Egypt's Ministry of Information and Communication Technology (MICT), National Computer Board (Mauritius) and Kenya National Bureau of Statistics

Employment in the sector grew at an annual average rate of 5.9 per cent in Egypt over the period 2006-2009[68], by 21.7 per cent in Mauritius over the period 2004-2009[69], and by 33.6 per cent in Kenya over the period 2001-2008.[70] This growth is believed to have had a significant impact on the growth of the service sector which has contributed significantly to the overall growth of most African economies. It has been argued that most of this contribution comes from productivity gains. The pace of productivity growth has accelerated over time, reaching 2.7 per cent in the 2000-2008 period from -0.2 per cent in the 1990-2000 period. This has mainly been attributed to structural changes, which have included access to new technologies as well as other elements such as economies of scale, increased competition etc. (Mckinsey Global Institute, 2011).

2.7 Emerging technologies, applications and usage

2.7.1 Business process outsourcing

The global Business Process Outsource (BPO) market[71] is forecasted to reach revenues of $93.4 billion in 2015 with a compound annual growth rate (CAGR) of 5.4 per cent from the $71.92 billion it hit in 2010. Africa, with a population of over 1 billion, will be the next big growth area for the global BPO market, after China and India. In the last five years, Africa has progressed from a continent of seemingly low potential to one of great opportunity. There are a number of positive factors, which Africa can utilize to take its share of the global BPO market. These are:

68 Calculations based on data from the Ministry of Information and Communication Technology (MICT), Egypt.
69 Calculations based on data from the National Computer Board, Mauritius.
70 Calculations based on data obtained from Kenya National Bureau of Statistics
71 http://www.biztechafrica.com/section/business/article/global-bpo-market-reach-revenues-usd934bn/1210/)

- The new undersea cables that have given new impetus to Africa's hopes for strong internet connectivity and a corresponding BPO boom;
- The rapid growing cellular market approaching over 400 million subscribers;
- An advantage of younger demographic and multi-lingual population (English and French skills) across the continent;
- Geographical proximity for some of the countries to the European/North American market;
- Favourable time zone differences with Europe and the Middle East.

Many countries such as South Africa, Kenya, Ghana, Egypt, Mauritius, Morocco, Senegal and Tunisia are growing and marketing their respective BPO services.

2.7.2 Cloud computing

Cloud computing is a new general purpose Internet-based technology through which computing services are delivered, on demand, from a remote location, rather than residing on one's own desktop, laptop, mobile device, or even on an organization's servers (Wyld, 2009). This is a promising area with high potential for the continent (OECD, 2010). Interest in cloud computing is mainly motivated by its potential to reduce capital expenditures, enable business continuity and recovery and allow for scalability of IT services at lower variable costs, with increased productivity. However, there is an absolute requirement for reliable high bandwidth services for cloud computer to work and make benefits.

This allows organizations to quickly source computing resources on-demand, following a 'Pay-as-you-go' model (KPMG International, 2011).

There are a number of practical examples by a number of African countries. In Ethiopia, teachers are tapping into Microsoft Azure Cloud to download school curricula and get assistance in planning, tracking of academic records and securely making student data available throughout the education system in the country. In South Africa, the call centre market has been one of the fastest growing users of cloud computing in the country, as they no longer need to own and maintain costly equipment. Thousands of call centre agents have moved out of dedicated call centre facilities, as they are able to provide their services from anywhere using IP lines.[72]

2.7.3 Emerging trends in Geospatial Information Technology

Observing the new trends and changes to business logics involving geospatial information, and also looking at expected technological progress, the main drivers of the market trends in the GIS industry are classified in three categories: data, tools and applications.

Regarding data, the growing availability and use of dynamic geoinformation, such as real-time traffic conditions, weather data and river water levels, has led to the development of location-based services (LBS). LBS exploit the location of the device to provide personalized services to the user of the device. However, LBS need highly accurate geoinformation, obtained primarily from high-resolution ortho-rectified satellite imagery and aerial photography, using the new map-building technologies that have become available. The future trend is moving to dynamically offered scalable solutions that support key open standards in reading, possessing and analyzing large collections of file-based imagery through Web services accessible to virtually any client.

72 http://www.itweb.co.za/index.php?option=com_content&view=article&id=25275:use-the-cloud-to-work-from-home&catid=279:virtualisation

Regarding tools, as the technology continues to evolve, web services like Google Earth and Microsoft Virtual Earth will permit individuals to become more involved with the creation, maintenance, and distribution of their own geospatial information. Web mapping or mash-up map services allow the integration and creation of new web-based maps. These will continue to introduce more people into daily experience and perception of spatially-enabled services. In turn, this will expand opportunities for the development of innovation, research and operational services, which can support economic growth.

Regarding applications, the translation of complex cycles of data acquisition, and bringing their processing, analysis, visualization and decision making potential into real time monitoring and management has become a reality. With popular applications such as Google Earth and Community mapping, the GIS industry is moving from analyzing and presenting discrete data sets towards working with streams of spatially-enabled data (e.g. real time location-based mobile services).

Positioning technologies are pervasively making our societies mobile in every aspect. Individual, environmental and business "objects" change across an ubiquitous positioning infrastructure and will be a key enabler for novel GSSTs applications. We expect to see a rapidly evolving market for geo-spatial solutions since we are approaching the final convergence of GIS, mobile location-based services and enterprise information technology into one integrated system. This convergence will spawn new markets and solutions that will drive growth in the future. If African expertise and enterprise in the relevant areas are developed, Africa can be a generator and seller of innovation and products in this area.

2.8 Concluding remarks

Trends in ICT access and usage on the continent show a staggering increased penetration of wireless technologies and an ever-increasing demand for ICT services. Use of mobile telephony has rapidly outstripped fixed mainline telephone use in Africa to a far greater extent than in other parts of the world. It is anticipated that the recent deployment of fibre optic cables will lead to a significant improvement in access, quality and cost of ICT services. Africa has already prioritized the building and deployment of the necessary broadband infrastructure that will link service providers and the people to the submarine cables on the shores of the African continent.

If Africa is to catch up and keep abreast of global development and commercial opportunities in the ICT area, it must develop capabilities in existing, new and emerging technologies. These include geospatial technologies, where some of the more technologically advanced countries on the continent are beginning to be active, and also space and satellite technologies. There is already an expansion of ICT-related academic courses, research and publications from within Africa, but more support for these academic and research activities is required.

Despite the low absolute number of Africans linking to the Internet and ICT services, the growth of mobile technology use indicates the potential for further growth. With over 620 million mobile connections as of September 2011, Africa has overtaken Latin America to become the second largest mobile market in the world, after Asia (GSMA, 2011). There is also a rapid growth in the use of social media and networks. Africa registered the highest growth rate of Facebook users globally in 2011. However, the main bulk of Africa's population, especially those in rural areas, still lack access to ICT services beyond mobile telephony. Where there is access, effective use of ICTs is reduced due to low literacy rates, language barriers, economic and other infrastructural factors.

The experience of the rapid expansion of mobile technology in Africa has highlighted the capacity for technical and business innovation within Africa. For example, Safaricom's M-PESA was the first system anywhere

in the world to transfer money via mobile phones, an activity that is now developing globally. There are other examples to indicate that there are major opportunities for more inventions and innovations that address Africa's problems through home-grown technology.

Governments and the private sector industry must continue, preferably in partnership, to invest in ideas, capacity and infrastructure to promote an environment that supports access and innovation, both in mobile technology and more advanced forms of ICT. The ICT sector already represents a major component of African GDP and GDI, including in low-income countries. In several countries, the ICT sector contributes considerably to exports. However, with a few exceptions, Africa's ICT-related exports focus entirely on software and services rather than hardware.

Of the many areas associated with ICT, it is expected that there will be a rapidly evolving market for geospatial solutions since there is an increasing convergence of GIS, mobile location-based services and enterprise information technology into integrated systems. This convergence will spawn new business opportunities that will drive innovation and economic growth in the future. New web services, architectures and collaboration tools will allow users to work together in new ways and deliver more cross-cutting approaches to problem solving (Dangermond, 2007).

References

Aker, J. C. (2008). Does Digital Divide or Provide? The Impact of Mobile Phones on Grain Markets in Niger. BREAD Working Paper # 177.

Armstrong, M. P. (2001). The Four-Way Intersection of Geospatial Information and Information Technology: A White Paper Prepared for the Workshop on the Intersection of Geospatial Information and Information Technology. Iowa: The University of Iowa.

Chang, H.J. (2002). Who Needs Technology Policy? Kenya: African Technology Policy Studies Network, Nairobi, Kenya.

Dangermond, J. (2007). Further Thoughts on "The Geographic Approach"- Understanding Our World. Available from http://www.esri.com; accessed August 2011.

Egypt (2006). Plan of Action 2007-2010, Government of Egypt, Ministry of Information and Communication Technology (MICT). Available from www.mict.gov.eg.

Egypt (2010). Statistical compilation of the ICT sector and policy analysis. Government of Egypt, Ministry of Communication and Information Technology (MCIT). Available from www.mict.gov.eg. Accessed in December 2011.

Ezel, S. and S. Andes (2010). ICT R&D Policies: An International Perspective. Available from www.computer.org/internet; accessed July 2010.

Gakuru, M., K. Winters and F. Stepman (2009). Inventory of Innovative Farmer Advisory Services using ICTs. The Forum for Agricultural Research in Africa (FARA).

Gasmi, F., A. Maingard, P. Noumba Um and L. R. Virto (2011). The impact of privatisation of fixed-line telecommunications operators in OECD, Latin American and African countries: One size does not fit all, Working Paper, OECD Development Centre, Paris, forthcoming.

Gereffi, G. and K. Fernandez-Stark (2010). The Offshore Services Global Value Chain. Center on Globalization, Governance & Competitiveness, Duke University.

Global Spatial Data Infrastructure (2001). Developing Spatial Data Infrastructure: The SDI Cookbook, GSDI.

GSMA (2010). mLearning: A Platform for Education Opportunities at the Base of the Pyramid. GSMA: London.

GSMA (2011). African Mobile Observatory 2011: Driving Economic and Social Development through Mobile Services. (www.gsma.com; accessed September 2011).

Guy P. and T. Gartenmann, (2000). Big Pharma can still find big value in e-Health, Boston Consulting Group. Available at www.bcg.com.

Heeks, R. (1996). Building Software Industries in Africa.

Indjilian, R. and D.S. Siegel (2005). The impact of investment in IT on economic performance: implications for developing countries. World Development, 33, 681-700.

Kearney, A.T. (2011). Offshoring opportunities amid economic turbulence: The A. T. Kearney Global Services Location Index. Available from http://www.atkearney.com. Accessed August 2011.

KPMG International (2011). The Cloud changing the business ecosystem, India. Available from www.kpmg.com. Accessed September 2011.

Manyika, J. and C. Roxburgh (2011). The great transformer: The impact of the Internet on economic growth and prosperity. McKinsey Global Institute (http://www.mckinsey.com. Accessed October 2011).

Mckinsey Global Institute (2011). Lions on the move: The progress and potential of African economies. Available from http://www.mckinsey.com. Accessed October 2011.

Mauritius (2010). ICT indicator outlook. Government of Mauritius, National Computer Board, Mauritius. Available from http://indicators.ncb.mu. Accessed August 2011.

OECD (2010). Information Technology Outlook 2010, OECD PUBLISHING, Paris.

Okello, J.J. (2010). Does use of ICT-based market information services (MIS) improve welfare of smallholder farmers? Evidence from Kenya. Available from http://www.acorn-redecom.org/papers/acornredecom2010okello.pdf. Accessed December 2011.

Oketch, M. O. (2007). To vocationalise or not to vocationalise? Perspectives on current trends and issues in technical and vocational education and training (TVET) in Africa. International Journal of Educational Development, 27, 220–234.

Olajide, K. (2009). Enabling environment for geospatial information technology uptake in Africa. Presented at the Committee on Development Information, Science and Technology First Session, 28 April to 1 May 2009, Addis Ababa, Ethiopia. Addis Ababa: UNECA.

Opoku-Mensah, A. and A. Chekol (2010). Promoting Free and Open Source Software as a Way of Enhancing Local Innovations. iConcept Magazine (http://www.iconceptmagazine.com, accessed October 2011).

Sowe, S. (2011). Free and Open Source Software in sub-Saharan Africa. Available from http://unu.edu/articles/science-technology-society/free-and-open-source-software-in-sub-saharan-africa. Accessed November 2011.

Tavares, R. (2009). Science and technology parks: An overview of the ongoing initiatives in Africa, Journal of Political Science and International Relations, 3 (5), 208-223.

Tunisia (2009). Investing in ICT in Tunisia. Government of Tunisia, Ministry of Communication Technologies. Available from www.infocom.tn. Accessed in August 2011.

UNCTAD (2011a). Ghana Science Technology and Innovation Policy Review, United Nations, Geneva.

UNCTAD (2011b). Information Economy Report 2011: ICTs as an Enabler for Private Sector Development. United Nations: New York and Geneva.

UNECA (2009). M-Banking – An African Financial Revolution? Centre of African Studies, Copenhagen University and International Books.

UNECA (2010). Implementing the World Summit on the Information Society Action Lines in Africa. Analysis of Country Reports.

UNECA and IICBA (2011), ICT-enhanced Teacher Standards for Africa, ECA-IICBA, Addis Ababa, Ethiopia, (unpublished draft).

UNESCO (2011). Global Education Digest 2011, UNESCO Institute for Statistics, Paris.

Williams, M.D. J, R. Meyer, , and Minges, M. (2011). Africa's ICT Infrastructure: Building on the Mobile Revolution. Washington, D.C.: The World Bank.

World Bank (2002). Republic of Tunisia - Information and Communications Technology: Contribution to growth and employment generation. Finance, Private Sector and Infrastructure Group, World Bank.

Wyld, D.C. (2009). Moving to the cloud: An introduction to Cloud Computing in Government. Washington, D.C.: IBM Centre for the Business of Government.

CHAPTER 3

The African STI policy environment

3.0 Overview

The main objective of this chapter is to provide a brief overview of the Africa STI policy landscape. It looks at the characteristics of African STI-related policies that are needed to inspire individuals and public and private institutions to invest resources in S&T development. The chapter looks at the targets that countries have set for themselves, the general governance of STI and the current innovation ecosystem. Thereafter, it draws on examples concerning S&T, ICT and biotechnology development in Africa to highlight the differences and potential impacts of relevant STI policies. Finally, it concludes by looking at the current efforts to harmonize STI-related policies, including regional ICT policy initiatives.

3.1 STI and Africa's national development plans

A number of African countries have set themselves a target to become prosperous middle- income countries by 2020 or 2030; science, technology and innovation are seen as one of the core pillars to attain this target. Uganda, for instance, has identified science, technology and innovation as one of the four priority areas in its National Development Plan for 2011-2015 that seeks to "transform Uganda society from a peasant to a modern and prosperous country within 30 years" (Uganda, 2010). STI is anchored in the broad national vision.

Although it is difficult to describe a modern and prosperous middle-income country in 2020/2030, it is possible to use current characteristics of middle income countries to reveal some of the common attributes of such a country (UNECA, 2011).[73] One common classification is based on monetary measures. For example, the World Bank classifies economies with Gross National Income (GNI) per capita between $1,006 and $12,275 as middle income. This group is further sub-divided into lower middle income ($1006-$3975) and upper middle income ($3976-$12,275).

It is understood that the general income-based assessment does not capture wealth distribution, impact of economic activities on the environment or human settlement or the general human development achievements. For example, Egypt had a GNI per capita of $5,269 while Equatorial Guinea had a GNI per capita of about $17,608 in 2011; yet Egypt has a higher Human Development Index than Equatorial Guinea (UNDP, 2011). Perhaps a prosperous middle-income country is one that has attained a decent living standard that for instance, is free from chronic poverty, hunger and illiteracy, and has improved industrial and technological sophistication.

Looking at the current state of development of individual African countries in terms of a combination of the indicators depicted in Table 3.1, countries in the East African Community, for instance, would have to take significant steps to meet the current level of development enjoyed by Mauritius and Malaysia (two typical examples of middle-income countries) in the next 10-20 years. It is clear that Mauritius and Malaysia have substantially higher incomes, life expectancy, education attainment and communication and transport infrastructure than the East African countries. From this simple comparison, African countries that aspire

73 It is perhaps important to remember that the current middle-income countries are not planning to stay at the same level, and thus, those seeking to catch up should aim higher.

to middle income status, but which are still at par with the East African countries, need to adopt measures to create a conducive environment for innovation and entrepreneurship to flourish. This would require continuous investment to build a robust and dynamic STI sector that is capable of generating the necessary intellectual capital, exploiting technological niches and seeding and nurturing successful firms and clusters of interacting firms.

Table 3.1: Comparison of East African countries to two middle-income countries

Indicator Name	East African Countries					Example Of Middle Income Countries	
	Burundi	Kenya	Rwanda	Tanzania	Uganda	Mauritius	Malaysia
School enrolment, tertiary (per cent gross)	3.2	4.0	5.5	2.1	4.2	16.0	40.2
Percent of population living on $2/day	93.4	39.9	90.3	96.6	64.7		2.3
Life expectancy at birth, total (years)*	50.3	57.1	55.1	58.2	54.1	73.4	74.2
GDP per capita (current $)	192.1	794.8	529.7	523.8	508.9	7590.8	8372.8
Percentage of manufactures in exports	11	35	13	17	30	60	70
Mobile cellular subscriptions (per 100 people)	13.7	61.6	33.4	46.8	38.4	93.0	119.2
Internet users (per 100 people)	2.1	25.9	13.0	11.0	12.5	28.7	56.3
Patent applications, residents		77.0					1233.0
Roads, paved (per cent of total roads)		14.3		6.7		98.0	

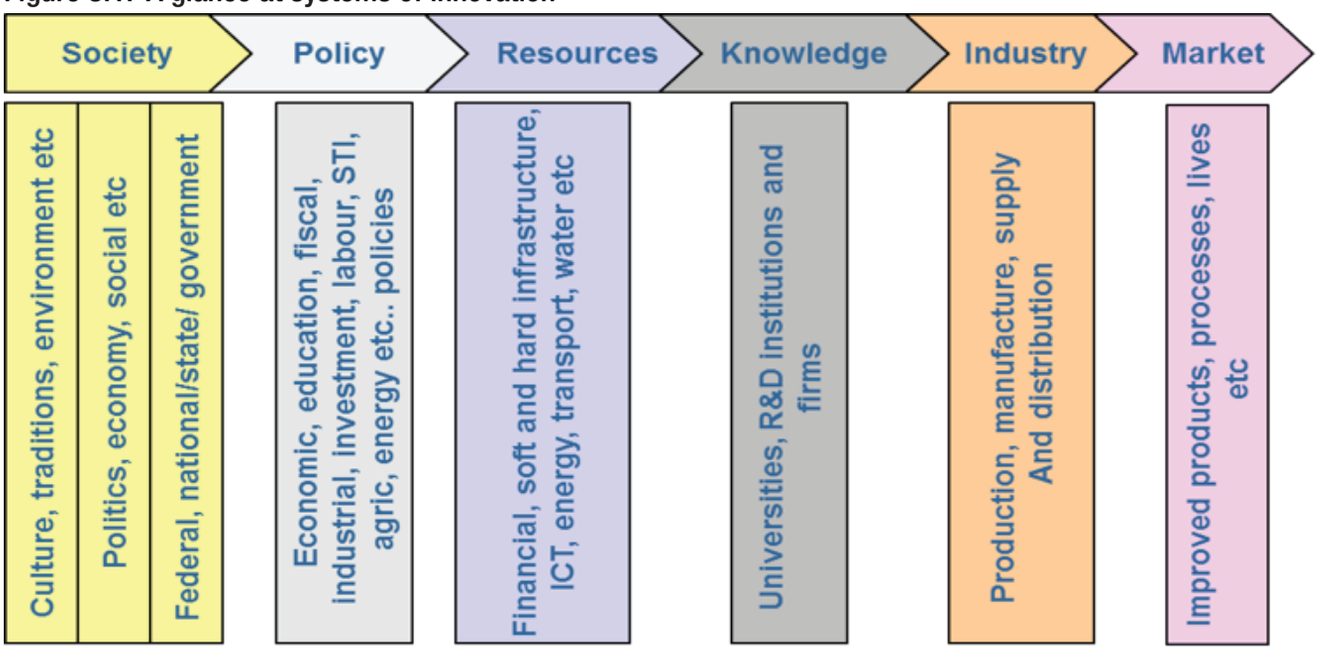
Source: UNCTAD Handbook of Statistics, ITU, WIPO and HDR database, accessed June 2012

A number of countries have prioritized STI as indispensable in meeting both economic and the social development targets. For instance, Ethiopia has decided to promote "the policy of 70:30 in higher education intake ratios in favour of science and technology" (MoFED, 2010) in order to meet the needs of its priority sectors: agricultural processing, textiles, construction, leather goods, pharmaceuticals/chemicals and metals (MoFED, 2006). This is important as the Government of Ethiopia is investing in several infrastructure projects to increase the population with potential access to electricity from 16 per cent in 50 per cent, fixed phone lines from 0.6 million to 3.2 million, mobile phone subscribers from 0.4 million to 6.4 million and construction and rehabilitation of over 700 water projects according to its national development plan. A large qualified and skilled human resource base will be required to build and maintain such a remarkable expansion in infrastructure.

3.2 Governance of STI

Science, technology and innovation governance cuts across all sectors of the country. A host of institutions are needed to supply human capital, technology, finance and non-monetary incentives in a number of areas such as agriculture, education, energy, health and transport. As shown in Figure 3.1, STI takes place and is anchored in society and its political systems. As such, the cultural practices, religious beliefs, values and traditions of a society have major implications on the use, generation and diffusion of technology. The strategies and legal and regulatory frameworks adopted in the various sectors often reflect this bias and can easily result in competing rationales and differences in perception and understating of the role of STI in national development (OECD, 2005). This presents a major challenge in successfully implementing national STI initiatives that require the commitment and dedication of institutions that have different mandates, planning cycles and clients.

Figure 3.1: A glance at systems of innovation



Source: Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan. Available from http://www.mext.go.jp/b_menu/hakusho/html/hpag200201/hpag200201_2_006.html

Leadership is particularly critical in bringing together the different arms of Government and mobilizing society to forge a common understanding, effect sufficient resource allocation and sustainability and ensure fair distribution and effective coordination of activities. Such leadership can be accomplished in a number of ways (UNECA, 2010). For instance, the head of government can chair the national committee that oversees S&T development (e.g. in Korea where the Prime Minister Chairs the STI Committee). This elevates STI planning, implementation and monitoring and evaluation to the very top of the national governance.

An advisory committee on STI to the President and Prime Minister or to the Cabinet could inform the political leadership of the priority sectors for the application of STI. Such bodies will not only inform the top leadership but may also have mechanisms to receive and analyze submissions from a variety of stakeholders (Juma and Serageldin, 2007). For example, South Africa's National Advisory Council on Innovation (NACI) "advises the Minister, and through the Minister, the Ministers Committee and the Cabinet, on the role and contribution of science, mathematics, innovation and technology, including indigenous technologies, in promoting and achieving national objectives, namely to improve and sustain the quality of life of all South Africans, develop human resources for science and technology, build the economy and strengthen the country's competitiveness in the international sphere".[74]

A broader mechanism for good governance of STI should seek to bring S&T to the people and promote their participation in informing policy-making. Parliaments can serve both as a bridge between the leadership and the people they represent. They can also be supporters and promoters of S&T by ensuring that relevant bills and laws reflect S&T components. Parliamentary committees scrutinize the work of the executive and agencies as well as defend their budgets and activities. A number of African countries have established such mechanisms in their parliaments (see Table 3.2).

The ministries responsible for STI may also wish to establish parliamentary liaison units whose main activities are to inform and facilitate the activities of the parliamentary committees on STI. For instance, the Parliament Unit of the Department of Science and Technology of India "ensures that the Parliamentary

74 National Advisory Council on Innovation Act. No.55 of 1997, Republic of South Africa (http://www.info.gov.za/view/DownloadFileAction?id=70801)

work pertaining to the Ministry of Science and Technology is accomplished as per the prescribed schedule and procedures". The Unit maintains liaison with other agencies and coordinates the visits of the Members of the Parliamentary Standing Committee etc. to scientific institutions under the administrative control of the Department.[75]

Table 3.2: Examples of parliamentary oversight on STI in Africa

Science and Technology	South Africa, Uganda
Education, Science and Technology	Gambia, Kenya, Malawi, Rwanda, Zambia
Education and Scientific Research	Algeria and Egypt
Education, culture and Social affairs	Benin
Others (e.g. Energy, Mines, Sport, ICT)	Mali

Source: UNECA (2011). Concept Note: African Inter-Parliamentary Forum on STI (APF-STI) meeting 2-5 may 2011, Addis Ababa, Ethiopia

Broader consultation on STI development could improve ownership and implementation of legal and regulatory measures and other support mechanisms. This can be achieved through independent and respected national institutions such as Councils and Commissions on STI. The presence of these bodies is only one component but their ability to serve as a platform for consensus building, knowledge generation and policy advocacy will depend on their structures and mandates.

For example, Finland's Science and Technology Policy Council comprises some 18 members that include the Prime Minister as the chair, the Minister of Education and Science and the Minister of Trade and Industry as vice-chairs, the Minister of Finance, up to four other ministers and 10 other members drawn from the Academy of Finland, the Finnish Funding Agency for Technology and Innovation, the universities, business and industry, and employees.[76] This enables the Council to bring in diverse talents, skills and knowledge that improve STI governance. Many of Africa's Science and Technology Councils and Commissions do not have a similar level of interaction between the executives and other stakeholders.

In general, STI governance can be achieved through a variety of processes that are aimed at achieving a higher level of integration, coordination and prioritization, especially in countries that do not have the luxury of abundant human, financial and institutional resources (OECD, 2005). However, care should be taken so that the need to build consensus among all key stakeholders does not lead to major compromises and long lists of "priorities" and negotiations that last for several years that will further hinder S&T development in the face of limited resources and rapidly changing technology fields.

Similar to any governance situation, learning improves practice. Learning requires Government to invest resources; in particular time and commitment by the leadership to monitor and evaluate the impact of their policies, monitor and understand global trends and their potential impact on various aspects of their societies as well as exchange of experiences with those that have managed successful STI for development. Africa has already laid some essential groundwork and initiatives, such as the ECA African Inter-Parliamentary Forum on Science Technology and Innovation[77] to facilitate such learning through diffusions of good practices among parliamentarians and ministers.

3.3 Characteristics of national STI policies

The alignment of STI to national development policies and the governance structures of STI are often the subject of STI policies and STI-related policies in areas such as biotechnology and ICT. STI policies often

75 http://www.dst.gov.in/admin_finance/adminfinance.htm#parliament
76 Government Decree on the Science and Technology Policy Council of Finland, 2005
77 http://www.uneca.org/eca_resources/Press_Releases/2011_pressreleases/pressrelease5511.html

describe the relationship between STI and society, the governance of STI, the priority sectors and mechanisms of implementation and monitoring. In order to provide a sketch of the STI policies, a cursory analytical and qualitative analysis of a selected number of African countries was undertaken using the framework presented in Figure 3.2.

Figure 3.2: Analytical frameworks for STI policy analysis

Source: OECD, 2005.

Given the limited resources, countries need to identify key priority areas where they could invest such resources by setting clear and measurable targets. For example, Malaysia's Second S&T policy[78] had two overarching objectives clearly defined: (a) to increase R&D spending to 1.5 per cent of GDP, and (b) to attain a ratio of at least 60 researchers, scientists and engineers per 10,000 labour force by 2010. Similarly, the South African Ten-Year Plan For Innovation[79] also targets six main priority areas: (a) To be one of the top three emerging economies in the global pharmaceutical industry; (b) Deploy satellites that provide a range of scientific, security and other services; (c) Supply a secure sustainable and diversified energy sector; (d) Achieve a 25-per cent share of the global hydrogen and fuel cell catalysts market; (e) Become a world leader in climate science and response to climate change, and (f)

Meet the MDG goal of halving poverty by 2014.

The case of ICT policies

A clear national STI policy makes it easier to plan, mobilize resources, increase understanding and hence promote integrating efforts to focus on and achieve policy objectives. Table 3.3 outlines key STI-related policies of three countries – Ghana, Mauritius and Malaysia. Mauritius and Malaysia represent typical examples of middle-income countries that many African countries aspire to become. Many African STI-related policies remain at a level of clarity similar to that of Ghana's ICT policy, which is lower than that of Mauritius and Malaysia. The policies of Malaysia are much clearer and more measurable, followed by those of Mauritius and Ghana (Konde, 2007). A lot remains to be done to clarify, align and enhance the role of institutional establishments to promote and implement STI. While national STI policies in several African countries may read well, they do not provide sufficient clarity and measurable targets to stimulate and direct innovation and entrepreneurship.

78 http://www.mosti.gov.my/
79 http://www.info.gov.za/view/DownloadFileAction?id=94066

Table 3.3: Comparison of characteristics of ICT policies

	Ghana (2004)	Mauritius (2004)	Malaysia
High-level Committee	Committee within the Ministry of Information	Ministerial committee chaired by the Prime Minister	Ministerial Council chaired by the Prime Minister
Vision	Provide every citizen and resident access to high-quality and affordable ICT services to transform Ghana into a knowledge-based and technology-driven economy	Make ICT the fifth pillar of the economy (after sugar, textile, tourism and offshore services)	Enhance the existing investments in information, communication and multimedia services (ICMS) infrastructure that will support future growth of ICMS services.
Targets	Universal access for all communities to internet, telephone and multimedia by 2010 Telecom service penetration to reach 25 per cent in urban and 10 per cent in rural by 2010 Connect all schools, clinics and public offices to advanced telecom services Fully open, private, competitive markets for all telecom services Streamlined, efficient and effective regulations of the industry that are technology neutral, fully transparent and competitive Affordable prices for telecom services, especially for the poor Profitable investment opportunities for business in all segments Ghana as a first-class hub for investment, jobs and development, leader in transformation of Africa.	Increase fixed telephone density from 28 per cent to 35 per cent by 2005 Increase mobile cellular telephone density from 37 per cent to 50 per cent by 2005 Extend broadband connectivity to all business hubs within the country by 2006 Provide at least 30 per cent of households with broadband connectivity by 2008 Provide at least 50 per cent of households with Internet connectivity by 2008.	By 2008: High Speed Broadband : 2.8 million subscribers; 3G and Beyond: 1.5 million subscribers Mobile TV: 75 per cent mobile users adopt mobile TV Digital Multimedia Broadcasting: 60 per cent household coverage for DTTB. Digital Home: 500,000 homes with external networks Short range communications: extensive usage in the supply chain management, Local manufacturing of RFID chipset VoIP/Internet Telephony: Residential & business service revenue constitute RM 1 billion Universal Service Provision: Increased broadband Internet individual access
Technology the policies seek to support	Technology neutral	Global mobile personal communications by satellite services, Internet telephony services, Mobile cellular services, Internet services, Wireless fixed services, International services Multimedia services Value-added services Cable Services	High-Speed Broadband 3G & Beyond Mobile TV Digital Multimedia Broadcasting Digital Home Short Range Communications (e.g. RFID-based) VoIP/Internet Telephony Universal Service Provision

Source: Konde, V (2007), What type of national ICT policies maximize ICT benefits? ATDF Journal Vol, Issue 1, 37-48.

The case of biotechnology policies

A review of the current biotechnology policies of Kenya, Zambia and South Africa found that the Zambian Biotechnology and Biosafety Policy[80] of 2003 was purely a biosafety document and lacked any strategic biotechnology development roadmap for the country. The Minister's foreword only mentioned the need for Zambia to meet its international obligation under the United Nations Convention on Biological Diversity. There was not a single sentence on the potential of biotechnology applications in agriculture, environment, health, industry and energy for the country.

The 2006 National Biotechnology Development Policy of Kenya identified industry and trade as the key areas for Kenya's use of biotechnology, offering the country a positive, if limited, opening into the biotech sector. It also notes the benefits that come from the safe development and application of biotechnology in

80 http://www.mstvt.gov.zm/

agriculture, environment, health, industry and research.[81] Even though some references are made to health biotechnology, the country's primary focus in the biotechnology sector remains on agriculture.[82]

National examples

Perhaps, a better practice is found in the South African biotechnology strategy (DST, 2001), which formed the basis for harnessing biotechnology for industrial and social development with a stronger focus on health, technology commercialization and strategic alliances. A number of Biotechnology Regional Innovation Centres (BRICs), such as LifeLabs, BioPad, BioPlant and Cape Biotech Trust were developed by the Government to provide funding and technical support needed for product commercialization (now part of the Technology Innovation Agency).[83] The country has also facilitated strategic alliances with various institutions and firms from countries such as Brazil, Cuba, China, India and Switzerland to enable indigenous firms or start ups to access a broader technology base and improve their product development.

Many African STI policies seem to be static rather than dynamic. A strategic and dynamic approach to STI policy design, development and implementation will significantly increase policy impact. This is evident in the STI development of the Republic of Korea. The Korean Biotech 2000 plan of 1993 (Korea, 1993) had three main phases and a total investment budget of $15 billion by 2007. The first phase (1994-1997) aimed at acquiring and adapting bioprocessing technologies and improving performance of R&D investment with the goal of establishing the scientific foundation for the development of novel biotechnology products. The second phase (1998-2002) focused on development of platform technologies and improvement of industrial R&D capabilities. The last phase (2003-2007) targeted development of commercialization capabilities to achieve increased global market share of Korean development biotechnology products. The target was to achieve a 5-per cent global market share for Korean novel biotechnology products.

In this regard, ECA has been developing tools to help policy design, implementation and monitoring. STI policy-making may need to draw lessons from practices at home and abroad. Policy learning should not be focused on copying and following a standard "format" or "formula" but must be focused on absorbing, configuring and adapting fundamental elements to suit a nation's specific context. STI policy development and implementation must be articulated to be an exercise at the national level, with a clear goal that inspires and directs participation of all relevant actors.

3.4 Assessing the national innovation ecosystem

STI policies are intended to improve the innovation ecosystem and regular assessments can shed more light on the issues raised in the previous sections of the chapter. Policy assessments are also intended to inform policy-making and policy learning. The assessments should cover all the key areas such as: (a) leadership that understands and celebrates STI achievements and contributions; (b) integration of STI into national development goals; (c) availability and accessibility of STI financing; (d) inclusion of STI in formal and informal education systems; (e) partnership between industry, government and academia; and (f) conducive legal, regulatory and administrative frameworks to develop and lay a fertile innovation ecosystem on the African continent (UNECA, 2010, 2011).

Measuring the legal, regulatory and administrative framework within which various responsible actors interact to impact STI is not easy, due to the lack of commonly adopted indicators and tools. Some attempts have been made to create and introduce more comprehensive frameworks for this purpose. For example,

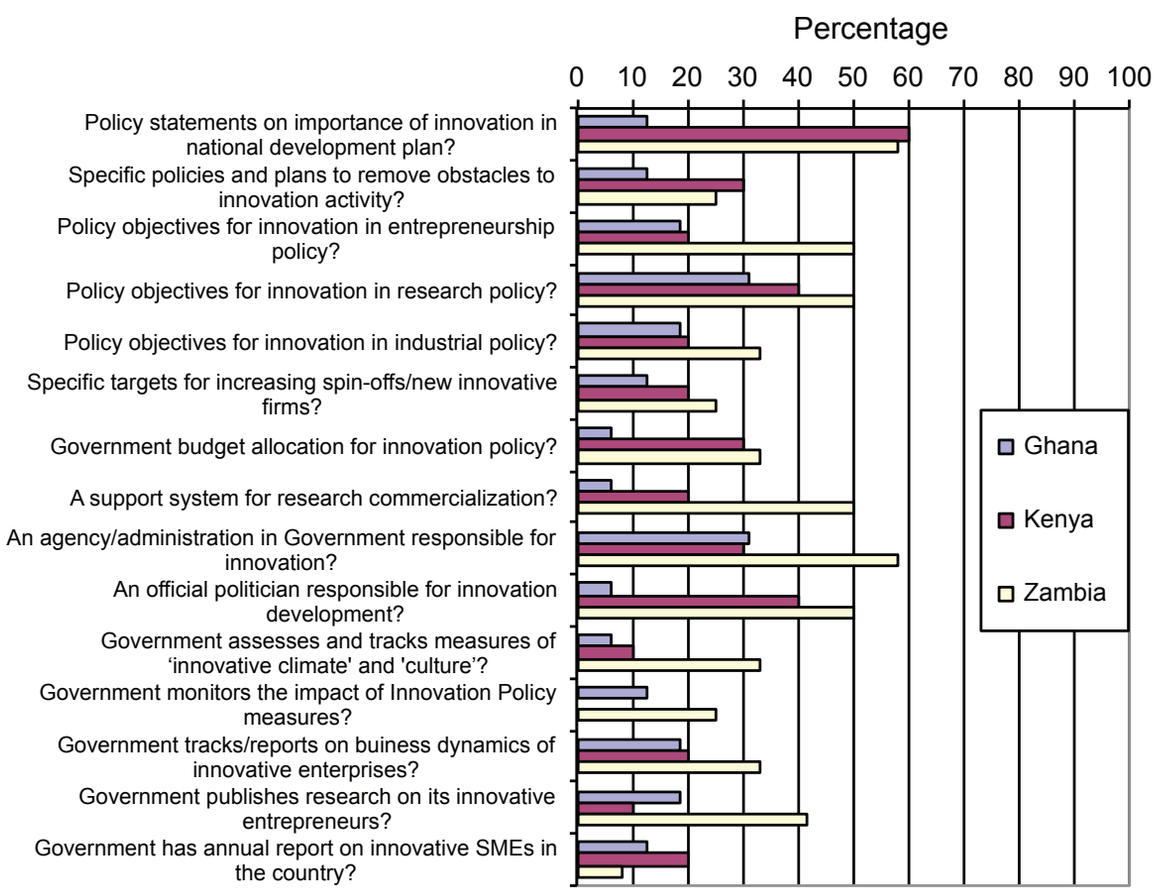
81 www.scidev.net article: "Kenya Approves a National Policy on Biotechnology" by Ochieng Ogodo, 24 October 2006. Accessed 2009.
82 Kenya Biotechnology Annual Report, prepared by Mary Onsongo for the Agricultural Biotechnology Annual
83 For details, www.tia.gov.za

the innovation policy comprehensiveness framework, which is developed by the Innovative Policy Research for Economic Growth launched by the Swedish Entrepreneurship Forum in 2005, identifies eight areas for assessment of innovation policy actions and initiatives that influence innovation performance. These include: (a) general innovation policy; (b) innovation in education; (c) business environment; (d) innovation financing; (e) promotion of innovation; 6) counselling and networking; (f) support for specific target groups; and (g) research policy to monitor and track innovation performance. In brief, it reveals STI governance in a similar manner as the assessment of investment climate (UNCTAD, 2011) and business environments (World Bank, 2011).

Adopting this framework, UNECA (2012) conducted a pilot survey of three African countries – Ghana, Kenya and Zambia – through face to face interviews with STI policy makers, top R&D managers, industrial and economic development agencies and funding and intellectual property offices to assess the innovation policy environment of the three countries. This assessment can also identify the gap in the understanding of policy measures and actions between the policy makers and other innovation stakeholders or actors.

It is shown in the results that all the sub-policy areas evaluated scored less than 50 per cent in terms of adequacy by the participants (see Figure 3.3). While over 60 per cent of the respondents in Kenya and Zambia agreed that the importance of innovation in national development is recognized and expressed in key national development strategies, less than 10 per cent in Kenya and 40 per cent in Zambia agreed that mechanisms to assess and track measures for 'innovation climate' and 'innovation culture' are in place. Similarly, less than 30 per cent of respondents in the three countries agreed that governments monitor and evaluate the impact of their innovation policy measures. As such, assessment efforts are lacking in general.

Figure 3.3: Comprehensiveness of the general innovation policy environment of Ghana, Kenya and Zambia (expressed as percentage)



Source: UNECA Innovation Survey 2011

This survey marks a fruitful initial step and provides a replicable model for conducting a more systematic and comprehensive assessment of the innovation ecosystem in other African countries. The survey of just three countries has already shown that one country may perform better in specific areas with an innovation framework than the others (see Figure 3.3). With 54 countries on the continent that are growing at different speeds, in different sectors and with different skill levels, African countries have a lot to learn from one another. Indeed, the survey reveals many promising areas in which a conducive innovation ecosystem can be developed and promoted in Africa, given that: the general business environment in many countries has improved significantly in the last decade; key institutions to work on innovation are present; and partnering opportunities in and outside the continent are recognized.

3.5 Legal and regulatory framework

Legal and regulatory frameworks play an important role in creating a conducive environment for the sector being addressed. For instance, the general Africa business environment has undergone profound transformation in the last two decades. The World Bank's Doing Business Survey shows in Table 3.4 that there are now about 25 countries in sub-Saharan Africa where the average time to register a firm is 30 days or less, up from only seven countries in 2006. Many such indicators as requirements to register products and services, recognition of property rights and labour-related issues have a particularly major impact on technology-intensive sectors such as pharmaceuticals and agriculture.

Table 3.4: Comparison of number of days needed to register a company

	2006	2012
Up to 10 days		Rwanda, Senegal, Liberia, Mauritius, Madagascar, Mali, Ethiopia, Guinea-Bissau, São Tomé and Príncipe
11 to 30 days	Burundi, Rwanda, Ghana, Central African Republic, Comoros, Sierra Leone, Gambia	Cape Verde, Ghana, Sierra Leone, Burkina Faso, Mozambique, Burundi, Cameroon, Niger, Zambia, Mauritania, South Africa, Central African Republic, Comoros, Gambia, Benin, Tanzania
31-60 days	Benin, Tanzania, Ethiopia, Uganda, Niger, Zambia, South Africa, Congo, Rep., Madagascar, Sudan, Malawi, Seychelles, Burkina Faso, Guinea, Mali, Nigeria, Cameroon, Côte d'Ivoire, Mauritius, Cape Verde, Kenya, Senegal, Gabon, Swaziland	Côte d'Ivoire, Kenya, Nigeria, Uganda, Sudan, Malawi, Seychelles, Guinea, Lesotho, Swaziland, Gabon
61-100 days	Togo, Chad, Eritrea, Mauritania, Lesotho, Namibia, Zimbabwe	Botswana, Congo, Dem. Rep., Chad, Namibia, Angola, Eritrea, Togo, Zimbabwe
more than 100 days	Botswana, Angola, Congo, Dem. Rep., Equatorial Guinea, São Tomé and Príncipe, Mozambique, Guinea-Bissau	Equatorial Guinea, Congo, Rep.

Source: Doing Business database (www.doingbusiness.org)

Many legal and regulatory issues still need to be addressed to improve STI performance and development. For instance, very few African countries have national intellectual property policies that provide guidelines on ownership, protection and commercialization of publicly funded research products and processes. South Africa is a positive example of a country that has adopted Intellectual Property Rights from its Publicly Financed Research and Development Act of 2008[84], whose main objectives are to ensure that "intellectual property emanating from publicly financed research and development is identified, protected, utilised and commercialised for the benefit of the people of the Republic, whether it be for a social, economic, military or any other benefit". To implement the act, the Government has established the National Intellectual Property Management Office.[85] This Act harmonizes how intellectual assets derived from publicly funded research is

84 http://www.info.gov.za/view/DownloadFileAction?id=94343
85 www.nipmo.org.za/

handled and treated by all arms of Government. Other African countries wishing to encourage technology commercialization could adopt similar guidelines.

Besides legal issues, regulatory and administrative issues also pose major challenges to the development of entrepreneurial institutions. It was observed that the greatest hurdles faced by R&D centres in commercializing their research include:

- The lack of clear guidelines and policies for technology commercialization
- Limited time allocation for technology commercialization activities
- Low personal rewards and hence low motivation to undertake technology commercialization
- Technology commercialization is not a priority area of the institution

A number of these issues could easily be improved by taking simple steps to provide clear guidelines.

ICT is an area where countries are taking significant steps to improve legal and regulatory regimes. The number of countries putting in place consumer protection measures such as safer online transactions and data protection is growing rapidly (see Table 3.5). These measures are intended to assure users that African countries are secure destinations for ICT- related businesses. This is particularly important for countries that are investing significantly in infrastructure for the growth of knowledge services such as e-services, Business Process Outsourcing, Information Technology Enabled Services and call centre services. These services require that countries take cyber security and cybercrimes seriously. National databanks will only be useful when key stakeholders trust that their data is safe, readily accessible and its integrity uncompromised.

Taking these measures could also trigger further innovation and investment in STI. In 2012, for instance, Nokia has chosen Nairobi, Kenya as its global centre for investment in innovation. This is a major confirmation that Africa is emerging as a knowledge hub for knowledge generation and application.

Table 3.5: ICT legislations to support knowledge services

Country	Legislations Enacted				Knowledge Services			
	e-currency, e-transaction,	Consumer protection and arbitration	Digital signature	Cyber-security laws	e-services	BPO	ITES	Call centres
Benin				√				√
Burkina Faso	√	√			√			
Burundi								
Congo								
Cote d'Ivoire	√							
Congo, DR	√	√						
Egypt	√			√		√	√	√
Ethiopia	»							
Gambia	√	√				√		
Ghana	√		√	√	√	√	√	√
Guinea-Bissau	√							
Kenya						√		√
Madagascar	√	√				√		√
Mali	√	√						√
Mozambique	√	√						√
Niger	√	√	√	√				√
Nigeria	√	√		√				

Country	Legislations Enacted				Knowledge Services			
	e-currency, e-transaction,	Consumer protection and arbitration	Digital signature	Cyber-security laws	e-services	BPO	ITES	Call centres
Senegal	√	√		√				√
Sudan	√	√		√				
Togo	√	√						
Uganda	√	√				√		√
Zambia				√				√
√ Adopted								
» In progress								

Source: UNECA WSIS Survey analyses for 2009 and 2011

3.6 Harmonization of policies, legal and regulatory regimes at subregional and regional levels

There are several efforts to harmonize STI policies and plans at the subregional and regional levels. For example, the Science and Technology Consolidated Plan of Action spearheaded by NEPAD (Commonly referred to as the CPA) is a regional initiative that prioritized STI initiatives at the continental level. The CPA sets a regional agenda on a selected number of R&D initiatives and capacity-building efforts that have been commonly agreed and endorsed by Heads of State and Governments. The CPA serves as a guide for STI activities by donors, RECs and United Nations agencies. To support this initiative, the African Cluster of Science and Technology and the African Ministerial Council of Science and Technology (AMCOST) have served as vehicles for planning, collaboration and coordination of STI activities on the continent.

At the subregional level, the Heads of State and Government of the Economic Community of West African States (ECOWAS) seek to harness the potential of STI to support regional development and the implementation of the ECOWAS Vision 2020.[86] To that effect, the ECOWAS Policy on Science and Technology (ECOPOST) and its action plan were adopted by the Ministers of Science and Technology in March 2012. ECOPOST addresses 12 thematic areas: (a) scientific research, innovation and technological development; (b) support for education and training; (c) higher education; (d) scientific culture; (e) enabling environment for scientific creativity; (f) regional and international cooperation; (g) capacity building; (h) science and technology and private sector involvement; (i) information on S&T: data, statistics and indicators; (j) gender, science and technology; (k) E-governance and Internet massification; and (l) transfer of technology and technology watch.

There are also efforts to develop the African Pharmaceutical Plan led by the African Union Commission (AUC) and the United Nations Industrial Development Organization (UNIDO). Such sub-regional and regional efforts are effective to enhance commitment of individual countries and promote their collaboration to implement important initiatives that are influential to their development as a whole.

There are collective efforts among African countries in promoting the adoption of ICT strategies in the economy and society at the sub-regional and regional level. The Kigali protocol from the Connect Africa summit held in 2007 urged RECs to harmonize policies and regulatory frameworks as an enabling framework to speed up regional interconnections and facilitate communication. One of the goals of the Kigali protocol

86 The ECOWAS vision aims at creating a borderless, peaceful, prosperous and cohesive region, built on good governance, where people have the capacity to access and harness its enormous resources through the creation of opportunities for sustainable development and environmental preservation.

urged countries to adopt national e-strategies, including a cyber security framework, and deploy at least one flagship e-government service as well as e-education, e-commerce and e-health services by 2012, with the aim of making multiple e-government and other e-services widely available by 2015.

In North Africa, efforts have been underway through the Arab Maghreb Union (AMU) to examine the feasibility of launching a subregional e-commerce platform. The Communauté Economique des Etatsd'Afrique Centrale (CEEAC)/Central African Monetary and Economic Community (CEMAC) adopted the ICT strategy for Central Africa in the framework of the CEMAC 2010 ICT Strategy, while the Common Market for Eastern and Southern Africa (COMESA) has also adopted the ICT Strategy for the subregion, together with a regional framework for ICT indicators. Furthermore, a regional framework for e-Government and Guidelines for e-Legislation was also adopted (UNECA, 2012). The East African Community (EAC) has also developed an e-government strategy for the subregion. With regard to policy, the strategy outlined the agreements and protocols that should be in place to sustain e-government services, applications and content in a harmonized manner across the region.

ECOWAS adopted a harmonized ICT legal framework. The framework includes guidelines on cybercrime and personal data protection.

Box 3.1 presents the status of legal and regulatory frameworks adopted at the ECOWAS subregional level and their adoption at the national level.[87]

Box 3.1: ICT policy harmonization efforts - the case of ECOWAS

ECOWAS with the support of ITU adopted six supplementary acts (one policy and five technical) in 2007 in Ouagadougou:

1. Harmonization of Policies and of the Regulatory Framework for the ICT Sector;
2. Legal Regime applicable to Network Operators and Service Providers;
3. Access and Interconnection in Respect of ICT Sector Networks and Services;
4. Numbering Plan Management;
5. Management of the Radio-Frequency Spectrum; and
6. Universal Access/Service.

With assistance of the 'Support for Harmonisation of ICT Policies in Sub-Saharan Africa (HIPPSA)' initiative, ECOWAS is working to transpose these frameworks at the national level.

With support from ECA, ECOWAS developed three e-legislation documents, namely

- Supplementary Act on Electronic Transactions
- Supplementary Act on Personal Data Protection
- Directive on Fighting against Cybercrime

Two of the e-legislation frameworks (i.e. the Electronic Transactions & Personal Data Protection) were adopted by the Heads of States in 2010 in Abuja, Nigeria. The one on Cybercrime is to be presented for adoption at the next Council of Ministers meeting.

Source: UNECA survey, 2011.

The e-SADC strategy aims to promote regional harmonization and capacity building in ICT policy formulation and the implementation of e-strategies. Accordingly, harmonization activities that SADC has undertaken[88] are depicted in Box 3.2.

87 Progress of Telecommunications/ICT Programme Implementation in ECOWAS Region. Programme for Infrastructure Development in Africa (PIDA) ICT expert meeting, 12 September 2011, Addis Ababa, Ethiopia.

88 SADC Projects. Programme for Infrastructure Development in Africa (PIDA) ICT expert meeting, 12 September 2011, Addis Ababa, Ethiopia.

Box 3.2: Harmonization of ICT Policies– Examples in the SADC subregion

SADC adopted the Regional Digital Terrestrial Television (DTT) migration plan for the subregion's smooth transition from analogue to DTT broadcasting by December 2013. It also works on the development of a framework for regional roaming regulations. With regard to cyber security, SADC works to develop the following model laws:

- Electronic transactions
- Protection of personal data and privacy
- Combating cybercrime

Currently, a subregional e-commerce readiness study is underway with the aim to develop a subregional e-commerce strategy for action. A number of harmonization activities are underway, which include:
Proposal of amendments to Chapter 10 of the TCM Protocol that is dedicated to telecommunications

- SADC Licensing Guidelines (terms of reference being developed)
- Harmonization Framework for Cross-border Communications
- SADC Numbering Guidelines (to review)
- SADC Interconnection Guidelines (to review)
- SADC Regional Legal and Investment Frameworks
- Introduction of Open Access for Major Public Facilities
- SADC ICT Indicator Database
- SADC Policy Framework for Convergence
- ICT Policy for SADC Region (revised)
- SADC ICT Model Bill (revised)
- SADC Guidelines on Universal Access and Service (revised)
- SADC Toolkit on Universal Access and Service Funding and Implementation.
- SADC Frequency Allocation Plan (revised)
- SADC ICT Consumer Rights and Protection Regulatory Guidelines

Source: UNECA survey, 2011

These are just a few examples of the trends in ICT policy development. As more and more countries have started to embrace the knowledge economy, increased collaboration and harmonization at the subregional and regional levels will be the call of the future.

3.7 Concluding remarks

Although strides have been made in developing STI policies in Africa, there is a need to urgently develop tools that can guide countries, and international institutions that support countries in policy development and implementation. Most current policy-making regimes are neither strategic nor innovative. They do not seem to provide sufficient guidance that takes current major economic and social transformation on the continent and the future needs of countries into consideration.

Policy learning seems to be largely absent, as policy monitoring and evaluation seem not to be undertaken systematically. Hardly any of the countries assessed produce annual reports on technology, innovation and entrepreneurship performance. This partly explains why data is very scanty, as Government agents do not seem to require institutions to provide annual reports on their performance in meeting their objectives.

The streamlining of STI in national development seems to take place on paper but the actual contributions of STI are often poorly coordinated and do not reach their full potential. There are two main challenges to STI policy in Africa: (a) the targets are frequently not clear or measurable; and (b) the role of the private sector is left at the level of collaboration rather than full integration. This lack of private sector engagement is

perhaps the weak link between policy and technology and economic trends on the continent. For example, the current growth in ICT on the continent, including the celebrated mobile money revolution, is driven by the private sector, as was shown in chapter 3. It is the public sector that has to catch up and formulate supportive policies and strategies with relevant and measurable outputs.

The popularization or socialization of S&T on the continent is not a major subject of regional policies even though it may explain the limited support that STI attracts. There is a need for strategies to promote S&T at all levels of society, to encourage students to consider the science, engineering and technology fields as rewarding career options, and to highlight the impact of S&T in the everyday lives of the people. This approach could build on the current positive performance of S&T industries and lead to the emergence of more innovative technology firms on the continent.

References

DST (2001). A National Biotechnology Policy for South Africa, Pretoria: Department of Science and Technology, Government of South Africa.

Juma, C. and I. Serageldin (2007). Freedom to Innovate: Biotechnology in Africa's Development. Report of the High-Level Panel on Modern Biotechnology, African Union and the New Partnership for Africa's Development.

Konde, V. (2007). What type of national ICT policies maximize ICT benefits? ATDF Journal Vol, Issue 1, 37-48.

Korea (1993). National Biotechnology Development Programme "Biotech 2000". Korea Initiative for Biotechnology Development 1994–2007, Ministry of Science and Technology, Republic of Korea.

MoFED (2006). Ethiopia: Building on Progress. A Plan for Accelerated and Sustained Development to End Poverty (PASDEP) (2005/06-2009/10),The Federal Democratic Republic of Ethiopia.

MoFED (2010). Education Sector Development Programme IV (ESDP IV) 2010/2011 – 2014/2015, Federal Ministry of Education, The Federal Democratic Republic of Ethiopia.

OECD (2005). Governance of innovation systems, Vol.1: Synthesis Report, OECD.

Uganda (2010). National Development Plan 2010/11-2014/15, Republic of Uganda.

UNCTAD (2011). The World Investment Report 2011, UNCTAD, United Nations: Geneva and New York.

UNDP (2011). Human Development Report: "Sustainability and Equity: A Better Future for All", United Nations Development Programme.

UNECA (2010). Science with Africa Proceedings: Science, innovation and entrepreneurship, ECA.

UNECA (2011). Development planning in Africa: Key issues, challenges and prospects. Background paper for the Meeting of the Committee of Experts of the 4th Joint Annual Meetings of the AU Conference of Ministers of Economy and Finance and ECA Conference of African Ministers of Finance, Planning and Economic Development, Addis Ababa, Ethiopia, 24-27 March.

UNECA (2012). Assessing African Innovation Policy Environment: A survey of Ghana, Kenya and Zambia, United Nations.

UNECA (2012). Framework for the set of e-government core indicators; Partnership on measuring ICT for development, March, Addis Ababa, Ethiopia.

World Bank (2011). Doing Business Report 2011, World Bank. Available from www.doingbusiness.org.

Chapter 4

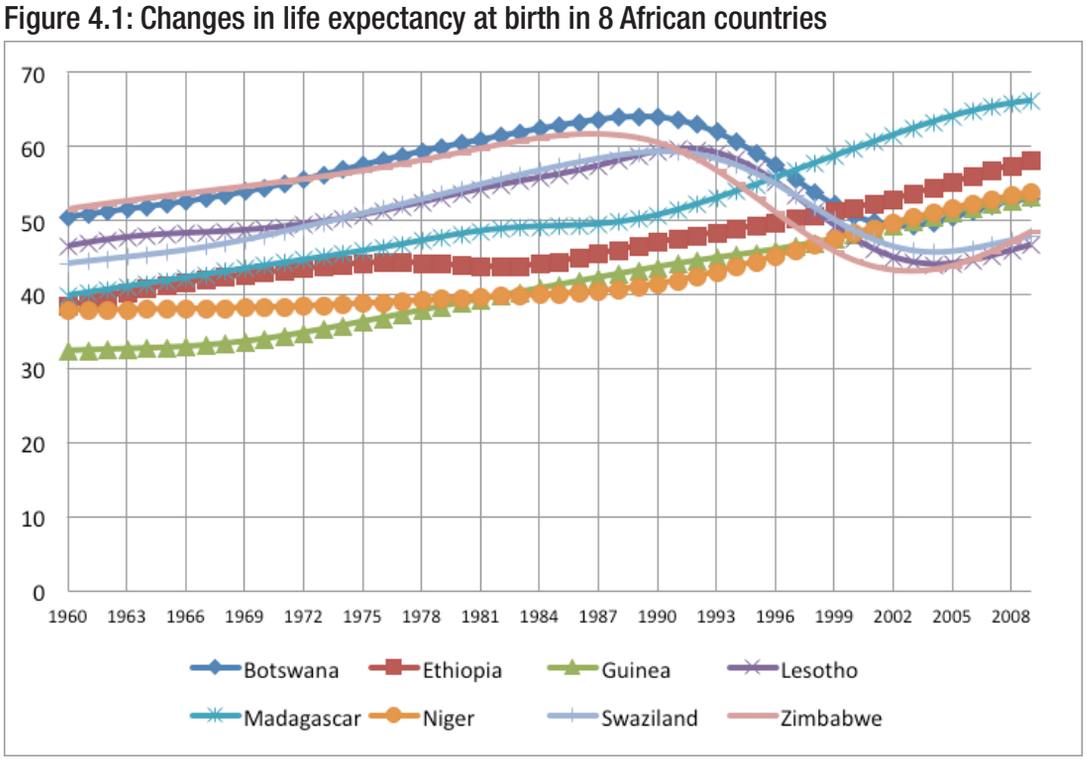
Africa's pharmaceutical industry

4.0 Overview

The pharmaceutical industry plays a critical role in the provision of quality healthcare and improved quality of life. It is a critical engine for economic and social development. It is also a knowledge-intensive industry and science and technology continue application have resulted in improved and new drugs, vaccines and other treatments that have curbed the spread, and eased the management of, many diseases. Vaccine technology has led to the eradication of smallpox and had a huge impact on diseases such as polio and measles. Drugs are now available to address many previously life threatening diseases, for example the availability of antiretroviral drugs over the past decade has significantly assisted the fight against HIV and AIDS on the continent and has improved the life expectancy and quality of life of those infected and affected by the disease.

Despite these developments, lack of access to pharmaceutical products and medical care contributes significantly to a continued high disease burden on the continent, which results in high mortality rates and reduced life expectancy in a number of African countries. The impact of HIV and AIDS on life expectancy in countries such as Lesotho, Botswana, Swaziland and Zimbabwe are illustrated in Figure 4.1. A marked fall in life expectancy occurred in the 1990's, linked to the emergence of the disease, with a positive upswing beginning to occur in the 2000's, linked to the improved availability of drugs and medical care for HIV and related infections. Many other countries in sub-Saharan Africa were similarly affected to the same or a lesser extent. However, despite these issues, countries such as Ethiopia, Guinea, Madagascar and Niger were able to register a continuous increase in life expectancy over this period.

Figure 4.1: Changes in life expectancy at birth in 8 African countries



Source: World Development Indicators online, 2012

A number of global, regional and national health initiatives have been put in place since the late 1990s/early 2000s, driven by the HIV and AIDS crisis and the MDG health-related goals. Initially, these initiatives focused on HIV/AIDS, tuberculosis and childhood malaria. However, they were followed by major efforts in maternal health, particularly addressing the dangers of childbirth. More recently, there has been increased interest in non-communicable diseases and health systems strengthening and support. Improved access to pharmaceutical products has played a significant part in associated policies and programmes, though it is apparent that further increased availability and access is needed to bring equity between Africa and much of the rest of the world.

The pharmaceutical sector is largely driven by a major global industry. The global market for pharmaceuticals is estimated to have reached $880 billion in 2011 and is expected to reach $1.1 trillion by 2014. Developed markets take the lion's share, with the United States alone accounting for a third of this market ($300 billion in 2009). However, strong growth is already being seen, and is expected to continue, from emerging markets such as Brazil, China, India and Russia. .

Africa's pharmaceutical industry is relatively small, accounting for only about 1 per cent of the global market; and much of this is dominated by South Africa, Egypt and Nigeria. In 2006, the International Finance Cooperation (IFC) estimated that the pharmaceutical market in sub-Saharan Africa was $3.8 billion.[89] By 2010, the South African market alone had reached $3.3 billion and that of Egypt and Nigeria were estimated at about $2.5 billion[90] and $800 million[91] respectively. All predictions indicate that the sector is growing rapidly at an annual rate of 10 to 20 per cent and presents many opportunities for domestic and foreign investment, plus increased technological learning in line with a deepening industrialization of the continent.

In this section, the review provides a synopsis of the African pharmaceutical sector and its performance and competitiveness in terms of trade, innovation capacity, current efforts to develop the African pharmaceutical industry and opportunities for collaboration and exploiting abundant natural resources and indigenous knowledge. Africa, to date, has primarily been a recipient of externally generated pharmaceutical technology. It may be that an increased market for pharmaceuticals in Africa, combined with appropriate policies, can lead to pharmaceutical innovation and business generation from within the continent.

4.1 Trade performance of Africa's pharmaceutical industry

4.1.1 Pharmaceutical exports

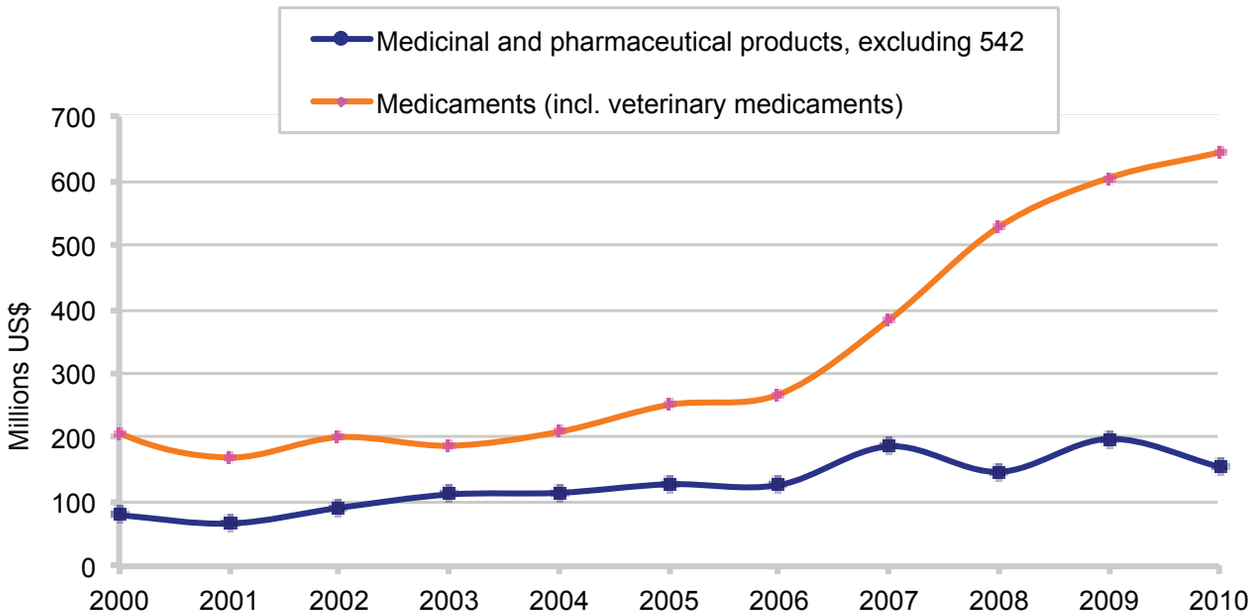
Exports are a strong proxy measure of the strength of a national industry. The pharmaceutical industry in Africa has grown rapidly since 2000. Exports of pharmaceuticals grew from about $287 million to about $800 million from 2000 to 2009 before falling slightly to $798 million in 2010. The Standard International Trade Classification of Pharmaceutical and Medicinal products distinguishes between medicaments, including veterinary medicaments (SITC 542) and other products excluding medicaments (SITC 541). The fastest growth in pharmaceutical and medicinal products exports in Africa was recorded by medicaments (SITC 542) as shown in Figure 4.2. The export of medicaments grew by 210 per cent from 2000 to 2010.

89 http://edms.matrade.gov.my/domdoc/Reports.nsf/svReport/275A244698E56FFE4825748A00044868/$File/Pharmaceutical per cent20In per cent20South per cent20Africa.pdf?OpenElement

90 http://www.researchandmarkets.com/research/d4a32f/egypt_pharmaceutic

91 http://businessdayonline.com/NG/index.php/news/76-hot-topic/30688-nigerian-pharmaceutical-market-to-yield-261bn-in-2016

Figure 4.2: Pharmaceutical exports for Africa

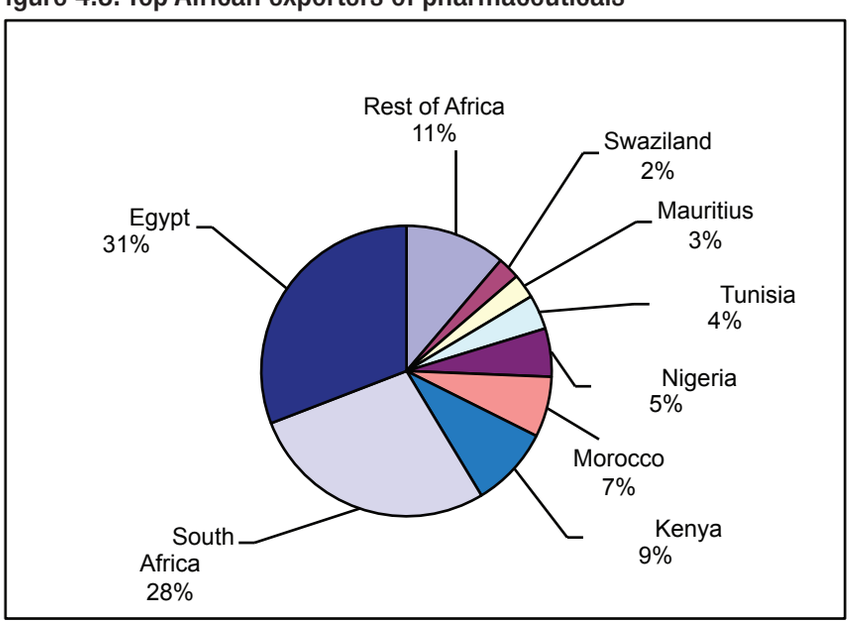


Source: UNCTAD Handbook of Statistics Online

Note: 542 refers to medicaments.

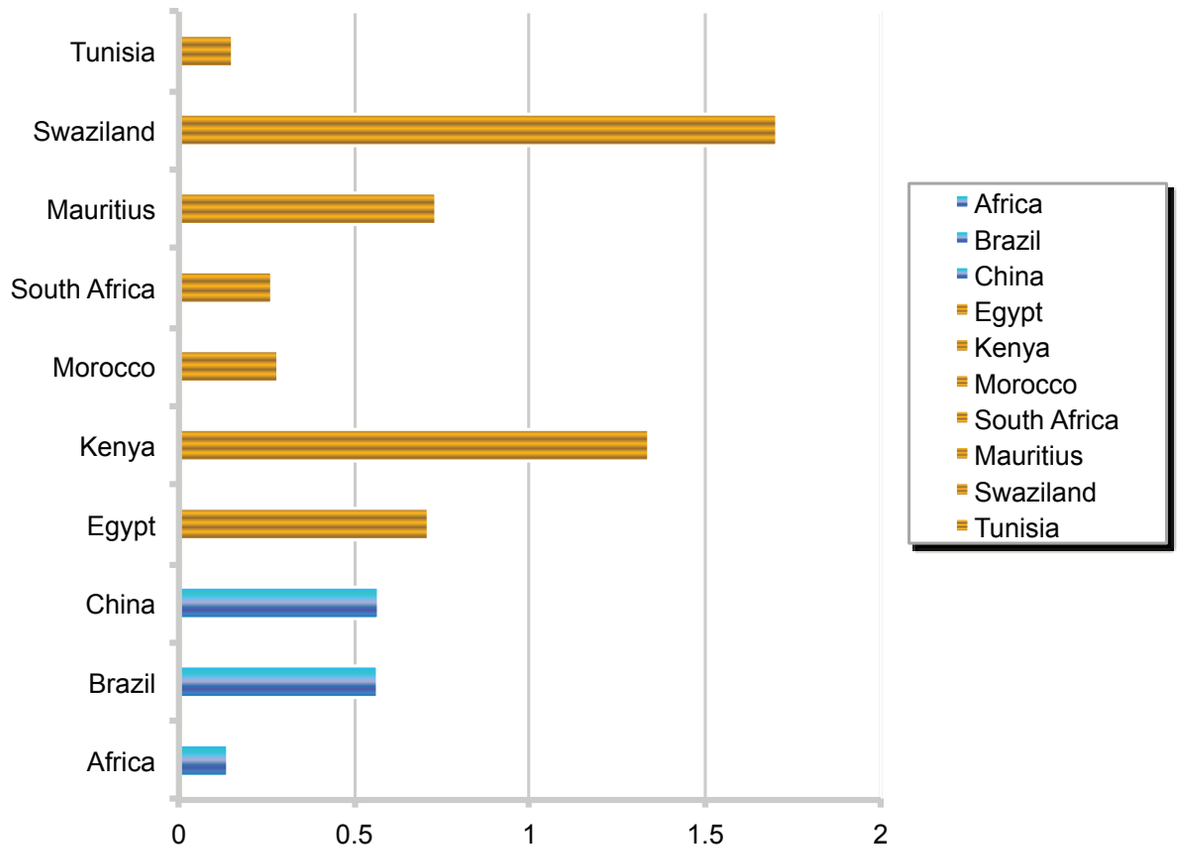
The top exporters of pharmaceutical products are Egypt and South Africa, collectively accounting for more than 59 per cent of Africa's total pharmaceutical exports. Other major exporters of pharmaceutical products include Kenya, Morocco, Nigeria, Tunisia, Mauritius and Swaziland. Collectively they account for about 30 per cent of Africa's total pharmaceutical exports (see Figure 4.3 for details). These countries could become frontrunners, as the pharmaceutical sector starts to grow.

Figure 4.3: Top African exporters of pharmaceuticals



Source: UNECA analysis based on UN Comtrade database online (http://comtrade.un.org/)

Figure 4.4: Pharmaceutical exports by African countries

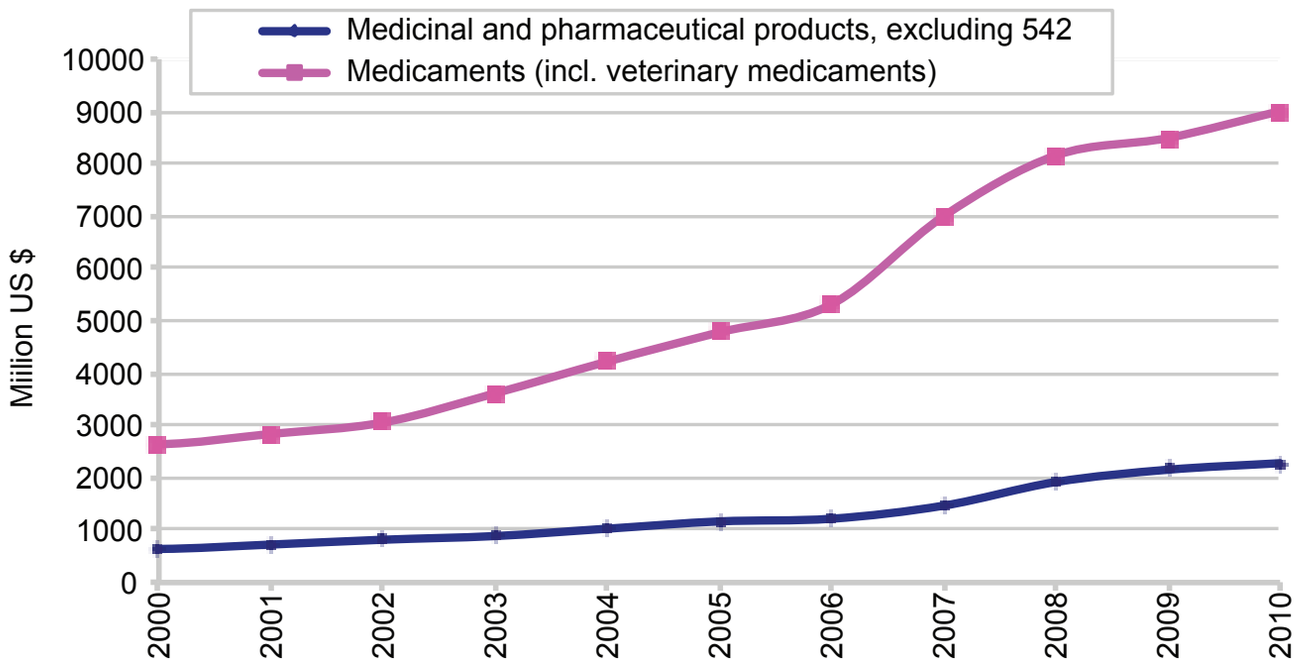


Source: UNECA analysis based on UN Comtrade database online (http://comtrade.un.org/)
Mapped by: United Nations Economic Commission for Africa

The share of pharmaceutical exports as a percentage of total exports fluctuated within the low range of 0.12 per cent to 0.2 per cent from 2000 to 2010. However, for countries such as Kenya and Swaziland, pharmaceutical exports make up more than 1 per cent of total merchandise exports, as shown in Figure 4.4. Interestingly, these figures compare favourably with Brazil and China but are below that of India, where pharmaceuticals make up more than 3 per cent of merchandise exports.

Pharmaceutical exports are thus as important to several African countries as they are to some developed countries. With active promotion and support, the pharmaceutical sector may serve as a major foreign currency earner, especially for countries such as Egypt, Kenya, Mauritius and Swaziland. It is worth noting that pharmaceutical exports seem to have weathered the global economic and financial crisis better than many other export products.

Figure 4.4: Average proportion of pharmaceutical exports in total value of merchandise exports (In per cent; 2010)



Source: UNECA analysis based on UN Comtrade database online (http://comtrade.un.org/)

The export markets of African countries vary widely. This is illustrated in Table 4.1. Egypt and South Africa have more export partners than most other African countries, perhaps and indication of the level of maturity of the industry in those countries. In 2009, South Africa exported pharmaceuticals to some 170 countries, and Egypt to 107 countries. . Kenya and Nigeria, on the other hand, exported pharmaceutical products to about 53 and 23 countries respectively. Within these countries however, there is significant concentration of trade with a fewer countries. For example, Egypt and South Africa's top 10 export partner countries account for about two-thirds of total pharmaceutical export value ; while the top 10 export partners for Kenya and Nigeria account for more than 90 per cent of total pharmaceutical exports. Nigeria has a particularly strong dependence on France. A broad base of export partners is likely to cushion changes in demand and economic conditions in the partner countries. It also ensures some level of stability in terms of export performance.

Table 4.1: Top ten export markets of four African countries (2009)

Egypt		Kenya		Nigeria		South Africa	
Partner	%	Partner	%	Partner	%	Partner	%
Iraq	14.0	Uganda	30.0	France	84.7	Zambia	16.6
Yemen	11.1	Tanzania	25.9	Antigua and Barbuda	9.2	Kenya	14.7
Romania	9.4	Sudan	11.9	Ghana	1.1	Nigeria	6.1
Sudan	7.8	Somalia	6.7	Turkey	0.7	Zimbabwe	6.1
Saudi Arabia	7.8	Nigeria	4.8	Austria	0.7	USA	5.8
Turkey	3.8	Rwanda	4.4	Gabon	0.6	Ghana	5.6
Libya	3.4	Malawi	2.7	Albania	0.5	Australia	4.4
Pakistan	3.4	Ethiopia	2.4	Barbados	0.3	Mauritius	4.3
Netherlands	3.3	Burundi	2.2	Netherlands	0.3	Uganda	4.1
Jordan	2.9	Zambia	1.9	Afghanistan	0.3	Germany	3.8
Total (per cent)	66.8		92.8		98.4		71.6

Source: UNECA analysis based on UN Comtrade database online (http://comtrade.un.org/)

From the regional integration standpoint, over 98 per cent of Kenya's pharmaceutical exports and 70 per cent of those of South Africa's go to other African countries. Proximity plays a significant role here, as Egypt's exports, for instance, are concentrated in North Africa, Europe and the Middle East, while those of Kenya are concentrated in Eastern and Southern African countries. Similarly, Southern African countries are among the top export partners of South Africa. Nigeria depends largely on export markets outside Africa. The pharmaceutical industry could promote intra-African trade and also serve as a vehicle for fostering collaboration across the entire value chain, from research and development to the market.

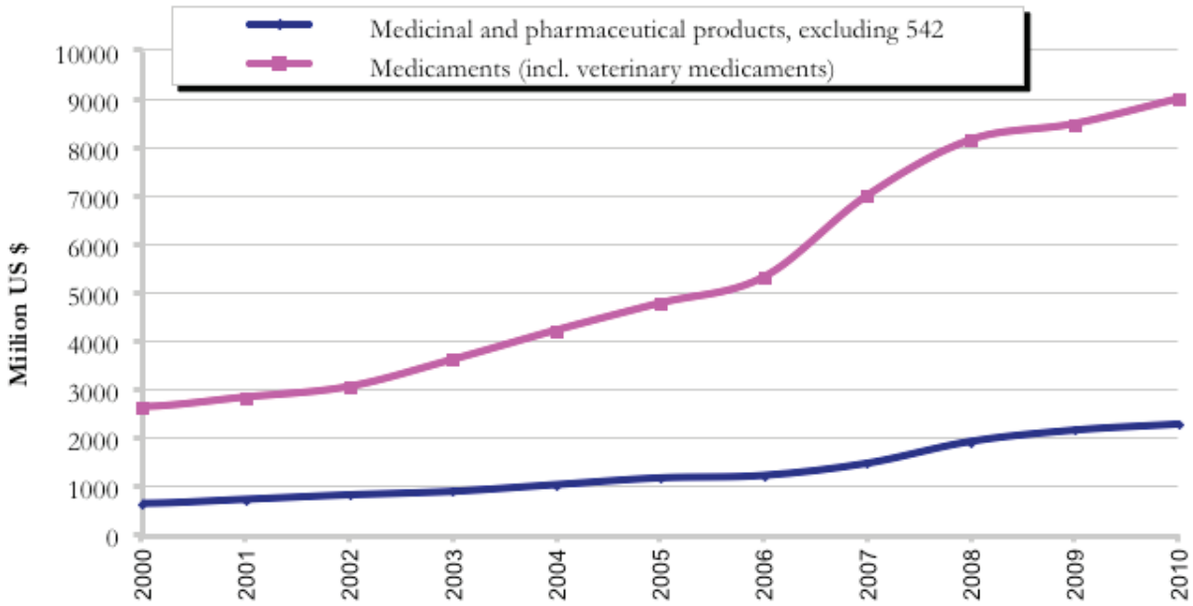
4.1.2 Pharmaceutical Imports

In 2010, pharmaceutical imports grew rapidly and outstripped exports in dollar terms by about 14:1. They rose from about $3.3 billion in 2000 to $11.3 billion in 2010 (see Figure 4.5). For some countries with limited pharmaceutical infrastructure this ratio is significantly higher. For example, Malawi spent 3,111 times[92] more money on imports than it realized from exports of pharmaceuticals in 2010. Other countries with similar high ratios of import to export value of pharmaceuticals in 2010 include Algeria (830 times), Libya (822 times), Sudan (680 times) and Gabon (640 times).

Not surprisingly, some of the major exporters have the lowest ratio of imports to exports on the continent. For example, Mauritius imported only 3.7 times more pharmaceuticals than it exported in 2010. Other countries with lower ratios include Kenya (4.1 times), Egypt (5.0 times), Swaziland (5.8 times), Morocco (9.0 times), Nigeria (9.8 times) and South Africa (10.5 times).

92 Times" is calculated in this paper as "the value of pharmaceutical imports in 2010 divided by the value of pharmaceutical exports in 2010. As such, a country that exported $2 worth of pharmaceuticals and imported $100 with of pharmaceuticals in 2010 imported ($100/$2) 50 times more in value terms.

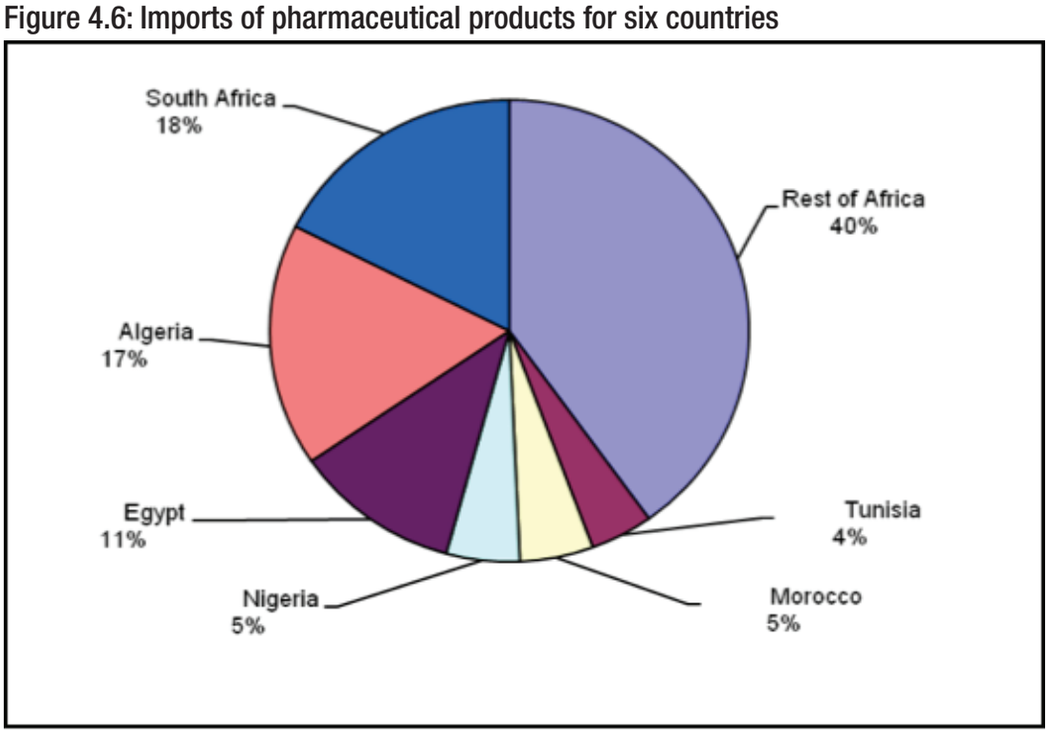
Figure 4.5: Imports of pharmaceutical products



Source: UNECA analysis based on UN Comtrade database online (http://comtrade.un.org/)

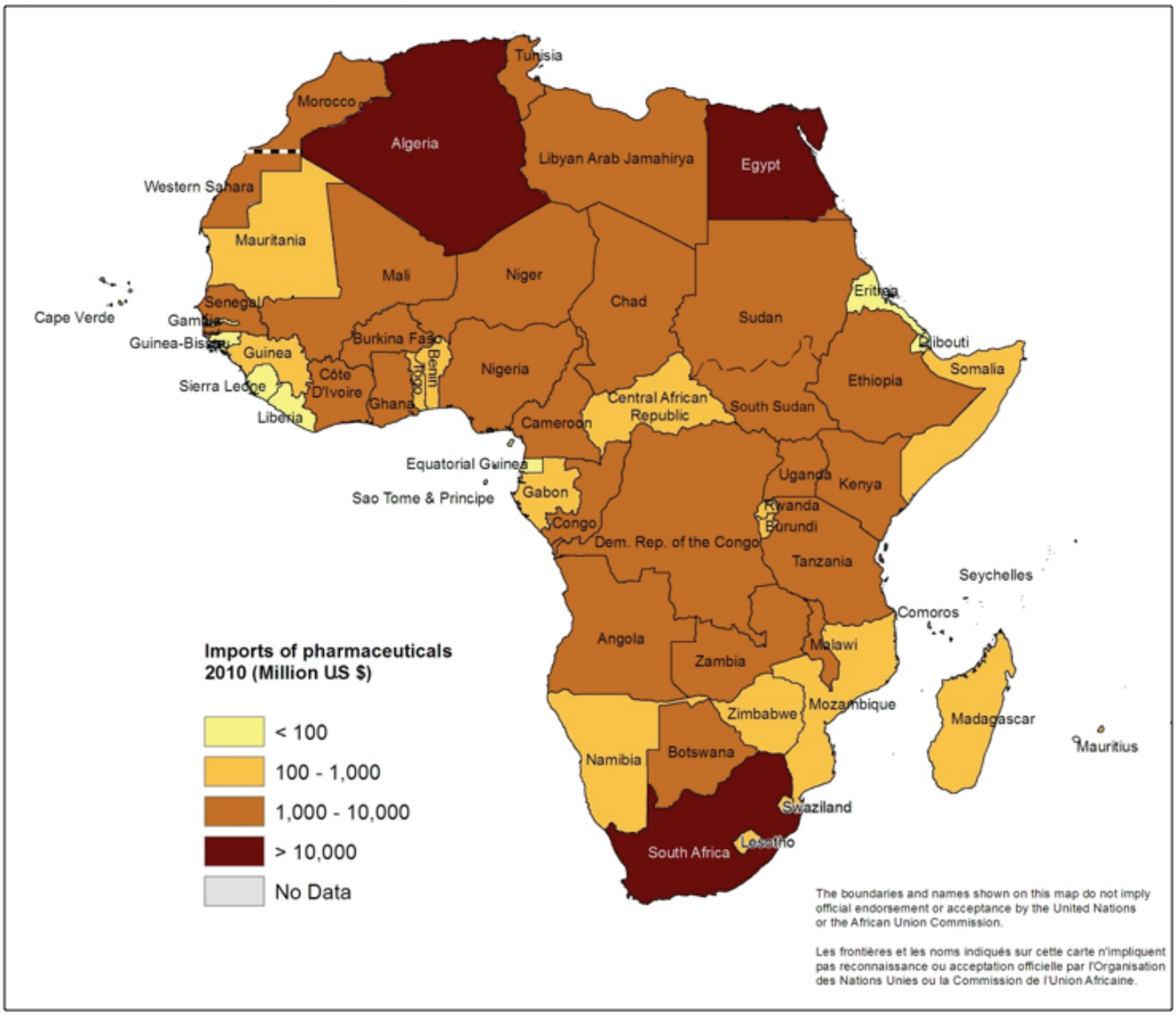
The top importers of pharmaceuticals in Africa largely reflect the size of their economies and include South Africa, Algeria, Egypt, Nigeria, Morocco and Tunisia as shown in Figure 4.6 and Figure 4.7. These six countries account for about 60 per cent of all pharmaceutical imports.

Figure 4.6: Imports of pharmaceutical products for six countries



Source: UNECA analysis based on UN Comtrade database online (http://comtrade.un.org/)

Figure 4.7: Pharmaceutical imports by African countries



Source: UNECA analysis based on UN Comtrade database online (http://comtrade.un.org/)
Mapped by: United Nations Economic Commission for Africa

Africa imports most of its drugs from developed countries and emerging economies. This is reflected in imports to the four main regional economies; Egypt, Kenya, Nigeria and South Africa (see Table 4.2). India and China accounted for about 42 per cent of pharmaceuticals imports to Nigeria in 2009, while India and South Africa, accounted for 43 per cent of Kenya's pharmaceutical imports. Germany, Switzerland and the United States accounted for 48 per cent of Egypt's pharmaceutical imports, while Germany, France and the United States accounted for 33 per cent of South Africa's pharmaceutical imports in 2009.

Table 4.2: Top 10 import partners of four African countries in 2009

Egypt		Kenya		Nigeria		South Africa	
Partner	per cent	Partner	per cent	Partner	per cent	Partner	per cent
Germany	18.2	India	33.9	India	30.4	Germany	12.8
Switzerland	15.5	South Africa	8.4	China	12.3	France	10.7
USA	14.4	Switzerland	7.0	Botswana	8.8	USA	10.5
Ireland	9.0	USA	6.4	Albania	7.7	India	10.2
France	8.8	Denmark	5.6	United Kingdom	5.5	United Kingdom	8.5
China	4.8	United Kingdom	5.3	Belgium	4.4	Switzerland	7.6
United Kingdom	4.0	China	4.7	Barbados	3.8	Ireland	5.6
Denmark	3.4	France	4.0	South Africa	2.7	Italy	5.4
Netherlands	3.0	Belgium	3.3	France	2.1	China	4.5
Italy	2.8	Germany	3.2	Switzerland	2.1	Belgium	3.3
Total (per cent)	83.9		81.9		79.7		79.1

Note: The 2009 data was more complete than that for the 2010 for some countries

Source: UNECA analysis based on UN Comtrade database online (http://comtrade.un.org/)

The cumulated import and export trade data reveal that a number of African countries have an emerging and growing pharmaceutical industry. For some, pharmaceutical exports account for over 1 per cent of total exports; an indication of a significant local industrial base.

4.2 Research and development in pharmaceuticals

Africa has a small but fast growing capacity in basic and applied pharmaceutical research. As there is limited data on national funding of health and pharmaceutical-related research and on patent and technology transfer, we use publication trends in science, engineering and technology fields related to pharmaceuticals as proxy for assessing trends in research and development performance. We complement this with data from some recent targeted surveys.

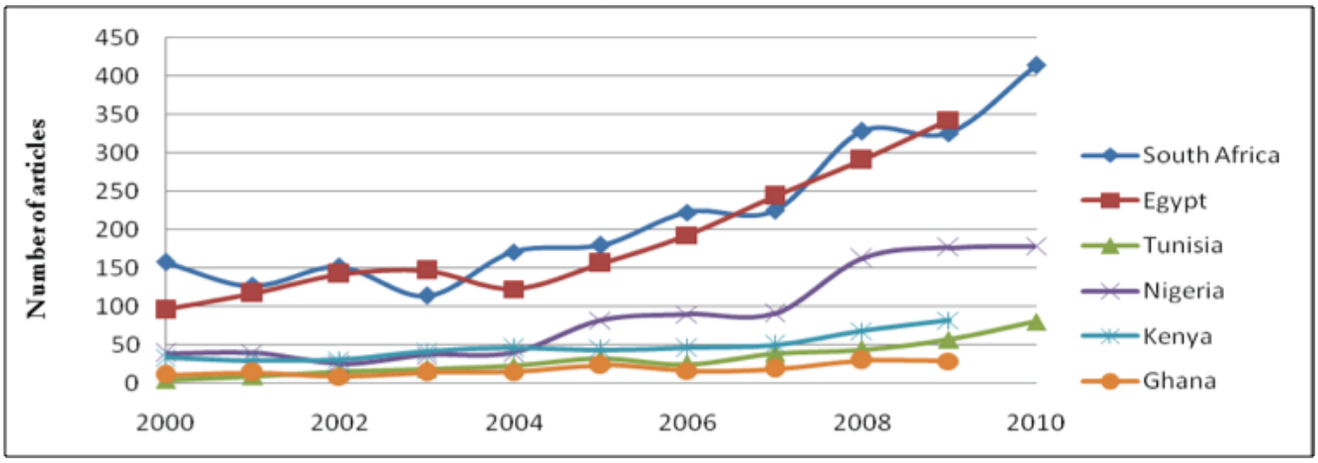
4.2.1 Trends in publications in the life sciences

Tracking publications in all sectors linked to the pharmaceutical sector is a major challenge due to the multidisciplinary nature of the area. To gain some insight, we tracked all publications that fall within the broad category of pharmacology, such as pharmacy, general internal medicine, chemistry, cardiology, infectious diseases, biochemistry and veterinary sciences.

Trends in peer-reviewed journals in these fields show a general and steady increase in publications, as shown in Figure 4.8. The number of papers published more than doubled from 2000 to 2009 in all the six countries compared here. Most of the capacity is concentrated in South Africa and Egypt, which now publish around 400 articles per year, followed by Nigeria and Kenya.

While the number of publications is increasing, the total number of papers published is still small internationally. For comparison, applying the same criteria, Brazil registered about 1538, while China published over 4077 in the same fields.

Figure 4.8: Publication profiles of selected leading countries in pharmaceuticals



Source: Web of Science, UNECA Analysis

4.2.2 Trends in pharmaceutical research and development investment

Globally, pharmaceutical firms are among the top investors in R&D. For example, seven of the top 30 R&D investing firms in the Europe are pharmaceutical related companies. As shown in Table 4.3 these firms invest up to 20 per cent of their sales in R&D. Traditionally, a pharmaceutical company may be assessed on R&D output, for example: the number of key products it has introduced on the market; the number of products submitted for regulatory approval; or about to be approved; and the number of innovative products under development, i.e. the R&D product pipeline.

Table 4.3: Top R&D based pharmaceutical companies in Europe

Rank	Company	R&D investment (in Euro billion)	Ratio of R&D to net sale
4	Sanofi-Aventis	4.390	13.6
5	GlaxoSmithKline	4.379	13.2
8	Bayer	3.211	9.2
9	AstraZeneca	3.205	12.9
14	Boehringer Ingelheim	2.453	19.5
24	BASF	1.507	2.4
25	Merck DE	1.397	15.6
27	Novo Nordisk	1.272	15.6

Source: UNECA analysis based on European R&D Scoreboard 2011
(http://iri.jrc.ec.europa.eu/research/scoreboard_2011.htm)

While in-house R&D performance is important, companies may undertake other activities to maximize their R&D-based return on investment. This may take the form of: (a) acquiring innovative start-up companies; (b) outsourcing R&D; (c) licensing in or out of new products; and (d) co-investment in emerging technologies, to complement its in-house R&D activities.

With respect to African pharmaceutical companies, some of the major global companies have subsidiary companies in Africa, but very few African companies have R&D units or R&D directors to oversee product development and technology transfer. Some of Africa's largest pharmaceutical firms have some limited R&D activity. There are also a few biotechnology-based pharmaceutical (biopharmaceutical) companies in South Africa and, to some extent, Egypt.

A Deloitte Consulting study on 10 R&D multinational pharmaceutical firms investing in South Africa revealed that they collectively invested about R400 million (about $57 million) in R&D in 2006. Almost

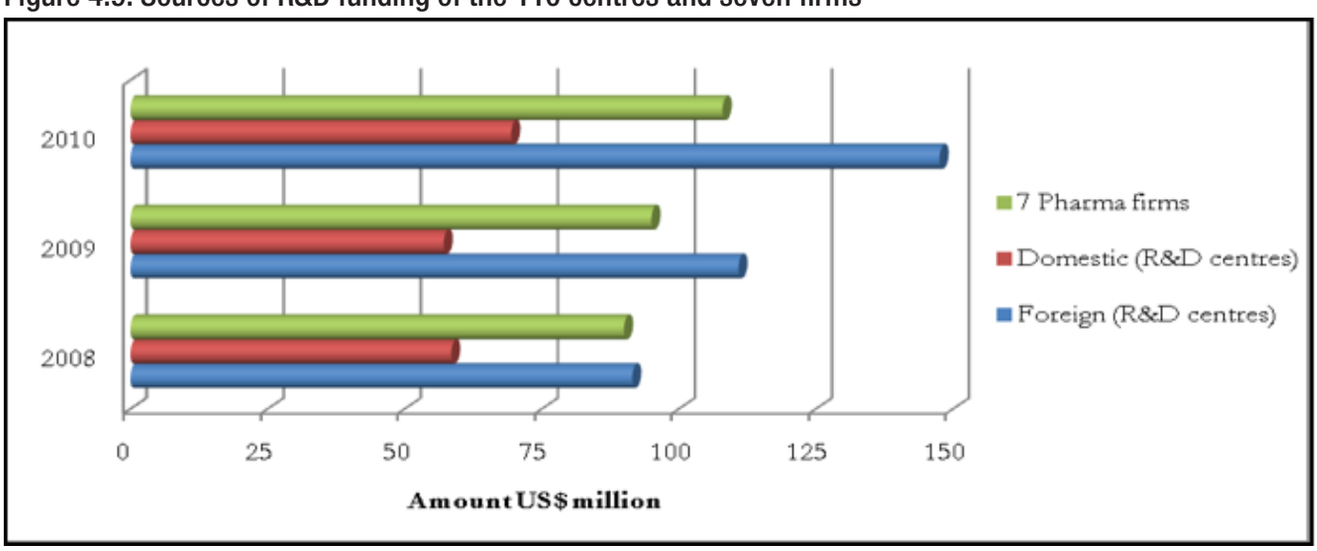
all of that was on clinical trials (Deloitte Consulting, 2007). The same companies spent about R5.3 billion on procurement of goods, services and skills, and R1.8 billion on infrastructure development in the same year. This suggests that although there is market-led international investment in Africa by some of the top multinational pharmaceutical firms, it is not directed at innovative R&D but rather at product evaluation and production, marketing and sales. These firms are not undertaking R&D activities to discover drugs and vaccines to counter Africa's unique health challenges .

There is growing realisation that African-led R&D will be needed to complement and compensate for international R&D to meet the specific health needs of Africa. A recent initiative partnered by ECA and WHO, the African Network for Drugs and Diagnostics Innovation (ANDI),[93] is attempting to stimulate such activity. A review of ANDI-initiated applications submitted by some of Africa's top health-related R&D centres revealed a steady but modest increase in annual funding of health innovations over the three year period considered (2008-2010). Of the 117 centres reviewed, seven were African-based pharmaceutical companies involved in R&D.

Figure 4.9 shows how significant private sector funding can be, with the seven firms accounting for about a third of the R&D investment among the 117 centres. The total R&D funding reported by the 117 centres increased significantly from $240 million in 2008 to $330 million in 2010, from about to over. This is a substantial increase, which is largely accounted for by increased foreign funding. As shown in Figure 4.9, domestic funding of R&D centres increased by about $10 million, while foreign funding increased by slightly over $60 million from 2008 to 2010. While the trend offers some hope that funding, including indigenous funding, for health R&D is increasing in Africa, the continuing high dependence on foreign sources of funding is worrying. Interestingly, as is common within the private sector in Africa, the R&D budgets of the seven innovative manufacturers were largely met by internal company resources.

Only 27 of the 264 agencies that funded the 117 centres were based in Africa. The National Research Foundations of South Africa was the only African institution that made the list of the 20 most frequently quoted health research donors in Africa, over the period covered here. European and North American agencies and countries are the main donors. Despite much international dialogue about South-South research partnerships, the emerging economies, namely China, India, Republic of Korea and Brazil, did not feature on the list of top donor countries.

Figure 4.9: Sources of R&D funding of the 110 centres and seven firms



Source: UNECA analysis based on 117 ANDI Applications for Centres of Excellence[94]

93 www.andi-africa.org
94 Ibid

4.3 Building an innovative and dynamic pharmaceutical industry in Africa

This section seeks to identify some of the opportunities and challenges that, if addressed, could help Africa to develop a dynamic and innovative pharmaceutical industry. It looks at the sector as an industry that has to compete globally, create wealth and jobs and contribute to the industrial development of the continent. The section therefore first provides a brief overview of the continent's pharmaceutical industry and identifies some of the major gaps. It then reports on ongoing efforts to address these gaps, identifies some emerging technological opportunities and highlights some of the challenges that need to be addressed to ensure a vibrant sector that contributes to national and regional development by meeting healthcare needs.

4.3.1 Basic components of an innovative pharmaceutical industry

The pharmaceutical sector is very complex. Figure 4.10 outlines the main functions that need to be undertaken to develop a new drug and, incorporates the average cost of the pre-clinical and clinical development phases to produce a new drug (di Masi and others, 2003). It is estimated that about $800 million dollars is required to bring one innovative drug to market in the United States and that this process takes between 10 and 15 years. Over half of the R&D costs of $800 million is spent on clinical trials alone (di Masi and others, 2003). Much of the high cost of development is obtained by pricing in the risk of failure, Only five in 5,000, or 0.1 per cent of the candidate drugs that begin pre-clinical testing ever make it to human testing. Only one of these five is ever approved for human use. Thus, investment pharmaceutical R&D carries very high risks of failure. Large pharmaceutical companies cover all these stages from early discovery to production and marketing. However, many other players, such as small and medium-sized enterprises specialize in production of the final product often developed by large firms or developed by universities, research centres and start-ups. Although the pharmaceutical process is described here as linear, the many players, projects and deals involving multiple individuals and partners make it complex. Research and development is not as orderly as it appears on this diagram. It is iterative, with lots of false starts and "failures", as biological concepts and the pharmaceutical properties of the candidate drugs and vaccines themselves often have to be revised. The process also often moves in fits and starts and may require side activities to develop capacity, methodological approaches and infrastructure to move activities forward in an iterative manner.

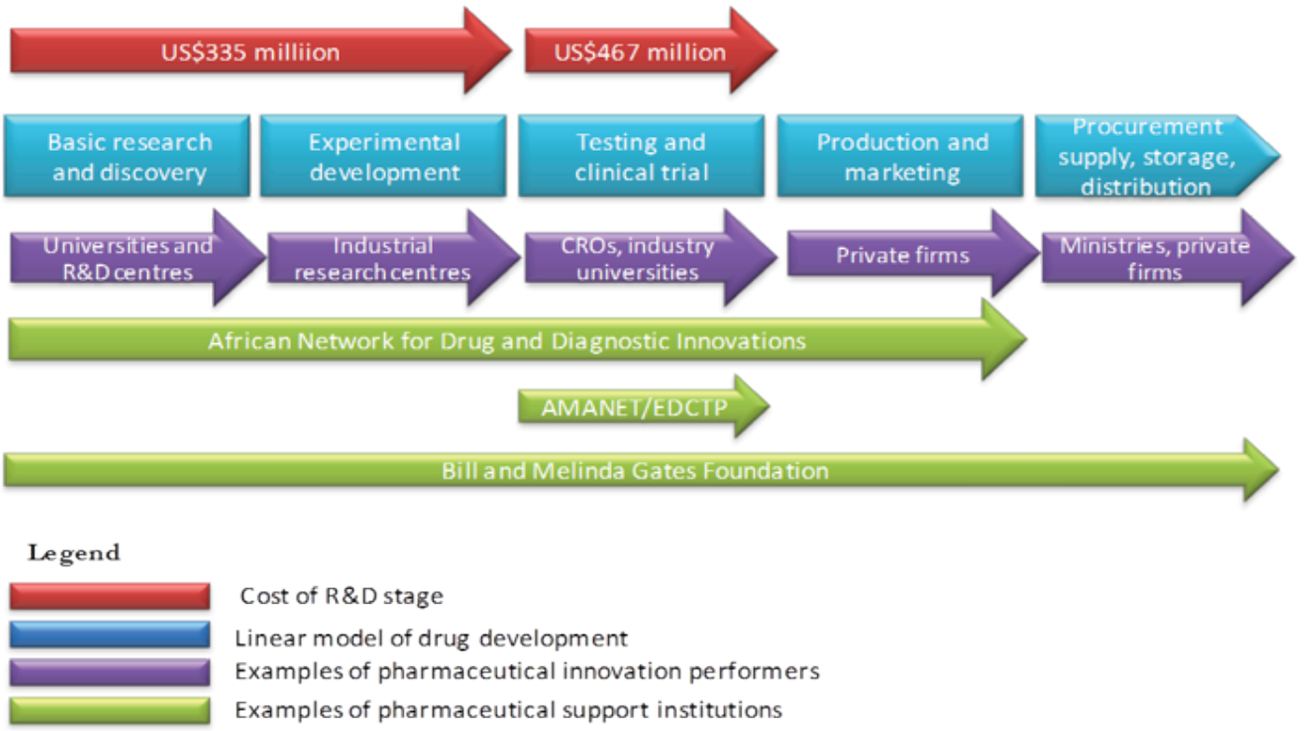
The linear diagram in Figure 4.10 also misses out a host of key players and industries that supply goods, services and skills in support of the process, for instance the packaging and labelling, marketing, training, financial, chemical and engineering industries. With globalization, some of these players may increasingly impact on the process from outside the country housing the parent pharmaceutical company. It is important to take a holistic view of the industry in order to map its innovation ecosystem effectively.

As with other industries, a host of legal, regulatory and administrative institutions are involved in creating a favourable business environment, some of which may include global commitments (e.g. the WTO Trade-Related Aspects of Intellectual Property (TRIPS) agreement). These factors impact on the investment, intellectual property, competition, licensing, registration, procurement and trading issues of the industry, among others.

Countries, both developed and developing, have put in place a host of regulatory requirements that have to be fulfilled in terms of efficacy, safety and stability of the products to be marketed.

In addition, there are several interest groups and organizations that may be involved in or support research in a disease of interest (e.g. cancer and HIV/AIDS) or in health in general. Some examples of such organizations working to promote innovation within the African pharmaceutical industry are shown in Figure 4.10.

Figure 4.10: The costs, supporters and performers in the development of pharmaceuticals



Source: Adapted from: di Masi, R. W and others (2003). The price of innovation: new estimates of drug development costs, Journal of Health Economics, 22, 151–185

4.3.2 Two major gaps in the pharmaceutical innovation value chain – experimental development and manufacturing

Taking the linear process of Figure 4.10 as a value chain of pharmaceutical innovation makes for rapidly assessing the strengths and weaknesses of the chain. As discussed below, the two major gaps in the pharmaceutical innovation value chain in Africa are in experimental development and production and manufacture. Capacity and expertise available in Africa are detailed below.

As discussed earlier, there is an emerging capacity for the first phase of the chain, namely basic research and discovery on the continent. The number of publications has grown steadily over the last 10 years, while and funding from within and outside the continent, is improving.

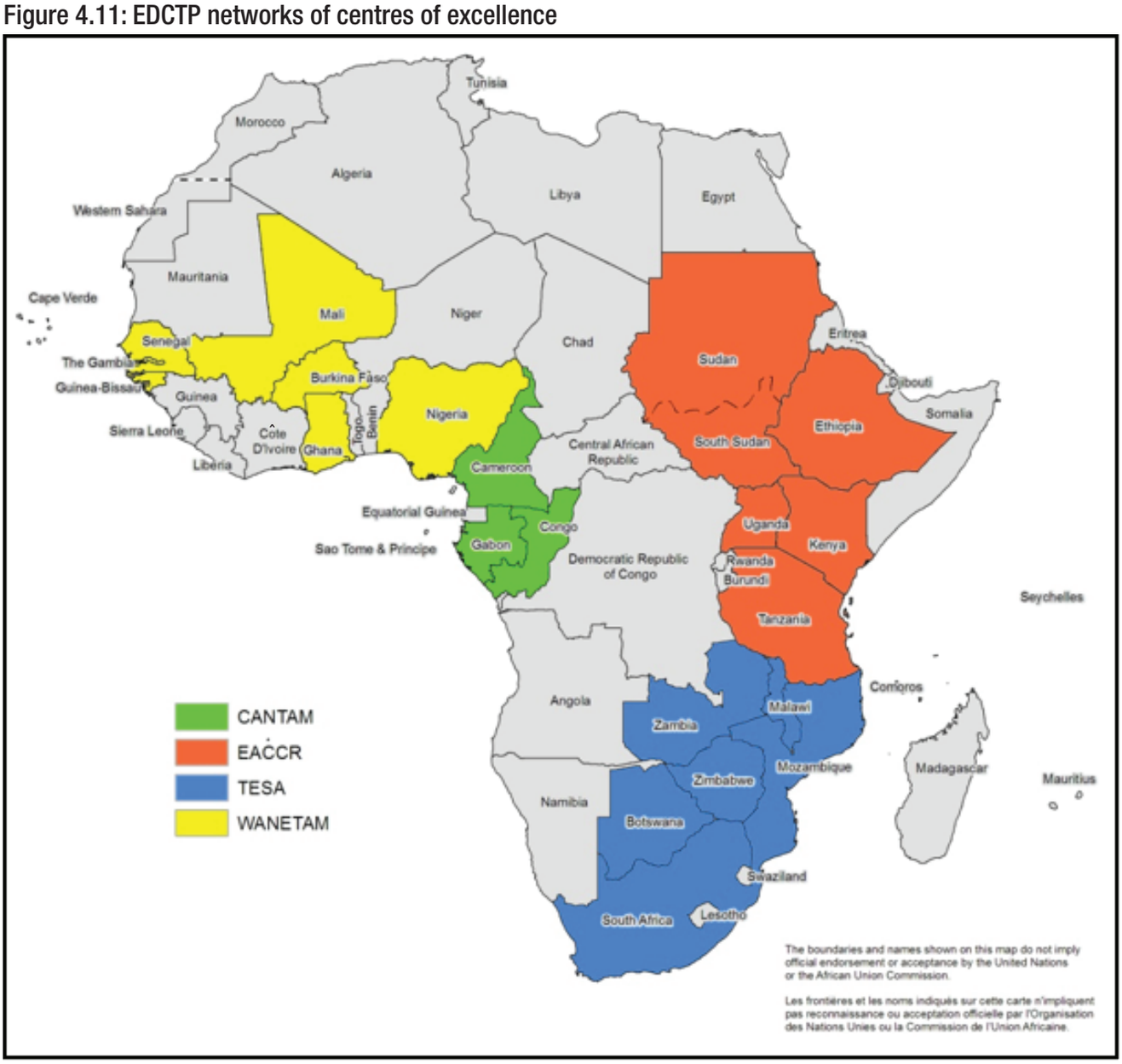
The second phase of the chain, experimental development, which seeks to fully test and evaluate compounds in cellular and animal models, to develop early production processes and to assess compounds for their pharmacokinetic and toxicology profiles, is however limited. This stage is often referred to as translational research as it is responsible for the translation of concept, or discovery, into a compound for testing in humans. It requires a unique set of competencies and infrastructure. The number of centres with this capability in Africa is currently extremely limited.

For the third phase of clinical testing, including clinical trials, there is significant capacity and expertise on the continent and this capacity is growing. Perhaps the largest single initiative to further develop this capacity over recent years has been the establishment of the European and Developing Countries Clinical Trials Partnership (EDCTP). With offices in The Hague and Cape Town, and focusing on clinical trials on HIV, tuberculosis and malaria to assist development of new products, EDCTP has invested substantial resources in a number of activities since its inception (EDCTP, 2011).

- It has linked 148 African institutions with over 80 external academic institutions and 23 private companies.
- It has supported over 50 clinical trials with an investment of over 270 million Euros.

EDCTP is also supporting four networks of centres of excellence in 21 African countries. These include The East African Consortium for Clinical Research (EACCR), the Trials of Excellence in Southern Africa (TESA), the Central African Network on Tuberculosis, HIV/AIDS and Malaria (CANTAM) and the West Africa Network of Excellence for Tuberculosis, HIV/AIDS and Malaria (WANETAM). The Networks seek to raise the quality of clinical research and practice and foster R&D cooperation (see Figure 4.11). As for much of research and innovation on the continent, there is a significant lack of capacity and activity in central Africa.

Figure 4.11: EDCTP networks of centres of excellence



Source: EDCTP Report 2011, Map by United Nations Economic Commission for Africa

Another initiative supporting clinical trial capacity development is the African Malaria Network Trust (AMANET[95]). AMANET was formed in 2002, following the realization that a number of vaccine candi-

95 www.amanet-trust.org

dates for malaria under development in developed countries were about to get to the clinical trial stage of development and were likely to be tested in Africa. As such AMANET was designed to strengthen the R&D capabilities of African medical research centres to undertake clinical trials for malaria vaccines. AMANET invests in human capital and infrastructure development of selected African centres. The network is composed of about 40 African and non-African partner centres.

There are a number of international initiatives with offices in Africa that also provide support for capacity development in clinical studies, again largely built around HIV/AIDS, TB and malaria. For example, the International AIDS Vaccine Initiative (IAVI) with country offices in Kenya, South Africa, Uganda provides support that strengthens Clinical Research Centres, laboratories and data management facilities.

The fourth phase of the chain, the critical one that generates significant income, namely production and manufacturing, is very weak in Africa. There are only a handful of African pharmaceutical firms that have the capacity to reproduce or design their own active pharmaceutical ingredient for drugs and vaccines. Almost all companies are limited to importing active pharmaceutical ingredients and then formulating them and/or packaging them for sale. The ability to chemically or bio-chemically manufacture the active pharmaceutical ingredient is a critical step that requires substantive investment if the continent is to fully develop its own pharmaceutical industry.

Much was made of the Doha Development Agenda of the WTO Declaration on Trade Related Aspects of Intellectual Property Rights and Public Health of 2001[96] which offered developing countries certain rights linked to pharmaceutical development and manufacture. Central to this agreement was a clarification of the scope of TRIPS, stating for example that TRIPS can and should be interpreted in light of the goal "to promote access to medicines for all." The rights granted to developing countries, and others, included the rights to determine what may constitute a national health emergency and the consequent right to determine the grounds for, and granting of, compulsory licenses for local manufacture. Significantly, the agreement also increased the period for least developed countries (LDCs) to comply fully with TRIPS from 2006 to 2016, thus providing a window in which they could further protect and develop their industry without fully exposing it to the globalized TRIPS agreement. However, at the same time, it was recognized that many LDCs lacked the manufacturing capacity to take advantage of these rights, in essence recognising the gap in pharmaceutical manufacturing in many countries. Paragraph 6 of the agreement specifically stated:

> "We recognize that WTO Members with insufficient or no manufacturing capacities in the pharmaceutical sector could face difficulties in making effective use of compulsory licensing under the TRIPS Agreement. We instruct the Council for TRIPS to find an expeditious solution to this problem and to report to the General Council before the end of 2002".

In summary, there are two major gaps that need to be addressed for the development of a vibrant African pharmaceutical industry addressing the complete pharmaceutical innovation value chain: (a) experimental development, sometimes referred to as translational research and (b) manufacturing, especially the ability to manufacture the active pharmaceutical ingredient as well as formulate and package medicines.

The current status quo of the pharmaceutical value chain in Africa allows for ideas and concepts to arise from developed country and developing country scientists, often working in partnership, in phase 1 of the chain. It further allows for human testing and clinical evaluation to occur in Africa in phase 3 of the chain, hence the major emphasis on clinical trial capacity on the continent. However, the intensive resource and infrastructure requirements of experimental development (phase 2) and manufacturing (phase 4) represent major impediments for African involvement in these phases. This limits African ingenuity and entrepreneurship from extensively addressing African priority needs in the health sector. As a result, African economies lose

96 http://www.who.int/medicines/areas/policy/tripshealth.pdf

out on the full economic development impact of pharmaceutical innovation and remain largely dependent on innovation generated outside the continent.

A natural home for the phase of experimental development, or translational research, is within the manufacturing industry itself. However, where nascent pharmaceutical companies are emerging in Africa their limited resources do not easily allow for R&D investment and they have very limited R&D capability. It therefore seems essential for the academic and public sectors step in to meet the translational research needs of the innovation chain and link with industry to complete the innovation chain. Interestingly, with the improvements in communications technology and a more open approach to innovation across the pharmaceutical industry, network-based approaches involving academia are increasingly being used by the international pharmaceutical industry. This might provide for a useful entry point to pharmaceutical innovation in Africa.

4.3.3 Potential models to address the experimental development and manufacturing gap

In most countries where pharmaceutical industries have emerged, there has been major strategic and legislative Government support to assist and maintain the industry. In some developing countries, the industry itself emerged from a strategic policy decision. The complexity of the pharmaceutical innovation process requires such national political and strategic support if it is to fully realize its potential and help meet the health needs of a nation's people.

Cuba is an example of a country that made a decision to undertake drugs and vaccine development as part of the mandate of its ministry of health. Cuba used this model to develop its health biotechnology sectors. In general, the Cuban strategy in medical and health-care biotechnology was specifically supported:

- As part of the national health-care system
- To address the country's health problems
- To focus on local research products generated largely by native scientists
- As a closed circle from research to commercialization
- To develop spin-off firms linked to research and production institutions
- As a national endeavour, with proper human and funding resources
- By national funds and not foreign investment

By making biotechnology part of the health-care system, biotechnology policies and support are discussed from a specific national area of interest rather than in general or solely academic terms.

Obviously, not all countries can follow Cuba's model, but it is notable how the Cuban approach departs widely from the approaches found in Africa, where R&D in pharmaceuticals is largely funded from outside and is rarely discussed from a national strategic position of meeting local needs. As such, the necessary strategic links between local firms, R&D centres and government in the pharmaceutical sector do not really exist. While there is nothing wrong with external funding, many good projects are often abandoned once the donor that supported the initiative leaves for reasons not related to the value of the project, nor the potential for the pharmaceutical industry, nor indeed the needs of Africa. A strategic linking of government, industry and research centres could stimulate activity and prevent the failure of potentially valuable projects.

Africa already has models of public sector-driven partnerships that can be more widely copied and expanded within the pharmaceutical sector. Countries such as Mali, Tanzania and Zambia have livestock vaccine production units in their agriculture ministries. Some of these vaccine production units are located on the facilities of national veterinary research centres. Their budgets and activities, including the number of doses and costs, are discussed as part of the broad agricultural sector and development strategy. Similar efforts could be made to integrate aspects of pharmaceutical development not addressed by the pri-

vate sector as part of a national healthcare system, with close links with universities and teaching hospitals. Indeed, properly supported, such an approach could lead to universities and teaching hospitals spinning off small innovative companies that can further the sector and promote national health.

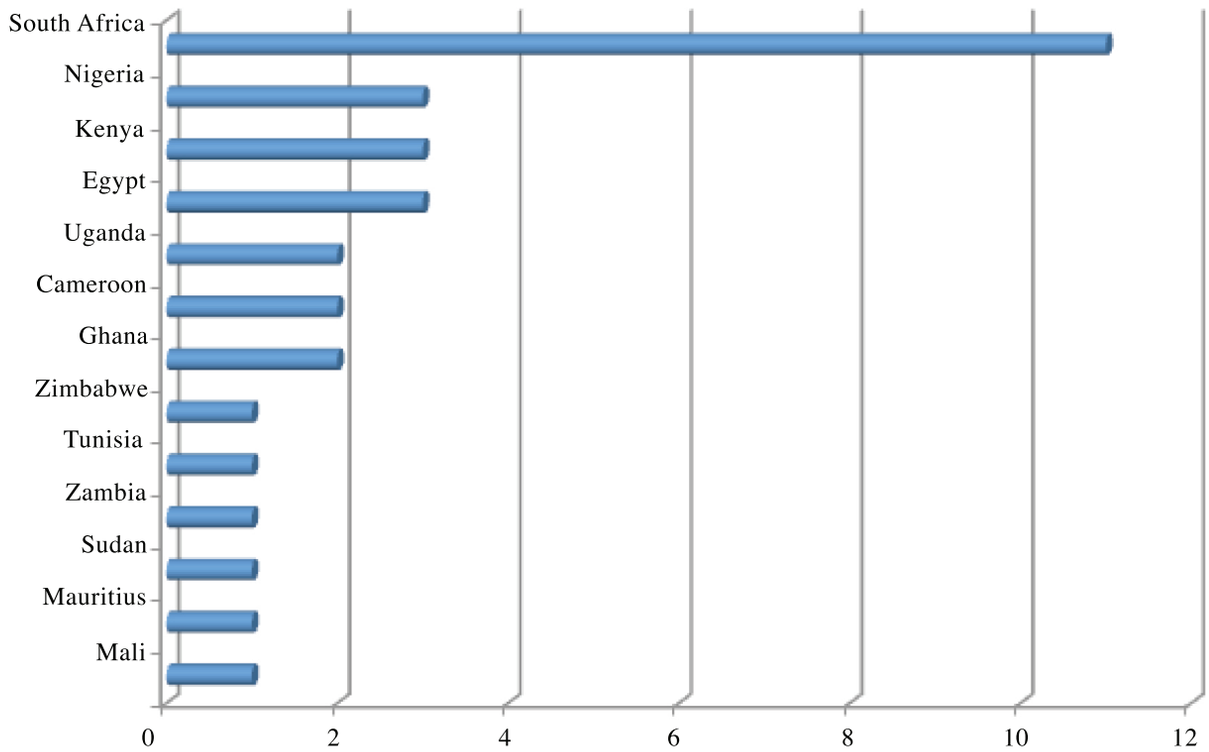
Another approach is to promote joint-ventures and strategic alliances in the pharmaceutical sector. There is increasing evidence that firms from developing countries are seeking partners in developing and developed countries. For example, South Africa's public-private partnership initiative supported the establishment of the Biovac Institute – a joint venture involving British, Cuban, Thai and local interests (jointly called the Biovac Consortium) and the Government of South Africa's former State Vaccine Institute. Similarly, the South African Government supported the acquisition of recombinant expression technology (strains of micro-organisms and cell lines) from the Swiss-based firm, Solidago AG, at a cost of $5.3 million. This facilitated the development of Ribotech Pty as a joint-venture between Bioclones and Solidago AG with Government support.

These arrangements are seen as crucial in enabling countries lagging behind in pharmaceutical technology to quickly gain access to knowledge and to learn and run a business without needing to "reinvent the wheel". The risks of developing, producing, distributing and marketing new products is drastically reduced in such joint-ventures because even the least developed country party may easily obtain ready access to its market, especially where the Government has a strategic stake in the firm. Key to these arrangements is the facilitating role Governments are playing in technology transfer and joint ventures. One key aspect that is often ignored as countries enter these joint venture negotiations for the first time is the need to set clear goals and indicate how much investment will be made at each stage of development in close partnership with the private sector. This is particularly important in a multidisciplinary, knowledge-dependent and highly regulated industry.

Both national and regional initiatives are feasible. For instance, the Organization of African Unity (OAU), now African Union (AU), launched the Pan African Rinderpest Campaign (PARC) in 1986 to completely eradicate rinderpest, a viral disease capable of wiping out up to 90 per cent of the cattle in a given area. With about $200 million investment from the EU and technical support from various institutions, PARC developed a vaccination campaign in 22 African countries, four regional emergency vaccine banks, two regional coordination centres and centres for vaccine quality control and disease diagnosis in a number of African countries. With 35 participating countries, PARC was successful, largely because of its communications unit, which helped sensitize farmers, veterinary experts, policy makers and donors. By 1999, the disease was confined to only a few locations in Africa.

Initiatives such as the African Network for Drug and Diagnostic Innovation (ANDI) (Nwaka and others, 2010) could play a similar role in the pharmaceutical sector. ANDI is creating a regional platform for pharmaceutical innovation through specialized centres of excellence selected on a defined set of qualitative and quantitative criteria, such as: availability of infrastructure and equipment; critical mass of researchers; track record of the technical staff; publication record in peer reviewed journals as well as patents registered and products discovered; access to modern communication tools and financial base of the institution. The geographic spread of such centres is provided in Figure 4.11. The centres of excellence include those that address the gaps highlighted in section 5.3.2 above. As the ANDI network develops additional centres in other countries, more centres and countries will be able to tap into a pool of continental expertise to develop their own projects and collaboratively develop products. This approach allows centres to focus on a few products and encourage specific specializations in the knowledge that other parts of the network can work with them to complement their expertise and needs.

Figure 4.11: ANDI Centres of Excellence



Source: ANDI open call for Centres of Excellence

4.4 Traditional medicine

The use of raw plant and animal extracts in the treatment and management of diseases and illnesses has a long history. A number of the modern drugs were originally used in their raw form by local communities before they were chemically synthesized and commercialized. For example, in the management of malaria, quinine was originally used as an extract of the bark of the Cinchona tree in Peru (South America) over 400 years ago, while artemisinin has its origins as an extract of the Artemesia annua plant in China over 2000 years ago. Today, their chemical structures continue to form a major component of drug discovery efforts in the fight against malaria. Similarly, the Madagascar periwinkle is the source of vincristine and vinblastine drugs used in the treatment of cancer.

For the purposes of this review, traditional medicine includes plant and animal extracts used to treat and manage illnesses, boost human and animal health (e.g. nutraceuticals) and improve general outlook and physical appearance (e.g. cosmetics, soaps and toothpastes). It does not address spiritual, divine and other cultural performances such as chanting, dancing, drumming and prayers. Research in these areas is outside the scope of this publication.

A large majority of Africans rely on, or have used, traditional medicine. The World Health Organization (WHO) estimates that about 80 per cent of Africans rely on indigenous knowledge and traditional medicine to some extent to meet their health needs (WHO, 2002). In some communities, traditional medicine may be the only choice, given Africa's limited healthcare facilities and personnel. Significantly, traditional healthcare practitioners are likely to live within the community in which they practice.

There are many challenges facing the use of traditional medicine. For the purposes of this review we only address value addition through bioprospecting and R&D on known remedies, the standardization of meth-

ods and treatments, the training of researchers in traditional medicine and the economic and social impact of traditional medicine based on case studies, global knowledge and surveys undertaken in Africa.

4.4.1 Innovation in traditional medicine

Research and development on traditional medicine in Africa is poorly developed, as is regulation of its use. This is in turn affected by the lack of a vibrant pharmaceutical sector and investment in pharmaceutical R&D. Most countries in Africa have nevertheless made efforts to establish centres to undertake research to verify claims of traditional healers and practitioners and to identify potential candidates and leads that can be used to develop commercially viable drugs and treatments that meet the health needs of their populations. A vast history of use of traditional medicine and indigenous knowledge remains to be documented and tapped in Africa. Similarly, Africa's biodiversity also remains largely untapped.

A number of research centres have focussed on screening and identifying the active ingredients of known traditional remedies. For example, the South African Medical Research Council established a traditional medicines research unit in 1997 with objectives to: undertake R&D on traditional medicines leading to patents and new drugs; attract young scientists; and develop the traditional medicine field in the Southern African region. Currently, these activities are undertaken through the Drug Discovery and Development Research Unit and Indigenous Knowledge Systems (IKS). The IKS has established databases for traditional medicine, pharmacopoeia monographs, medicinal plants and GIS mapping of traditional health practitioners.

Similarly, the Institute of Traditional Medicine at Muhimbili University in Tanzania was established in 1974 by an Act of Parliament and is currently composed of the Departments of Biological and Preclinical Studies, Natural Products Development and Formulation and Medical Botany, Plant Breeding and Agronomy. The overall objectives are to undertake research in traditional medicine in the country and to identify and develop potential drugs. Similar centres exist in other research institutions and universities across Africa.

At the regional level, there have been efforts to develop databases of traditional medicines. There are at least three regional databases for Southern, Eastern and Western Africa. These databases contain thousands of items of information on chemistry, plants, treatments, pharmacology and toxicology of traditional medicines used in Africa. For instance, the Pharmacopée et médecine traditionnelle africaines database has about 19,691 preparations and 4,000 records on medicinal plants[97] from across the continent, while the Plant Resources of Tropical Africa database contains information, references and photographs on about 8,681 species and 11,750 scientific names of African plants.[98] Other notable databases include the PRELUDE database of veterinary and human medicinal plants, the South African Traditional Medicine Database managed by the University of Cape Town[99] and Natural and Traditional Pesticidal Materials and Pest Control in sub-Saharan Africa.

Botswana and Madagascar also have their national databases. In 2010, the World Health Organization (WHO) announced the intention to develop a global database on traditional medicine. Such databases provide the preliminary information on the potential sources and uses of medicine plants to researchers, users and firms.

However, there are other areas of research that are not yet fully addressed by current efforts. They include systematic national and regional bioprospecting of Africa's rich biodiversity, development of specialized libraries (e.g. collection of semi-processed medicinal plant materials), standardization of methods for preparing, analysing and formulating traditional medicines and standards for certification, packaging and marketing

97 Available at the Universite Libre de Bruxelles (http://www.ulb.ac.be/sciences/bota/pharmel.htm)
98 http://www.prota.co.ke/en/
99 www.mrc.ac.za/Tramed3

traditional medicines. Efforts in Nigeria and Sudan provide some of the potential for standardizing the planting, sustainable harvesting and processing of medicinal plants.
These efforts will enable scientists, researchers and traditional medicine practitioners to exchange samples and materials. For instance, NEPAD brokered a deal between a Zambian traditional healer and the Council of Scientific and Industrial Research (CSIR) in South Africa to enable CSIR to undertake R&D on a concoction termed the "Sondashi formulation" for the management of HIV and AIDS. CSIR has validated the claim of the traditional healer, developed a pill and is now seeking to undertake clinical trials. If successful, this indigenous knowledge will join a battery of other modern treatments for managing and fighting HIV and AIDS around the world. Initially, the treatment was administered as a cup-sized crude liquid by the traditional healer.

Similarly, the National Institute for Pharmaceutical Research and Development in Nigeria developed a sickle cell anaemia treatment called NIPRISAN from four plants. NIPRISAN reduces the frequency of hospital visits and admissions, as well as and bone pains (Wambebe and others, 2001). Such achievements are made possible by the existence of centres of excellence interested in the potential of traditional remedies and utilizing Africa's biodiversity as a resource of pharmaceutical leads. Countries may wish to strengthen their R&D centres that undertake research on traditional medicines. Such an approach allows academic capacity to be built in the physical, biological, agricultural and health sciences while also promoting research capacity, community outreach and capacity for scientific and business innovation and development.

4.4.2 Protecting the intellectual wealth in traditional medicine

Unlike modern medicine, traditional medicine is very diverse and the practices are passed on from one family member to another or to apprentices. As such, the modern intellectual property system faces many challenges, as the claims made often do not have clear originators (often seen as community knowledge) and are rarely new (i.e. have been used before) while the components to be protected are unknown (e.g. one cannot patent a plant that naturally exists in nature). However, it is possible to protect such knowledge with patents if there is an innovation in the way the plant material is used and/or if the active elements are identified. It is also possible to utilize the names of medicinal trees as trade names or trademarks, and the areas where the plants originate as geographical indications. It is also possible to protect the methods and preparations of the medicine as trade secrets in the same wayas Coca Cola, for instance, protects its recipe.

Despite movements by the WIPO and WTO, many practical challenges remain for the fair use and equitable sharing of the proceeds and profits from indigenous knowledge. A level of awareness and education on the importance and value of knowledge is an important starting point to protect traditional knowledge on medicinal plants. This could include national authorities that oversee export and import of goods and services, along lines similar to that of the protection and conservation of endangered species. Beyond a general awareness, there is a need for more people to be specifically aware of the community rights enshrined in international conventions such as the Convention on Biological Diversity[100] and to be able to effectively negotiate deals based on these rights.

100 Convention on Biological Diversity: http://www.cbd.int/convention/

4.5 Technology changing the hunt for pharmaceuticals

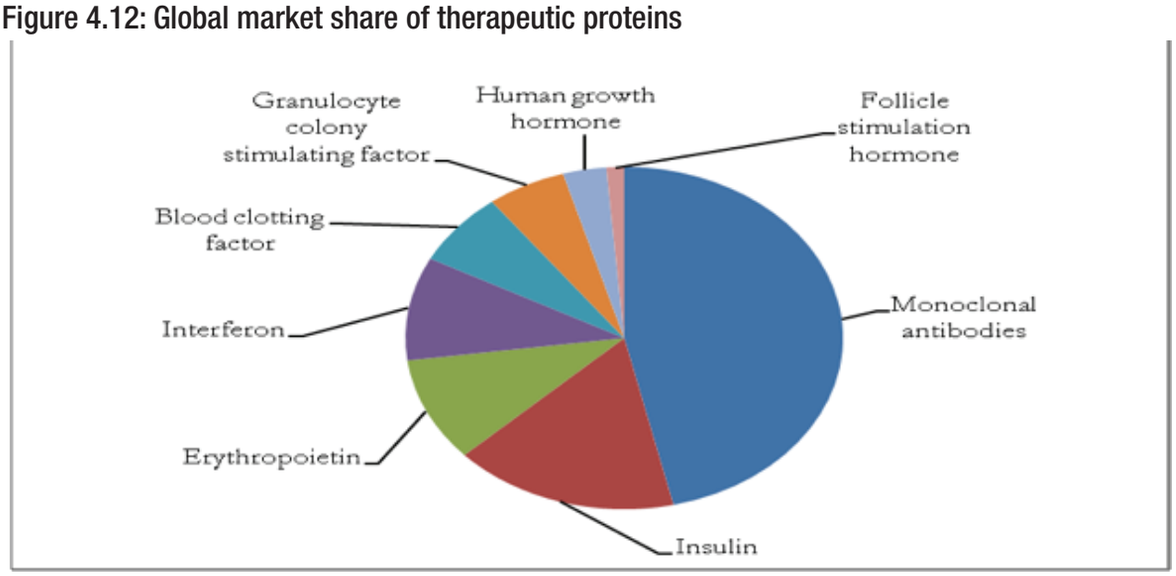
4.5.1 Biotechnology

Biotechnology, a set of revolutionary techniques originating in the 1970s and 1980s, has been the subject of public policy aspirations for the last four decades. The number of modern biotechnology-based drugs and vaccines currently in the market increased from about 23 in 1990 to over 200 by 2011. There are about 400 biotechnology-derived drug and vaccine candidates in clinical trials targeting over 200 diseases. As a result, the global market for biopharmaceuticals – pharmaceutical products that are based primarily on biotechnology – is estimated to have reached $92 billion in 2010 and is expected to reach $160 billion in 2015 (IMARC, 2011). The top markets (the United States, Germany, Japan, France, Italy, Spain, the United Kingdom and Canada) are likely to account for 79 per cent of the total global biopharmaceutical sales by 2015, from its current level of 83 per cent while that of the emerging markets (Brazil, Russia, India, China, Mexico, Turkey and South Korea) may increase from less than 5 per cent in 2009 to more than 8 per cent by 2015. The majority of products in the clinical trials pipeline of pharmaceutical firms in the United States are for cancer (44 per cent), followed by neurology (10 per cent) and infectious diseases (9 per cent) (Ernst and Young, 2011).

In terms of subsectors of the biopharmaceutical market, recombinant proteins account for more than 65 per cent of the market. These include both recombinant vaccines and therapeutic proteins. Low market growth is expected in this area as a result of the introduction of "biosimilar" products and other measures resulting in substantive cost containment. Monoclonal antibodies form a significant component of the biopharmaceuticals market. Estimates suggest significant growth in this area such that by 2015, the global market for antibodies is likely to reach $79 billion, or about 47 per cent of the global biopharmaceutical market.

A description of the therapeutic protein market is outlined in Figure 4.12, itemizing key therapeutic recombinant proteins and monoclonal antibodies. This diagram does not include recombinant proteins manufactured as vaccines.

Figure 4.12: Global market share of therapeutic proteins



Source: RNCOS (2011) Global Protein Therapeutics Market Analysis, Reportlinker.com

Genome projects, including the human genome project, resulted in a multitude of data, methods and technologies of great interest to the pharmaceutical industry. While by 2000, only a handful of developing countries (notably Brazil and China) had invested in genome sequencing projects, the rapid fall in the costs of

the technology for decoding genomes is now making it possible even for developing country institutions to participate in biotechnology. For example, the cost of sequencing a human genome fell from about $1 billion in 2000 to between $5000 and 10,000 in 2011. At this price, the limit is no longer the cost of or ability to sequence genomes (this can be outsourced to dedicated companies) but rather to analyse and identify leads and develop them into products and processes.

Besides South Africa and Egypt, Africa does not have a vibrant biopharmaceutical or biotechnology industry. The debate on genetically modified organisms (GMOs) in agriculture has prevented policy makers from making efforts to build the necessary technical infrastructure, skills and scientific capacity needed to develop a biotechnology industry. In some countries, there is also a reluctance to engage in trials that can document certain genetic characteristics in populations linked to health outcomes, despite the success of this approach in cancer research for instance. It is imperative to improve communication between technical experts and policy makers in this area.
Unlike many other fields of pharmaceutics, biotechnology was led by universities and health-research centres that generated the knowledge, owned patents on the technologies and incubated firms and products that have grown into large companies or have been sold on to large pharmaceutical and chemical companies. In short, academia created the knowledge base and its application for a whole new industry related to biotechnology. It is a classic case of how basic research can lead to industrial innovation.

It is not too late for the continent of Africa to catch up by learning from others through partnerships and joint-ventures. There is a growing interest by biotechnology firms in developing countries looking for partners in other developing countries, facilitated by the rapid economic growth of some developing countries (e.g. Argentina, Brazil, China, Egypt, India and South Africa) and their shared health challenges with less developed countries (e.g. malaria, HIV/AIDS and tuberculosis). In the pharmaceutical industry, Cuban, Indian and Chinese pharmaceutical firms are becoming leaders in this regard.

For example, Cuban biopharmaceutical firms have signed numerous partnership arrangements with a host of Brazilian, Chinese and South African firms. In general, they offer their technological innovations and their partners provide further funding and the necessary infrastructure. Similar arrangements have also been observed with other developing country firms (see Box 4.1).

Box 4.1: The example of South-South cooperation in technology transfer

The Chinese company Dongbao (Shanghai) transferred technology for the production of recombinant insulin to the Holding Company for Biological Products and Vaccines (VACSERA) in Giza, Egypt. This product was previously imported and often in short supply. Since then, Egypt has developed a facility that can produce recombinant insulin locally, and diabetics in the country have a reliable and readily accessible supply of insulin that is cheaper than the imported product.
Similarly, East Coast Rapid Diagnostics (now split into Tulip South Africa and Life Assay, both of Durban, South Africa) is a joint venture between the publicly funded LIFElabs in South Africa (Durban) and the Indian Tulip Group Diagnostics (Bambolim, India). Under the agreement, the Indian company transfers several diagnostic technologies to South Africa, including rapid malaria and pregnancy diagnostic kits that are stable at high temperature.

Source: Thorsteinsdóttir H. and others (2010). South-South Entrepreneurial Collaboration in Health Biotech. Nature Biotechnology. 28, 407–416

4.5.2 Nanotechnology application in pharmaceutical development in Africa

Nanotechnology is a multidisciplinary field covering the design, manipulation, characterization, production and application of structures, devices and systems at nanometer scale (1-500 nm size range). At this

size range, it is possible to create structures with fundamentally new properties and functions of essentially all natural and man-made things (Bawa and others, 2005). As such, nanotechnology will have a significant impact on almost all industries and all areas of society through the development of longer lasting, cleaner, safer, and smarter products.[101] One of the areas where nanotechnology is already making significant impact is in the pharmaceutical sector, where it is being used for example: (a) to address the targeted delivery of medicines to specific tissues; (b) to help make drugs more bio-available in the body, either intravenously or orally so that they can be more efficacious; (c) to reduce toxic side effects.[102]

Nanomedicine may be viewed as the application of nanotechnology in the medical sciences. Nanoparticles may act as "nanocarriers", taking molecules to the appropriate place in the body, where they can act to treat and prevent disease at the atomic, molecular and macromolecular levels (McNeil, 2005,Malam and others, 2009) For example, antibody-coated nanoparticles can identify proteins in cells associated with specific disease states. If the nanoparticle also contains a fluorescent tag or other visualisation tool, the diseased cells can be identified, either for treatment or surgical removal. Diseases such as cancer, diabetes, Parkinson's disease and Alzheimer's disease are all likely to benefit from this technology through a more personalized approach to medical diagnosis and treatment.

According to a market forecast by BCC Research published in January 2010 (http://www.bccresearch.com/report/nanotechnology-medical-applications-hlc069a.html), the global nanomedicine market was valued at $53 billion in 2009, and is forecasted to increase at a compound annual growth rate of 13.5 per cent to reach more than $100 billion in 2014. Nanomedical products for cancer were found to be one of the largest market segments, worth nearly $20 billion in 2009. This sector is expected to increase at a compound annual growth rate of 11 per cent to reach $33 billion in 2014. Another major market sector is nanomedicine for Central Nervous System (CNS), including brain-related indications, valued at nearly $11 billion in 2009 and expected to reach $18 billion by 2014, an 11.1 per cent compound annual growth rate (CAGR).

South Africa could provide a hub around which nanotechnology on the African continent can develop. The field of nanotechnology is relatively new in Africa and is not well exploited in terms of its application to the improvement of poverty related disease (PRD) therapies. The most significant progress in this area has been made by research groups in South Africa, where there are adequate resources to provide the expensive infrastructure that nanotechnology requires. The Government of South Africa has taken nanotechnology very seriously, providing substantive support. In the rest of sub-Saharan Africa, nanotechnology activities are minimal.

South Africa's investment has been policy driven. The Department of Science and Technology in South Africa launched a national nanotechnology strategy in 2007 to support the long-term growth of nanoscience and nanotechnology research to address critical national problems such as water, energy, health, chemical and bio-processing, mining and minerals and advanced materials and manufacturing. As a result, the country established two nanotechnology innovation centres at the Council for Scientific and Industrial Research (CSIR) and at Mintek, as well as a number of flagship projects.

Some successes have already been registered. For example, the CSIR Nanotechnology Innovation Centre has developed nanotechnology-based fire-resistant, better flowing paints and coatings. Similarly, the University of Kwa Zulu Natal's Quantum Research Group has developed a quantum encrypted communication security system. In the area of health, Mintek NIC is in the process of finalizing an external validation for point-of-care diagnostic devices for tuberculosis and malaria and teams at CSIR and the University of Witwatersrand are investigating sustained release nano-drug delivery systems that will enable anti-tuberculosis

101 http://www.crnano.org/whatis.htm, (Accessed in July 2012)
102 Roadmaps in Nanomedicine. Towards 2020; Joint European Commission / ETP Nanomedicine Expert Group Report 2009

drugs to be administered at lower doses (Choonara and others, 2011; Swai and others, 2008). There are other groups in South Africa making similar advances.

In the rest of Africa, there is little advancement in nanomedicine research for the treatment of diseases, besides a few groups at the University of Mauritius and the American University in Cairo, where the focus is on infectious diseases such as tuberculosis and schistosomiasis. However, several other African universities are starting to engage in pharmaceutical nanotechnology.

In order to advance nanotechology applications in medicine, the CSIR nanomedicine platform organized the first international sensitization workshop on nanomedicine for infectious diseases of poverty in South Africa in March 2011. The team has also visited 18 institutions in Kenya, Nigeria and Ethiopia to promote nanomedicine applications and is seeking to organize the first pan-African summer school in nanomedicine, in collaboration with leading nanomedicine experts from Europe and the United States, as well as African health experts. The School aims to bridge the gap between the sciences, health and development in Africa, by educating young African scientists on the potential of applying nanomedicine in drug development research. In conclusion, the field of nanotechnology has great potential in Africa and needs to be developed, including for nanomedicine. To date, research in nanomedicine in Africa has focused on disease areas of importance to Africa and relatively neglected outside of Africa. If Africa is to truly benefit from this and other pharmaceutical technologies, it will have to provide a framework to encourage local regional and national investment in the field.

4.5.3 ICT applications in the pharmaceutical industry

Recent development in ICT has provided many industries with various opportunities to improve their operational efficiency, increase competitiveness and growth. In the pharmaceutical sector, successful integration of ICT in drug discovery, design and development; testing, manufacturing, certification, quality control, marketing, sales distribution as well as the over-all management of the supply chain of the healthcare system is likely to reduce industry operations costs and enhance efficiency and effectiveness. The follow up of this section provides an overview of some areas of the pharmaceutical industry where ICT has a significant impact.

4.5.3.1 Bioinformatics in drug discovery and design

Bioinformatics - the use of computers programmes, mathematics and simulation modelling to capture, analyse, arrange and visualize biological information – has become a major tool in the study of life. Developed in the 1990s, bioinformatics has reshaped the use of computer-related programmes to analyse the huge amount of data that various genome sequencing projects have generated. It made for rapid and accurate identification of potential drugs and vaccines by comparing unknown genetic sequences to that of known proteins.

Bioinformatics is now an established tool that is indispensable in the practice and theory of drug design and development. Traditionally, potential drugs were either generated in the laboratory or obtained from natural products and then randomly screened to identify the active compound (Baldi, A., 2010). This was followed by the further synthesis and modification the compound to improve its efficacy. Bioinformatics has helped rationalize this approach. New drug development can start with the identification of a potential drug target (e.g. key enzymes in the replication of HIV) and then proceed through the rational design of a potential drug (i.e. a chemical that can interact with and inhibit the identified target) (Davidov, E. and others, 2003).

It is standard practice for innovative pharmaceutical companies to develop a portfolio of potential products at different stages of the drug development/innovation value-chain. ICT has made it possible to establish improved management and tracking of the various products along the value chain, including when research, development and production is undertaken by partners. ICT is also increasing efficiency and ease in collabo-

rative R&D between large pharmaceutical firms and clusters of smaller (pharmaceutical) firms and R&D centres.

The National Center for Biotechnology Information in the United States provides public domain DNA sequence information. Its Genbank databank contains about 126,551,501,141 bases in 135,440,924 sequence records from similar databanks of Europe, Japan and the United States.[103] This open source database is a major resource where interested scientists and institutions deposit gene sequences and access genetic sequences deposited by others. Perhaps one of the major recent developments in this field was the 2010 unveiling, by the Craig Venter Institute, of the first artificial living organism that was designed on a computer, chemically synthesized and then used to kick-start new life.[104]

4.5.3.2 ICTs and clinical trials

ICTs are envisaged to play a significant role in patient recruitment for clinical trials and reduction in administrative challenges associated with managing large numbers of clinical trial participants and investigators (Houghton, 2002). It is now easier to recruit, monitor and manage patients online, enhancing trial speed and accuracy.

The development of advanced computer models that could be used to simulate the effect of a drug on the human body presents many challenges and opportunities. The ability to predict the unintended effects (or side-effects) of a drug on various systems of different human beings could save money and reduce the failure rate of drugs at the clinical trial stage (Guy and Gartenmann, 2000). Computer models have been shown to accurately predict the side effects of drugs (Lounkine and others, 2012). For example, the computer model correctly predicted that synthetic oestrogen could cause abdominal pain through the inhibition of the enzyme cyclooxygenase-1. Such level of accuracy achieved by computer models will reduce the risk to human clinical trial subjects (Houghton, 2002).

4.5.3.3 Marketing and distribution

The traditional mode of pharmaceutical marketing heavily relied on sharing information with the doctor through their sales personnel. Getting the doctor to prescribe the drug correctly ensures both sales and protection of the brand. The advent of the internet has seen pharmaceutical firms shift to online provision of information.

Online marketing of pharmaceutical products is now common, although there are limitations due to safety concerns, brand protection and regulatory requirements (Contextweb, 2011). Nevertheless, patients are now able to independently access information on drug use and side effects and question doctors about suitable treatments. Further development of online information for consumers is anticipated.

4.5.3.4 Tracking abuse of drugs and counterfeit drugs

Two of the major challenges in healthcare are the abuse of prescription drugs and the sale of fake or counterfeit drugs. Abuse of prescription drugs may cause injury and death, while failure to adhere to prescribed dosage for anti-infective drugs may result in the emergence of drug resistant organisms. To meet these challenges, there are a number of mobile applications that remind individuals to take their drugs in the right dosage at the right time. Donors, NGOs and Government agents have all sought to develop these mobile applications.[105]

103 http://www.ncbi.nlm.nih.gov/
104 This was an artificial life breakthrough announced by scientists, BBC, 20 May 2010 (www.bbc.co.uk)
105 http://www.int.iol.co.za

A pill micro-sensor was developed recently.[106] Once ingested, the sensors of the tablet will send signals to a specially designed patch worn by the patient. The patch will collect the information on physical activity of the individual that is then sent as an SMS either to the patient or a medical practitioner. This technology does not only encourage compliance but also provides rich information about the patient. The technology is likely to find wider use in research and healthcare.

To tackle counterfeit and fake drugs, companies like Sproxil[107] have developed technologies that could be used by consumers to verify the authenticity of a drug. The technology takes advantage of the widespread use of mobile phones. A code attached to the drug is sent for authentication through an SMS and the consumer then receives a return SMS indicating whether the drug is genuine or not.

4.5.3.5 Enterprise-wide solutions for business process enhancement

ICTs are integrated in all aspects of the pharmaceutical value chain (from laboratories to pharmacies), leading to improved efficiency, accuracy, decision-making and achievement of strategic competitive advantage. The increased complexity of corporate management requires the pharmaceutical industry to invest more in enterprise-wide solutions to improve the business performance and achieve strategic competitive advantage. One of the examples is the use of the Enterprise Resource Planning (Bosilj-Vuksic and Spremic, 2005) : a platform that integrates all departments, applications and functions across the firm. It can also integrate some software solutions aimed at enhancing cluster functions of the value chain such as the management of the supply chain and customer relationship. Other commonly used platforms include laboratory information management systems, sales force automation and rapid prototyping and manufacturing that help reduce the time and cost of the product design phase (Schell, 2009).[108]

4.5.4 Geospatial science and technology applications

Geospatial science and technology has also been contributing to knowledge generation and research in the pharmaceutical industry. The pharmaceutical industry is trying to leverage technology-driven productivity into all its operations across the value chain and regulatory processes.

One of the applications of GIS is the health sector. Important entities in health databases are patients, doctors, infrastructural facilities, and health services (hospital, dispensaries, blood banks, pharmaceutical outlets, etc.). All these entities have spatial dimensions. Understanding these dimensions and interactions is the key to health planning and management, providing the means for analyzing epidemiological attributes and revealing spatial trends, dependencies and inter-relationships.

In the context of health spatial database, GIS offers powerful techniques to present information to the level of individual occurrences and conduct predictive modelling. It determines the geographical distribution and variation of diseases and their prevalence and incidence. This intelligent system can keep track of the geographical locations of service providers, customers, resources and health plans and programmes as health objects.

It allows policy makers to easily visualize problems in relation to resources and effectively target resources to communities in need of them. Spatial dimensions of health data give detailed answers to major questions asked by health service providers and pharmaceutical companies.

106 Smart Pill Contains Microchip to Monitor Patients' Medication (see: http://medgadget.com/2012/01/smart-pill-contains-microchip-to-monitor-patients-medication.html)
107 Visit http://sproxil.com
108 See Schell, D. (2009)

As new drugs become available, pharmaceutical companies have to compete on the open market by promoting their products to users. The management of marketing and sales within any pharmaceutical company also requires detailed understanding of the distribution of healthcare services in relation to the company sales territories. Pharmaceutical companies use GIS to target physicians that are most likely to use their products, to achieve more balanced sales territories and the most efficient routes for distribution.

GIS can be integrated into sales and marketing databases to provide users with up to date information on health service locations (such as doctors, surgeries, chemists, hospitals), product orders and demographic details for the company to better understand the potential take-up for a product within a given area, thereby assisting in developing realistic sales targets.

Mobile sales staff can also benefit from access to geographically referenced corporate databases as well as mapping and routing services to assist in the optimization of their sales visits. Route network analysis can be used for delivery management system for the distribution of pharmaceutical products to use the shortest possible route to help meet delivery requirements and timelines.

For example, pharmaceutical products may demand a stable temperature range at all times during delivery, requiring processes that go beyond route management. GPS and sensor technology in the vehicles can enable the office to synchronize with what the driver experiences in near real time. To compute a route, the navigation tool in the vehicle connects wirelessly to the server in the office. Weather, traffic and other factors affecting the route are accessed online and included in the route computation. For instance, FedEx uses GIS to meet its delivery deadlines. In the case of delivery of pharmaceuticals that require strict temperature controls FedEx uses ArcGIS Server to solve route problems and to have the same information that the driver has in the vehicle dashboard via ArcLogistics Navigator[109].

Pharmaceutical companies also use remote sensing techniques, to improve the quality of their products. For instance, spectral camera can be used to determine the chemical composition and spatial distribution of the sample of a pharmaceutical product[110].

Traditional/Herbal Medicine can also benefit from the use of geospatial technology. Cultivation of medicinal plants requires suitable land. Geographically, the distribution of land that can be used for cultivation of medicinal plants are very broad and can be analyzed. The identification of a suitable area for medicinal plant cultivation uses key criteria for assessing land suitability, based on the habitat of the medicinal plant, so as to obtain a suitable location for distribution. To assess land suitability, data and analysis tools are needed. For instance, the suitable area can be generated from GIS analysis tools and methods, using relevant data such as land use and land cover maps, rainfall data, soil maps, elevation and remote sensing imagery. By using GIS analysis tools and the land suitability criteria, the location and distribution of land suitability can be found. The result of the analysis can be in a form of a land suitability map, which can show the areas as highly suitable, suitable, less suitable or non-suitable according to the criteria.

Another application is for emergency response. For instance, international relief organizations also use GIS technology to help collect and distribute medical supplies and pharmaceuticals to countries, in emergency response and aid distribution efforts. For instance, when the catastrophic Haiti earthquake of early 2010 devastated the country, it indiscriminately demolished Government buildings, homes, health care centres and schools. An estimated 230,000 people died, some 194,000 were injured, and 1.3 million were displaced. In the chaotic aftermath, survivors were in need of medical supplies and drinking water. Direct Relief International (DRI), a non-profit, humanitarian medical-material aid organization was able to respond right away. DRI distributes medical supplies and pharmaceuticals to about 72 countries including the United

109 http://www.esri.com/industries/retail/pdfs/fedex_flr.pdf
110 http://www.vision.uji.es/~essys/where.html

States. In the six months following the Haiti earthquake, DRI provided more than 400 tons of emergency medical assistance worth more than $57 million to 53 Haitian health care facilities, international medical teams, mobile medical clinics, tent-based hospitals, and medical units at camps for displaced people across the country. Workers for DRI were able to share and communicate the details of their activities through an interactive map application based on Esri technology[111].

4.6 Opportunities and challenges for the pharmaceutical industry in Africa

it is important to reemphasize that the pharmaceutical industry should not only be viewed as tool for improving access to medicines, but also as a key industry that offers employment to thousands of people, contributes to national exports and revenue, as well as to general economic and social development. As shown in Table 4.4, a UNIDO study confirmed that the industry was important in several countries in Africa in terms of market size and employment. The differences largely reflect national policy priorities in both industry and in research and academia, linked to the domestic capacity to innovate.

Table 4.4: The pharmaceutical sector in Africa: Case of four countries

	Kenya	Nigeria	Zimbabwe	Egypt
Market size (US$ 000,000)	240	600-2,000	142	2,500
Local production (% of demand)	28%	25%	47%	81%
Imports (% of market)	72%	75%	53%	19%
Annual growth rate		10-15%		11%
Number of firms	1,534	42	9	58
Manufacturers of API	No	No	Yes	Yes
Firms with WHO cGMP	No	No	Yes	Yes
Installed capacity utilization (%)	50-70%	40%	20-50%	
Employment	3,389	500,000	600 – 1000	36,000
Central procurement agency		Yes	Yes	

Source: UNIDO Pharmaceutical Sector Profiles of Kenya, Nigeria and Zimbabwe, and various reports on Egypt, and additional data from Geoff Banda, Open University, United Kingdom

A number of opportunities exist for pharmaceutical development on the continent.

1. **An expanding market**. The market for pharmaceutical products (drugs, vaccines, diagnostics reagents, cosmetics and nutraceutical products) is expanding very rapidly although complete data is not available to prove this. The number of people that can afford to pay for pharmaceutical products is likely to keep increasing with the growth of the middle class, increased health budgets and increased access to health insurance schemes among others. As shown in Table 4.4, countries such as Nigeria and Egypt have pharmaceutical markets in excess of $2 billion and are starting to attract the interest of pharmaceutical companies globally. As Egypt has demonstrated, it is possible for domestic production to be stimulated and meet almost 80 per cent of the local market. Currently, local production is thought to meet less than 30 per cent of the market across Africa.
2. **Pre-existence of production experience**. As already noted, most countries have some form of pharmaceutical production capacity although almost all depend on imported active pharmaceutical ingredients. This provides the domestic experience upon which expansion of production can be based. Domestic procurement policies could be designed to encourage domestic firms to upgrade their technologies. For instance, it is in the interest of Governments to ensure that their firms are helped to meet the basic international standards of pharmaceutical manufacture. In a globalized economy, the competitiveness of

111 http://www.esri.com/library/newsletters/healthygis/healthygis-spring2011.pdf

domestic firms is key to ensuring that the private sector contributes to employment creation, skills accumulation, taxation and technological learning. The pharmaceutical industry is one such industry where all these could be met.

3. **Commercialization of research outputs and traditional medicine.** Africa has significant research capacity that is being applied to some of the key health challenges of the continent, such as malaria, HIV/AIDS and tuberculosis. However, much of this credible research has no clear strategic sense of direction, no clear alignment with national goals and, significantly, no alignment with commercialization vehicles. The ministries of health, science and technology and industry may have to develop special vehicles for accelerating the commercialization of R&D outputs. In this regard, traditional medicine could provide an area of competitive advantage for new innovations on the continent. Finally, a number of countries have good pharmaceutical research centres or units, clinical trial centres and industries operating below capacity that could be mobilized and expanded through networks to create virtual centres for pharmaceutical technology development and commercialization. The existence of ANDI, with a strong intergovernmental governance structure, provides a potential vehicle for such a development.
4. **Regional and international partnerships**. Intra-Africa trade is potentially more important in pharmaceuticals than in other sectors, such as agriculture and mining, and thus regional and international partnerships may emerge organically. Regional platforms for pharmaceutical innovation (i.e. beyond regulation) are either just emerging (e.g. ANDI) or do not exist, despite regional similarities in disease burdens. It is amazing that Africa does not have a credible regional centre for HIV/AIDS drug and vaccine development, given the huge burden and toll that it has taken on the continent. Africa is tagging on to the initiatives of others, instead of leading the pharmaceutical development agenda of the continent. In a technology- rich world, Africa could form virtual centres of excellence around specific diseases, technologies or products as long as the goals were very clear. If appropriately supported, the sector could provide a major vehicle for African integration, a key policy of the African Union and African Development Bank.

   A good example of networked activity leading to innovation is Brazil's establishment of the Organization for Nucleotide Sequencing and Analysis (ONSA) in 1997. This was established as a virtual institution comprising 34 laboratories located in geographically distant places and belonging to different organizations, to sequence the Xylella fastidiosa genome, an organism that infects oranges, a major Brazilian export. ONSA managed to complete the sequence of the genome two months ahead of time and $2 million within their budget. Rather than appoint agents to do the sequencing, ONSA requested interested laboratories to apply to join the project and laboratories were paid based of the quality of sequences they deposited. The initial success of the project attracted some Brazilian nationals based abroad to return home. At least three firms were developed out of ONSA, while the project trained 200 young geneticists and the private sector began to seriously consider investing in genomics. There is no reason why Africa cannot use the same model to build a virtual pharmaceutical institute with clearly defined goals and an organizational structure. Such an effort could anchor intra-African, South-South and North-South partnerships.

A number of critical challenges exist:

1. **Unfriendly business environment for local production**. The general business environment has improved tremendously since the 1990s. The ease of starting a business, trading across borders, dealing with licensing and taxation requirements and access to credit, among others, have all made steady improvement (See Doing business annual surveys of World Bank[112]). However, as the case of Zimbabwe reveals in Table 4.5, the license fees for pharmaceuticals often remain high, given Africa's level of economic development, income and size of firms and there is a need to streamline the bureaucratic provision of licenses. In some cases, countries may overtax locally produced products compared to foreign sourced products.

112 www.doingbusiness.org

The single most important requirement however is probably that Governments recognize the strategic value of a strong indigenous pharmaceutical sector and promote and implement appropriate policies to engender and sustain local pharmaceutical manufacture and associated R&D.

Table 4.5: Schedule of fees applicable to local manufacturers in Zimbabwe

Activity	Fee (US$)
Application for a license for a pharmaceutical manufacturer's premises	5000
Application for the renewal of a license for a pharmaceutical manufacturer's premises lodged not more than two months and not less than one month before the expiry of such license	3750
Application for the registration of a locally manufactured medicine:	
Human medicine	900
Veterinary medicine	600
Application for reinstatement of registration of a previously registered product locally manufactured	1000
Retention of a registered medicine, locally manufactured, annually:	
Human medicine	200
Veterinary medicine	150
Application to conduct a clinical trial funded by a local sponsor:	
Human medicine	2000
Veterinary medicine	1000

Source: UNIDO

Lack of design and production of pharmaceuticals. As noted earlier, Africa relies on pharmaceutical ingredients and products developed for and by others. For companies involved in formulating and packaging pharmaceuticals it can take up to six months from the time the active pharmaceutical ingredient is ordered and paid for to the time it is received in landlocked countries such as Zambia, according to the Production Manager of Circle Pharmaceutical in Zambia. This ties up operating cash and makes it much more expensive than if it were produced in nearby countries such as South Africa or Tanzania. The industry requires skilled and experienced chemical engineers and industrial chemists, among others, who can design, manage and maintain the production systems associated with modern pharmaceutical plants. Research should be undertaken to understand the volumes of active pharmaceutical ingredient imported now and a in the future to determine if local production may be justified at regional, subregional and national levels.

Regulatory capacity and standards. As African pharmaceutical manufacturers begin to develop their own products, there is an increased need for local regulatory expertise. African regulators must base their decisions less on the documentation reviewed by a foreign country and more on a review of documentation and data generated from within their own country. Such a capability needs to be complemented by laboratory capacity to test products entering the country to ensure that they are of appropriate quality and to detect counterfeit medicines. This capability requires a high level of experience and technical expertise. Given the high international standards, this could result in a requirement for very large bureaucracies. For this reason, there have been calls to establish a pan-African regulatory agency or subregional regulatory agencies that utilize the networked resources and capacities of multiple countries and provide economies of scale that bring in common standards at a reasonable cost.

Promoting research–– led innovation. In addition to promoting local pharmaceutical manufacture, there is a need to place pharmaceutical research and development within a more general promotion of a research–driven innovation culture. The gap in phase 2 of the pharmaceutical innovation value chain, namely experimental development and translational research, is critical. The global potential for academic-driven innovation in health care and pharmaceuticals has been enunciated earlier in this chapter. In Africa, there is a growing capacity for early phase research, but not for its translation into product R&D and business development. To realize the fruits of good ideas and research relevant to Africa's needs, there is a require-

ment for better support of: translational research; intellectual property management; and the establishment of entrepreneurial public-private partnerships. Such support must consider the particular issues surrounding indigenous and community-based knowledge and the rights of communities to share any dividends arising from that knowledge appropriately.

4.7 Concluding remarks

The pharmaceutical sector accounts for a significant percentage of economic activity across Africa and its contribution to national health and development is critical. In countries that are beginning to specialize in pharmaceuticals, even though they are starting from a low base globally, pharmaceutical exports represent a significant percentage of national exports, with significant opportunity for future growth. Imports currently exceed exports in the pharmaceutical sector in Africa by over 10:1. Africa is overly dependent on external innovation, developed primarily for non-African markets, rather than generating innovation focused on the continent's health needs. The nature of the pharmaceutical industry promotes intra-African and subregional trade and is a potential vehicle for continental integration.

There is potential for increased pharmaceutical innovation and business on the continent. However, there are two main gaps that need to be bridged. The first is in experimental development, or translational research, which can build on a growing continental health research base and take an idea or discovery forward for clinical evaluation. The second is the need for enhanced manufacturing capacity, especially for the active pharmaceutical ingredient, which provides the major profits associated with the pharmaceutical industry, and hence will also increase capacity for private sector-led investment from within the sector.

A networked model of pharmaceutical innovation, which is becoming significant globally, may bear fruits in Africa. If appropriately and actively promoted, it can better utilize and build on existing expertise in a cost-effective manner rather than tying up excess resources in expensive duplicated industrial plants and duplicated research. A number of networks are in existence or under development. Indigenous knowledge, combined with technological development, may provide a competitive advantage for a nascent innovation-driven African pharmaceutical industry.

Significant strategic and policy support is needed across the pharmaceutical innovation value chain. This is required at national, subregional and regional levels. It must stem from an appropriate prioritization of the sector for regional and national development and must address: (a) the business environment, including appropriate regulatory capacity and support for quality medicines; (b) promoting academic and translational research; (c) bridging academic and industrial research with business development and entrepreneurship.

References

Bawa, R., Bawa, S. R., Maebius, S. B. and others (2005). Protecting new ideas and inventions in nanomedicine with patents. Nanomedicine, 1,150-158.

Baldi, A. (2010). Computational approaches for drug design and discovery: An overview, Syst Rev Pharm 1(1), 99—105.

Bosilj-Vuksic, V. and M. Spremic (2005). ERP System Implementation and Business Process Change: Case Study of a Pharmaceutical Company. Journal of Computing and Information Technology, 13, 11–24.

Choonara, Y. E., Pillay, V., Ndesendo, V. M. Kand others (2011). Polymeric emulsion and crosslink-mediated synthesis of super-stable nanoparticles as sustained-release anti-tuberculosis drug carriers. Colloids Surfaces B, 87,243-254.

Contextweb (2011). Pharmaceutical digital marketing: Go beyond traditional targeting, Contextweb Intelligence Report. Available from http://www.iab.net/media/file/CONTEXTWEBpharmastudyposting_6-1-1_final.pdf.

Deloitte Consulting (2007). The economic and social benefits of R&D-based multinational pharmaceuticals on the South African economy, Strategy and Strategic Finance, Future of the World.

di Masi J. A., Hansen, R.W., Grabowski, H.G. (2003). The price of innovation: new estimates of drug development costs, Journal of Health Economics 22, 151–185.

Davidov, E., J. Holland, E. Marple, and S. Naylor (2003). Advancing drug discovery through systems biology. Drug Discov Today 8 (4), 175-83.

EDCTP (2011). The European and Developing Countries Clinical Trials Partnership (EDCTP) Annual Report, 2011.

Ernst and Young (2011). Beyond Borders: Global biotechnology report.

Guy P. and T. Gartenmann (2000). Big Pharma can still find big value in e-Health, Boston Consulting Group. Available from www.bcg.com.

Houghton, J. (2002). Information technology and the revolution in healthcare, Working Paper 4, Pharmaceutical Industry Project, Centre for Strategic Economic Studies, Victoria University of Technology, Melbourne, Australia.

IMARC (2011). Global biopharmaceutical market report 2010-2015, IMARC Group. Available from http://www.imarcgroup.com/global-biopharmaceutical-market-report 2010-2015.

Lounkine, E., Keiser, M. J., Whitebread, S., Mikhailov, D., Hamon, J Jenkins, J. L. Lavan, P., Weber, E., Doak, A. K., Côté, S., Shoichet, B. K. and Urban, L.O. and others (2012). Large-scale prediction and testing of drug activity on side-effect targets, Nature, 486, 361-367.

Malam, Y., Loizidou M. and Seifalian, A. M. (2009). Liposomes and nanoparticles: nanosized vehicles for drug delivery in cancer. Trends Pharmacol Sci., 30, 592-599.

McNeil, S. E. (2005). Nanotechnology for the biologist, J. Leukoc. Biol, 78, 585-594.

Nwaka, S., Ilunga, T. B., Da Silva, J. S., Verde, R. E., Hackley, D., and others (2010). Developing ANDI: A Novel Approach to Health Product R&D in Africa. PLoS Med 7(6): e1000293. doi:10.1371/journal.pmed.1000293 per cent.

RNCOS (2011). Global Protein Therapeutics Market Analysis. Available from http://www.reportlinker.com/p0200068/Global-Protein-Therapeutics-Market-Analysis.html.

Schell, D. (2009). Tips for Enterprise-wide ERP Deployment in Pharma. Life Science Leader, November, 2009. Available from www.lifescienceleader.com.

Swai, H., Semete, B., Kalombo, L. and others (2008). Potential of treating tuberculosis with a polymeric nano-drug delivery system. J. Control. Release., 132, e48.

Wambebe, C.O., Bamgboye, E.A., Bandru, B.O., and others (2001). Efficacy of NIPRSAN in prophylactic management of patients with sickle cell disease, Current therapeutic research, 62, 24-34.

WHO (2002). Traditional Medicine Strategy 2002-2005, World Health Organization, Geneva.