African Innovation Outlook 2010

NEPAD

A PROGRAMME OF THE AFRICAN UNION

NEPAD Planning and Coordinating Agency
Agence de Planification et de Coordination du NEPAD

African Innovation Outlook 2010

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Any citations to this publication should read:
AU–NEPAD (African Union–New Partnership for Africa's Development) (2010),
African Innovation Outlook 2010, AU–NEPAD, Pretoria.

ISBN: 978-1-920550-45-5

Publication compiled by: Claes Brundenius and Philippe Mawoko
Copyediting: Write Connection, Pretoria
Desktop composition and printing: DS Print Media, Johannesburg

Acknowledgements

African ministries responsible for science, technology and innovation (STI) and national statistics offices are gratefully acknowledged for waiting in anticipation for the implementation of the African Science, Technology and Innovation Indicator (ASTII) initiative, of which this publication is a major outcome. The ASTII initiative is a programme in Africa's Science and Technology Consolidated Plan of Action (CPA), which was adopted in Dakar, Senegal on 30 September 2005 by the African Union Ministerial Conference in charge of Science and Technology (AMCOST). At that conference, AMCOST resolved among other things "to establish an inter-governmental committee comprising of relevant national authorities to develop, adopt and use common indicators to survey and prepare an African Science, Technology and Innovation report".

The governance of the ASTII initiative looks assured, thanks to the leadership of Prof. Jean-Pierre Onvehoun Ezin, Commissioner of Human Resources, Science and Technology at the African Union Commission (AUC-HRST) and Dr Ibrahim Assane Mayaki, the CEO of the NEPAD Agency. Both provide the kind of leadership that will ensure that the ASTII initiative fits into the mandate of the African Union and that the initiative is implemented in synergy with other relevant programmes of the NEPAD Planning and Coordinating Agency (NCPA).

The Swedish International Development Cooperation Agency (Sida) has been the major financial contributor for most ASTII activities thus far. This has been possible thanks to the dedication of Dr Berit Olsson, the former Director-General of SAREC at Sida, and Dr Tomas Kjellqvist, Head of Department at the Secretariat for Research Cooperation. Dr Tekaligne Godana and her predecessor Dr Ros-Mari Bålöw, in their capacities as senior advisors at Sida provided the necessary leadership to ensure that the project was funded.

Also worthy of mention is Mrs Vera Brenda Ngosi, the Director at AUC-HRST, for providing the necessary political guidance and liaison on behalf of the AUC. Similarly, her predecessor Dr Abdul-Hakim Elwaer worked towards the harmonisation of the NEPAD Secretariat and AUC-HRST to ensure that Africa speaks with one voice. Prof. Crispus Kiamba, Permanent Secretary of Kenya's Ministry of Higher Education, Science and Technology, in his capacity as chair of the Steering Committee of AMCOST-III and of the African Inter-governmental Committee on STI, ensured that relevant STI initiatives on the continent were complementary to ASTII. It is in this context that the workshop that validated the outputs of the ASTII surveys was held under the auspices of the AUC-HRST in Addis Ababa, Ethiopia in December 2009.

Prof. Aggrey Ambali, in his capacity as Head of the then NEPAD Office of Science and Technology, provided the strategic impetus. He strove to ensure that the necessary resources were mobilised for the implementation of the ASTII activities. An equally important contributor to the genesis of the ASTII initiative was Prof. John Mugabe, who was at the helm from the inception of the Science and Technology Unit within the NEPAD Secretariat. As Head of the unit at the time, he provided the initial roadmap for the birth of the *African Innovation Outlook.*

The Canadian International Development Research Centre (IDRC) provided support in the earlier stages of the ASTII initiative.

In its formulation as well as in the current stages of implementation, the ASTII initiative continues to benefit from the experience and knowledge of a group of dedicated STI experts. Termed ‘the ASTII Faculty’, this group of experts serves as resource persons at training workshops and has played a pivotal role in assisting the Focal Points in overcoming the challenges encountered in conducting national surveys and analysing the results. The Faculty comprises Mr William Blankley and Dr Neo Molotja (both at the Centre for Science, Technology and Innovation Indicators [CeSTII], Human Sciences Research Council [HSRC]); Prof. Claes Brundenius (Research Policy Institute [RPI], University of Lund); Prof. Fred Gault (UNU Maastricht Economic and Social Research Institute on Innovation and Technology [UNU-MERIT] and Institute for Economic Research on Innovation [IERI]); Mr Koffi Marc Kouakou (Department of Statistics, African Development Bank); and Mr Martin Schaaper (UNESCO Institute for Statistics).

During implementation, a number of experts were called in and generously contributed their expertise and know-how, namely: Mrs Bitrina Diyamett (Tanzania Commission for Science and Technology); Mr Simon Ellis and Mr Ernesto Fernández Polcuch (UNESCO Institute for Statistics); Prof. Michael Kahn (former Executive Director, CeSTII, HSRC); Dr Fetson Kalua (University of South Africa); Dr Ousmane Kane (African Regional Centre for Technology, Senegal); Prof. Hatem M'henni (former Director General of L’Observatoire National des Sciences et de la Technologie, Tunisia); Prof. Banji Oyelaran-Oyeyinka (Monitoring and Research Division, UN-HABITAT); Mr Rasigan Maharajh (IERI) and Dr Astrid Szogs (University of Lund).

The Centre for Science, Technology and Innovation Indicators, HSRC, South Africa provided support to NEPAD in scoping and setting up the ASTII programme. The experience of the centre in conducting R&D and innovation surveys, especially their survey instruments, has proved valuable and has been shared with participating countries. This was possible thanks to the leadership of the then Minister Mosibudi Mangena of the South African Department of Science and Technology, who committed his support to the programme.

The ASTII initiative has benefited from valuable inputs by several institutions that have been involved in similar work, including: UNESCO; RPI, University of Lund; IERI, Tshwane University of Technology; OECD-NESTI; Department of Statistics, African Development Bank; University of Pretoria; Statistics South Africa; Eurostat; UNU-MERIT, Chinese Academy of Science and Technology Development (CASTED); Council for Health Research and Development (COHRED); International Food Policy Research Institute (IFPRI); and INDEPTH Network.

As early as 2004, the United Nations University Institute for New Technologies (UNU-INTECH) conducted a study on behalf of NEPAD entitled "Designing a policy-relevant innovation survey for NEPAD". The study contributed to the discussions leading up to the current ASTII initiative.

We would like to acknowledge with appreciation the group of experts who met in May 2005 and provided the rationale for the development of the ASTII programme. The outcomes of that meeting set the pace for the current shape of the ASTII initiative. These experts were Prof. Seewant Bhoojedhur (Mauritius Research Council); Ms. Bitrina Diyamett (Tanzanian Commission for Science and Technology [COSTECH]), Mr Clement Entsua-Mensah (Institute for Scientific and Technological Information, Council for Scientific and Industrial Research, Ghana); Ms Nduta Irene Gathinji (Pact Kenya); Prof. Fred Gault (Statistics Canada/OECD); Prof. Michael Kahn (CeSTII, HSRC, South Africa); Prof. Nelson Lujara (Kigali Institute of Science, Technology and Management, Rwanda); Prof. Banji Oyelaran-Oyeyinka (UNU-INTECH); Prof. Anastassios Pouris (Institute for Technological Innovation, University of Pretoria, South Africa); Dr John Mugabe (NEPAD Office for Science and Technology); and Mr Simon Mpele (National Advisory Council on Innovation, South Africa).

Production team

The core team of experts who assisted the countries to analyse the outputs of their R&D and innovation surveys, compiled additional indicators and then produced the *African Innovation Outlook* comprised:

- Mr William Blankley and Dr Neo Molotja (CeSTII)
- Prof. Claes Brundenius (RPI, University of Lund)
- Prof. Fred Gault (UNU-MERIT and IERI)
- Rasigan Maharajh and Prof. Mario Scerri (IERI)
- Dr Philippe Mawoko (NEPAD Agency)
- Prof. Johann Mouton and Mr Nelius Boshoff (Centre for Research on Science and Technology [CREST], University of Stellenbosch).

The ASTII Focal Points undertook the surveys at the national levels.

The Secretariat for the ASTII programme was made up of Ms Anna Ekermo, Mr Lukovi Seke and Ms Nancy Ngum.

The overall coordination for the production of the *Outlook* comprised:

- Prof. Claes Brundenius (RPI, University of Lund) as the technical advisor to the ASTII initiative on behalf of Sida
- Dr Philippe Mawoko of the NEPAD Agency, in his capacity as ASTII Coordinator.

ASTII Focal Points

The following experts from the national ASTII Focal Points are acknowledged:

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Acronyms

AfDB	African Development Bank
AMCOST	African Union Ministerial Conference in charge of Science and Technology
AMU	Arab Maghreb Union
AOSTI	African Observatory for Science, Technology and Innovation
APRM	African Peer Review Mechanism
ARC	Agricultural Research Council
ASTII	Science, Technology and Innovation Indicators
AU	African Union
AUC	African Union Commission
BERD	Business enterprise sector
CAEMC	Central African Economic and Monetary Community
CASTED	Chinese Academy of Science and Technology Development
CEC	Commission of the European Communities
CEO	Chief executive officer
CeSTII	Centre for Science, Technology and Innovation Indicators
CGIAR	Consultative Group on International Agricultural Research
CIRAD	La Recherche Agronomique pour le Développement
CIS	Community Innovation Surveys
CISM	Centro de Investigação em Saúde at Manhiça
CNRS	Centre National de la Recherche Scientifique (National Centre for Scientific Research)
COHRED	Council for Health Research and Development
COMESA	Common Market for Eastern and Southern Africa
COSTECH	Tanzanian Commission for Science and Technology
CPA	Consolidated Plan of Action
CREST	Centre for Research on Science and Technology, University of Stellenbosch
CSIR	South African Council for Scientific and Industrial Research

DUI	Doing, using and interacting
EAC	East African Community
ECA	United Nations Economic Commission for Africa
ECCAS	Economic Community of Central African States
ECOWAS	Economic Community of West African States
EIS	European Innovation Scoreboard
EU	European Union
FDI	Foreign direct investment
FRANC ZONE	Communauté Financière Africaine
FTE	Full-time equivalent
GDP	Gross domestic product
GERD	Gross domestic expenditure on research and experimental development
GERDAT	Groupement d'Etudes et de Recherches pour le Développement de l'Agronomie Tropicale
GOVERD	Government sector
HC	Headcount
HDI	Human Development Index
HERD	Higher education sector
HSRC	Human Sciences Research Council
HRST	AUC Department for Human Resources, Science and Technology
ICCT	Instituto de Combate e Controle das Tripanossomíases (Institute to Combat Trypanosomiasis)
ICIPE	International Centre of Insect Physiology and Ecology
ICRAF	International Council for Research on Agro-Forestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information and communication technology
IDRC	International Development Research Centre, Canada
IERI	Institute for Economic Research on Innovation, Tshwane University of Technology
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
INDEPTH	International Network for the Demographic Evaluation of Populations and Their Health in Developing Countries
INERA	Institut de l'Environnement et de Recherches Agricoles
IRAT	Institute for Research in Tropical Agriculture
IRCT	Institute for Research on Cotton and Textiles
IRHO	Institute for Research on Oil and Oil-bearing Plants
ISCED	International Standard Classification of Education
ISI	Institute for Scientific Information
MDG	Millennium Development Goal
Mintek	Council for Mineral Technology

NAADS	National Agricultural Advisory Services
NACRRI	National Crops Resources Research Institute
NARO	National Agricultural Research Organisation
NCPA	NEPAD Planning and Coordination Agency
NEPAD	New Partnership for Africa's Development
NEPAD OST	NEPAD Office of Science and Technology
NESTI	Working Party of National Experts on Science and Technology Indicators
NSI	National system of innovation
OAU	Organisation for African Unity
OECD	Organisation for Economic Cooperation and Development
ORSTOM	Office de la Recherche Scientifique Technique Outre-Mer (Office for Overseas Scientific and Technical Research)
OST	Office of Science and Technology
PhD	Doctor of Philosophy
PICD	Programme Implementation and Coordination Directorate
PNP	Private non-profit organisation
PPP	Purchasing power parity
R&D	Research and experimental development
RPI	Research Policy Institute, University of Lund
S&T	Science and technology
SADC	Southern African Development Community
SAP	Structural adjustment programme
SAREC	Sida Department for Research Cooperation
Sida	Swedish International Development Cooperation Agency
SMME	Small, medium and micro enterprise
STI	Science, technology and innovation
UIRI	Uganda Industrial Research Institute
UIS	UNESCO Institute for Statistics
UK	United Kingdom
UNDP	United Nations Development Programme
UN	United Nations
UNESCO	United Nations Educational, Cultural and Scientific Organisation
UN-HABITAT	United Nations Human Settlements Programme
UNU	United Nations University
UNU-INTECH	UNU Institute for New Technologies
UNU-MERIT	UNU Maastricht Economic and Social Research Institute on Innovation and Technology
US/USA	United States of America
WAEMU	West African Economic and Monetary Union
WoS	Web of Science

Preface

In 2005, the African Union Ministerial Conference in charge of Science and Technology (AMCOST) adopted the Africa's Science and Technology Consolidated Plan of Action (CPA) as a framework in the context of science, technology and innovation (STI) to respond to the socio-economic challenges facing the continent.

Two years later, in January 2007, the Summit of the Heads of State and Government of the African Union (AU) stated that "the African people are now more than before determined to banish poverty, combat disease, improve public health, increase agriculture production, and achieve the Millennium Development Goals (MDGs)". Furthermore, they went on to reaffirm that "the achievement of these goals depends amongst other things, on the countries' ability to harness science and technology for development and also on an increase and sustained investment in science, technology and innovation".

Since then, the Department of Human Resources, Science and Technology of the African Union Commission (AUC) and the then NEPAD (New Partnership for Africa's Development)[1] Office of Science and Technology (OST) have collaborated in the implementation of the CPA programmes and projects. One of these programmes is the African Science, Technology and Innovation Indicators (ASTII) initiative, which aims to provide information and analysis on STI activities in Africa.

Countries implementing this initiative, though at different paces, have an unprecedented opportunity to create a proactive environment for mutual learning and to experiment with the measurement of science, technology and innovation. This is an opportunity to provide evidence that will assist policy processes for national and regional development.

It is with an honour to have witnessed ASTII growing from a mere intention to concrete and tangible outputs. We commend and encourage the collaborative efforts of the 19 participating countries in bringing this publication, the *African Innovation Outlook*, into being. While we welcome the first in the the *Outlook* series, we understand that the measurement of science, technology and innovation requires perseverance.

As indicated in the *Outlook*, during the implementation phase, several challenges have emerged and a number of lessons have been learned. We encourage countries to use this cumulative knowledge as a springboard for developing indigenous capabilities and addressing African STI-specific problems that are crucial for the socio-economic transformation of the continent. Strategic interventions need to be informed in areas such as agriculture and food security, regional integration and infrastructure, climate change and natural resources management, human development as well as economic and corporate governance.

Clearly, measuring STI in African countries has been the missing link in our efforts to get to grips with the STI puzzle on the continent. The establishment of Focal Points to spearhead the production of STI indicators at national level is therefore a crucial undertaking that we need to promote in all African countries. The old management adage that “you can't manage what you don't measure” remains accurate today. Africa needs STI indicators to measure the significance of STI in its development.

The publication of the *Outlook* is a journey. Over time, it will tell the story of STI in all AU member states and set off new areas of application. It is evident that a community of practice is emerging, setting the pace towards improving the quality of STI policies in Africa.

We commend the numerous AU member states that have invested their own resources to implement the ASTII programme and we encourage other African countries to follow suit. The involvement of the Department of Statistics of the African Development Bank and the Centre for Science, Technology and Innovation Indicators (CeSTII) of the Human Sciences Research Council in South Africa are encouraging examples that other African institutions should emulate.

Equally encouraging has been the involvement of partner institutions with vital experience in STI for supporting the implementation of the ASTII initiative. We are grateful to the Swedish International Development Cooperation Agency (Sida) for providing the initial funding, the United Nations Educational, Scientific and Cultural Organisation (UNESCO) Institute for Statistics for sharing its experience on STI measurement in Africa and Canada’s International Development Research Centre (IDRC) for its support during earlier stages of this work. We call upon other development agencies to do likewise.

The forthcoming establishment of the African Observatory for Science, Technology and Innovation (AOSTI) Observatory and the publication of the future series of the *Outlook* will contribute to building national and regional capacities to develop and implement strategies and policies that will govern STI in Africa.

We strongly support the expansion of the ASTII initiative to all member states of the African Union as well as the widening of the scope of its contents. We urge African governments and other stakeholders to domesticate this programme in their countries and institutions.

Prof. Jean-Pierre Onvehoun Ezin

Commissioner

AUC-Human Resources Science and Technology (HRST) Department

Dr Ibrahim Assane Mayaki

Chief Executive Officer

NEPAD Agency

[1] The NEPAD OST was a sector of the then NEPAD Secretariat, which has been transformed into the NEPAD Planning and Coordinating Agency (NPCA).

Executive Summary

Introduction

Africa suffers from a lack of an adequate, African-led, science, technology and innovation (STI) system of indicators in support of evidence-based policy. This has been attributed to the continent's use of traditional development approaches that have ignored the role of measuring science and innovation activities in the socio-economic transformation of the continent. African political leadership has recommended several schemes to advance the role of STI for development, yet there are no appropriate instruments to gauge the implementation of these schemes by member states of the African Union (AU).

Notwithstanding this development, the African Union Ministerial Conference in charge of Science and Technology (AMCOST) has repeatedly called for better understanding of, and improvement in, the state of STI on the continent. These recurrent calls have been embodied in the outcomes of AMCOST decisions over the last decade. The African Science, Technology and Innovation Indicators (ASTII) initiative is a response to AMCOST calls to address the lack of evidence-based policy processes. The African Innovation Outlook is an outcome of the implementation of the ASTII initiative.

Over the last three years, ASTII has been implemented through designated Focal Points at national levels coupled with coordination at continental level by the Directorate of Human Resources, Science and Technology of the African Union Commission (AUC–HRST) and the NEPAD Office of Science and Technology.[2] The first phase of the initiative was implemented in 19 countries and benefited from seed-funding provided by the Swedish International Development Cooperation Agency (Sida) and contributions from participating countries, namely: Algeria, Angola, Burkina Faso, Cameroon, Egypt, Ethiopia, Gabon, Ghana, Kenya, Lesotho, Malawi, Mali, Mozambique, Nigeria, Senegal, South Africa, Tanzania, Uganda and Zambia.

The ASTII programme forms part of Africa's Science and Technology Consolidated Plan of Action (CPA), which among other things aims to build the human and institutional capacities needed to produce common internationally comparable indicators as tools for the ongoing survey of research and innovation at national levels. One of the outcomes has been the establishment of national capacity to conduct such surveys regularly.

This phase of the programme was designed to serve as a learning mechanism based on implementing R&D and innovation surveys, analysing the data and using the results in policy-making. The knowledge and experience gained will be consolidated to improve the process in future, inform the roll-out to further countries and increase the scope of the programme.

The *African Innovation Outlook 2010* is published as the first in a series, intended to inform the people of Africa and other interested parties about STI activities in African countries. The availability and usage of the *African Innovation Outlook* is expected to generate debate, which will enrich the process of collecting better quality data and improve understanding of policy processes in Africa. The debate is expected to contribute to African solutions to African problems and influence the work on STI indicators.

The R&D and innovation surveys are underpinned by international best practice. The R&D surveys are informed by the definitions in the OECD *Frascati Manual* and the innovation surveys by the OECD/Eurostat *Oslo Manual*, as adopted by the first Intergovernmental Meeting on Science, Technology and Innovation Indicators in Maputo, Mozambique in 2007.

The *African Innovation Outlook* comprises six chapters. Readers are advised to refer to the various chapters and references therein for more information.

Chapter outlines

Chapter 1: Background

Chapter 1 sets the scene and describes the genesis of the programme by stating its objectives and scope. The chapter also highlights the roles and structures of the national Focal Points, which implemented the surveys, as well as outlining the essence of the *African Innovation Outlook.*

Chapter 2: Economic growth and human development challenges for science, technology and innovation in Africa

Chapter 2 utilises the systems of innovation approach to development in trying to broaden the discussion of identified structural impediments that tend to constrain and inhibit African economic growth and human development. The chapter argues that improving institutions, so that they become broadly participative, transparent and universal, is imperative in redressing the failures of the past and ending the inevitable continuities with path dependencies and trajectories. The chapter is structured around themes, including: demographics; economic sectors; diversity; growth and development; entrepreneurship; global competitiveness; industrialisation; the macro-economic environment; regional integration; science, technology and innovation institutions and policies; and the Millennium Development Goals.

Chapter 3: Research and experimental development

Chapter 3 presents the estimates of two main R&D indicators developed on the basis of the R&D surveys conducted in 13 of the 19 participating countries between April 2009 and February 2010, namely:

Cameroon, Gabon, Ghana, Kenya, Malawi, Mali, Mozambique, Nigeria, Senegal, South Africa, Tanzania, Uganda and Zambia. The reference year for the surveys was 2007. The main indicators of interest were: (1) gross domestic expenditure on R&D by source of funds and sector of performance; and (2) R&D personnel by level of formal qualification and occupation, gender, headcount and full-time equivalent, as well as researchers by gender and field of study/research. A full R&D survey requires that the business enterprise sector, government sector, higher education sector and private non-profit organisations (PNP) be covered.

Where a sector has not been covered or reference parameters differed (for example, with respect to the reference year or survey period), a note to that effect has been added. Readers are advised to exercise caution in interpreting certain related statistics. The text points to areas that need further work. The estimates of the indicators, as mentioned, are described and broken down as follows:

Gross domestic expenditure on research and experimental development (GERD). This is one of the most common and most often quoted R&D indicators, indicating how much a country spends on research and experimental development as a percentage of GDP. The target for African countries of spending 1% of GDP on R&D – as endorsed by the Executive Council of the African Union in the Khartoum Decision (EX.CL/Dec.254 (VIII) on Science and Technology in 2006 – is an example of the use of this indicator for policy purposes.

- *The R&D intensity or the GERD/GDP ratio.* The survey results indicate that three countries (Malawi, Uganda and South Africa) scored an R&D intensity above 1%. For the other countries, the percentages range between 0.20% and 0.48%.
- *GERD by sector of performance.* With the exception of South Africa and Malawi, the public sector (comprising the government and higher education sectors combined) accounted for the lion's share of R&D expenditure in all of the countries surveyed. The two sectors combined accounted for over 50% of total GERD. The private non-profit sector accounted for a relatively small share of total R&D activity.
- *GERD by source of funding.* The survey data indicate that government is the most important funding source of R&D activities in participating countries. In addition to financing its own research institutes, government also finances R&D at public universities, and universities sometimes finance R&D from their own funds. In future research, the programme intends to look at the combined sum of expenditure in the government and higher education sectors in order to make a more detailed comparison of the role of governments. The data also indicate that R&D activities in Africa are to a large extent financed by international donors and other foreign sources. Among the countries surveyed, Mozambique is currently the most dependent on foreign donors, in that more than 50% of its R&D is financed from abroad, followed by Mali (49.0%), Tanzania (38.4%), Senegal (38.3%) and Malawi (33.1%). By contrast, Nigeria and Zambia show very low dependence on foreign funding. In countries such as Ghana, South Africa and Malawi, the business enterprise sector accounts on average for 40% of R&D funding, while in most other countries its share of funding is less than 10%.
- *GERD by type of R&D.* The survey data show that Nigeria devotes relatively more resources to basic research (36.1%) than other countries, although the share of R&D funding for

basic research is also relatively high in South Africa (20.6%) and Tanzania (19.2%). South Africa devotes most of its resources to experimental development research (45.2%), while Tanzania focuses on applied research (58.6%). The picture is rather different for Malawi, Mozambique and Uganda, where basic research accounts for only about 10% of GERD; by contrast, applied research accounts for 60% of R&D expenditure in Malawi, 83.2% in Mozambique and 59.3% in Uganda.

R&D human resources. These statistics indicate the human resources devoted to R&D in the survey year. The allocation of these human resources among the sectors describes the available R&D personnel and their actual utilisation in conducting research, as well as the qualifications of researchers and their distribution by gender. More specifically, the survey results show the following:

- *Researcher density or the deployment of R&D human resources.* The data reveal that South Africa, of all the countries surveyed, has the highest number of human resources available for R&D activities, with a researcher density of 825 per million inhabitants, followed by Senegal with 635 researchers per million inhabitants. At the lower end of the scale, Mozambique, Uganda and Ghana have a researcher density of fewer than 25 per million inhabitants. The findings related to this indicator call for further investigation in order to understand these differences, some of which may be attributed to the complexity of the definition of 'researcher'.
- *The role of women in R&D.* The data show that Tanzania and South Africa lead in terms of the participation of women performing R&D, since women account for 40% of all researchers in those two countries. The next highest percentages of women researchers are found in Mozambique and Uganda. The female participation ratios are similar for women employed as researchers and as support staff. This indicator is worth monitoring over time, as it will show whether there is growth in the participation of women in scientific careers in Africa.
- *Where do the researchers conduct research?* Most researchers in the surveyed countries are employed in government research institutes or public university laboratories. The role of the business enterprise sector in R&D ranks higher in Mali, South Africa and Ghana than in other participating countries. Private non-profit institutions play a very modest role in R&D activities in the surveyed countries, with the notable exception of Malawi.
- *Qualifications of researchers and support staff.* The data indicate that South Africa and Senegal have the highest percentages of PhDs among their R&D staff, scoring 32% and 26% respectively. However, several countries (Ghana, Malawi, Mali and Mozambique) have low percentages of PhDs among their R&D personnel as well as high percentages with non-tertiary education. Although this situation needs attention, it does not necessarily mean that research projects in these countries are staffed by less competent R&D staff. This is an area that warrants future research.
- *Estimating full-time equivalents (FTE).* The FTE data indicate the proportion of their working time that researchers and support staff devote to R&D activities. By comparison, headcount data record only the numbers of R&D personnel. Six countries provided data on FTEs. The average ratio between FTE and headcount is approximately 50%, with South Africa as a

case in point. Malawi and Senegal are in the same range, and Ghana follows with a slightly higher ratio. Nigeria and Uganda are at the lower end of the range, although the FTE status of women employed in research in Uganda seems to be higher than for men. This area calls for further research.

- *Researchers by field of science.* This indicator shows the shares of researchers in six countries (Ghana, Malawi, Mozambique, Senegal, Tanzania and Uganda) in the fields of the natural sciences, engineering and technology, medicine and health, agricultural sciences, social sciences and humanities.

Chapter 4: Innovation

Chapter 4 summarises the outcomes of the innovation surveys conducted as part of the ASTII project. Ten of the 19 participating countries conducted such surveys using the reference period of 2005–2007, namely: Burkina Faso, Egypt, Ethiopia, Ghana, Lesotho, Mozambique, Tanzania, South Africa, Uganda and Zambia. As stated with reference to R&D surveys, where reference parameters differed, caution is recommended in interpreting the data.

The surveys used the definition of ‘innovation’ given in the *Oslo Manual*, namely that an innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations. A common feature of an innovation is that it must be connected to the market. For there to be a ‘product innovation’, the product has to be new or significantly improved, and for there to be a ‘process innovation’, the means of producing the product or delivering the product to the market has to be new or significantly improved.

The participating countries piloted a Community Innovation Survey (CIS)-type questionnaire. This served as a learning mechanism in defining and measuring innovation for statistical purposes. The main aim was better understanding of the innovation system in Africa. At this stage of the programme, the survey data at hand do not support precise comparable findings between countries, and care ought to be exercised in reaching policy conclusions based on a single survey. However, the findings could serve to attract policy interest and provide a basis for the selection of a set of core questions that have been shown to work in most countries and can be used for the next series of surveys. In addition to the core questions, countries might be invited to add questions of particular national interest.

This chapter discusses the significance of the survey findings and highlights areas for future research. It also offers ways of interpreting the survey findings and using the outcomes for policy purposes.

Findings

Innovation is pervasive. The data show evidence of innovation in all participating countries, in both small and large firms. The innovations included product and process innovations, as well as organisational and marketing innovations. In all cases, some of the resulting goods and services from innovative firms were sold outside the producing country. Trade is a means of connecting the firm not just to purchasers, but to the knowledge of markets, technologies and practices in other countries.

Innovation is a connected activity. The client or customer is the lead source of ideas for innovation outside the firm itself. Public institutions such as universities, governments and public research organisations are low on the list of external sources of innovation. Innovative firms collaborate, and their first choice of collaborator, within their own country, is the client or customer. Partners of choice vary in the case of collaboration outside the country. In most countries, the lead innovation activity has been the acquisition of machinery, equipment and software, followed by R&D conducted by the firm. This order was reversed in the case of Ghana and Tanzania.

Innovation has impact. Most countries consider the main impact of innovation to be the improved quality of the goods and services offered, followed by flexibility in production, an increased range of products and increased capacity to produce.

There are barriers. The barrier most frequently cited is the lack of funds in the enterprise and the cost of innovation. Other barriers include the domination of the market by established enterprises and the lack of information on both technologies and markets. In Burkina Faso, the most significant barrier is the lack of qualified personnel.

Size matters. Innovation activities, including both R&D and innovation itself, are related to the size of firm. Ghana examined the propensity to innovate in small, medium and large firms and demonstrated a clear correlation between size and propensity to innovate. This situation is also observed in industrialised countries, but the statistics require further investigation in other African countries to prove their robustness on the continent. Another observation on firm size and innovation is that surveys of firms with large employment or turnover tend to yield a high estimation of the propensity to innovate.

In most countries, many firms that innovate do not perform R&D. Innovation can and does take place without the need for inhouse R&D within the firm, but this raises questions about the source of the knowledge supporting the creation of value in the firm.

Interpreting the findings

The results of this first round of innovation surveys describe the innovative firm in Africa, but the results cannot support country comparisons, because different size cut-offs, sample sizes and reference periods were used. The interested reader or researcher is encouraged to review the reports of participating countries as they become available and raise questions that could enrich and contribute to future rounds of innovation surveys or surveys in new participating countries. Access to micro data will be a valuable asset. Notwithstanding the comparability challenges, the results are sufficiently robust to support certain observations, such as (1) the importance of the client and customer as both a source of ideas for innovation and as a collaborator and (2) the fact that not all innovative firms perform R&D. The latter observation raises policy questions about promoting entrepreneurship and R&D, especially among small firms.

Using the findings

- The importance of the relationship of the innovative producer with the client, both as a source of ideas and as a collaborator, might suggest support for collaboration.

- The fact that the leading innovation activity is the acquisition of machinery and equipment could lead to discussion of tax incentives to encourage investment in certain classes of machinery and equipment, such as those related to information and communication technologies (ICTs).
- The tendency of innovative firms to trade abroad might suggest a role for an export development bank or other institutions providing support for firms that are trying to enter the export market.
- Human resources are a factor in all innovation activity. There is thus a link between innovation and policies on education, health, training and migration that governments use to create framework conditions through service provision, regulation and practice.
- Understanding what firms are doing, and how or whether government programmes support what they are doing, is an area for further research. In particular, better understanding is required of firms that innovate without performing R&D.

Chapter 5: Bibliometric analysis of scientific output

It is well understood that a more realistic and complete picture of the science, technology and innovation landscape in participating countries will require additional indicators to those produced from the R&D and innovation surveys. To this end, Chapter 5 provides a bibliometric analysis of science and technology production and knowledge flow as a critical aspect of the state of science, technology and innovation in the participating countries. The analysis used the Scopus database as the primary data source.

The bibliometric analysis reveals that the production of science is dependent on a wide range of systemic, institutional and individual forces and that the scientific effort in most of the countries reflects physical and material realities and challenges related to the three main areas of food security, disease control and industrialisation. The analysis further assesses the impact of historical influences, particularly colonial legacies, on science in many African countries.

The study shows that knowledge production in all 19 countries, irrespective of their size, is dominated by the work of academics and scholars at the major universities. The smallest science systems on the continent often rely heavily for the production of knowledge on the role and contribution of just a few public universities (or possibly just a single university).

Whereas agricultural research dominated the research agendas of African countries in the 1990s (especially in anglophone countries), research in medicine and related fields now dominates. In addition to the challenges of dealing with traditional tropical and other infectious diseases such as sleeping sickness and malaria, the HIV/AIDS pandemic and the continuing effects of tuberculosis have led to renewed R&D effort in these areas. Issues related to food security, the effects of drought, poor crops, and the impact of internationalisation and open trade on certain markets have yet to generate appropriate R&D.

South Africa, Egypt, Algeria, Nigeria, Kenya and Tanzania have developed some local capacity in the engineering sciences, especially metallurgical and mining engineering, chemistry and chemical engineering, and physics (including nuclear physics and astrophysics). Coupled with growing pockets of expertise in electronics, mathematics and computing sciences, the shape of knowledge production in these countries differs markedly from the rest of the continent.

It should be noted that Africa's share of world science continues to decrease. The few African countries where scientific output is substantial and even growing are not as productive as developing countries elsewhere in the world; these countries therefore do not have a significant effect on the overall findings in this regard. For Africa to become more competitive with respect to scientific output will require greater investment in human capital development, the strengthening of scientific institutions and equipment, as well as significantly higher funding for science.

Chapter 6: Recommendations

Chapter 6 provides an overview of the next steps for ASTII in its contribution to addressing the challenges to STI in Africa.

Conclusion

Evidence from the implementation of the first phase of ASTII demonstrates that participating countries need to place the measurement of STI on their national development agendas, but that measuring STI is easier said than done.

This initiative is the first major African-led, politically authorised effort to generate a comprehensive and comparative survey of STI on the continent. Implemented by a network of national Focal Points, the initiative has benefited from the synergy of information exchange, the richness of diversity and shared resources. It establishes a foundation for Africa to continue experimenting and measure the effects of STI on its economic and social transformation. At the same time, the initiative leads to the creation of a community of practice in African countries.

In order to sustain the ASTII programme and increase its significance for the development and implementation of STI policy for development, additional work is required, including the use of STI indicators for policy formulation and implementation, strengthening statistical capabilities to improve the quality of data and a greater investment in human capital development.

Over time, the *African Innovation Outlook* series is expected to contribute to better understanding of the interventions required of African governments, international partners and the STI community in the further development and application of science, technology and innovation in Africa.

[2] The text makes reference to the then Office of Science and Technology in the New Partnership for Africa's Development (NEPAD) Secretariat under which the first phase of the ASTII initiative was implemented. Since the integration of NEPAD into the structures and processes of the African Union in February 2010, the NEPAD Secretariat has been transformed into the NEPAD Planning and Coordinating Agency (NPCA), and ASTII operates under its Programme Implementation and Coordination Directorate (PICD).

Chapter 1: Background

1.1 Introduction

African countries are increasingly recognising that they should invest in science, technology and innovation (STI) capabilities in order to respond to the socio-economic challenges they face. This sentiment was expressed in the Addis Ababa Declaration on Science, Technology and Scientific Research for Development at the African Union Summit in January 2007:

> We, the Heads of States and Government of the African Union, ...recalling our millennium commitments to achieve sustainable development for our Continent, ...realizing that the achievement of these goals depends on our countries' abilities to harness science and technology for development and also an increased and sustained investment in science, technology and innovation, ...commit ourselves to promote and support research and innovation activities and the requisite human and institutional capacities. (AU, 2007a)

This recognition is manifested in the various initiatives that countries have launched, both individually and collectively (Mugabe, 2006). At national level, a growing number of countries are reviewing and revising their policies and strategies for creating conducive environments for investment in STI, and in some cases new policies and strategies are being designed. There are regional efforts such as the approval, in Johannesburg in 2008, of the Southern African Development Community (SADC) Protocol on STI by the SADC Heads of State and Government (SADC, 2008); the creation, in 2007, within the Economic Community of West African States (ECOWAS) Commission responsible for human development and gender, of a Department for Education, Culture, Science and Technology with a mandate to promote STI for regional integration, economic development, overall poverty reduction and social emancipation of the people of West Africa (ECOWAS, 2007); and the inclusion in the East African Community (EAC) Treaty of several provisions that promote the application of STI for development in the East African region (EAC, 2010).

Africa's Science and Technology Consolidated Plan of Action (CPA) proposes a regional approach to promoting the role of science and technology in support of the social and economic transformation of the continent (Mugabe, 2006). An example worth noting is the set of recommendations from the High-level African Panel on Modern Biotechnology, which enables African development practitioners to delve into each of the identified areas and exploit the potential from biotechnology for the transformation of African economies (Juma, 2007). A series of applications of STI for the development of Africa have been highlighted in the report "Knowledge for Africa's Development: Policies, Priorities and Programmes" (Mugabe, 2009).

Notwithstanding these commendable efforts to advance the role of STI for development in Africa, there have been no significant African-led efforts or African-owned instruments in use to gauge the state of STI on the continent. This is borne out by the description of the state of statistics in Africa by the Chairperson of the African Union Commission (AUC), Jean Ping: "Although there has been significant progress in Africa's statistical system over the last years with the advent of several initiatives, it should be pointed out that there is an immense gap between the supply and demand for statistical information needed for development and for the African integration process. For the moment, quality statistical data produced by the African statistical system is virtually non-existent" (AU, 2007b). The situation is no better with respect to STI statistics, as indicated by Michael Khan at the first workshop on African Science, Technology and Innovation Indicators (ASTII): "African countries, like most of the developing countries, have, over the years, provided socio-economic data to international organisations. Africa, however, does not have a history of measuring and managing science and technology information" (NEPAD, 2007).

The African Union Ministerial Conference in charge of Science and Technology (AMCOST) has consistently called for better understanding of, and improvement in, the state of STI on the continent. These recurrent calls are embodied in the outcomes of AMCOST decisions over the past years. The ASTII initiative is a response to the AMCOST' quest, as it aims to address the lack of measurement of STI by member states of the African Union (AU) and build related indicators to inform policies at various levels of African leadership .

Over the last three years, 19 AU member states have implemented the ASTII initiative, namely: Algeria, Angola, Burkina Faso, Cameroon, Egypt, Ethiopia, Gabon, Ghana, Kenya, Lesotho, Malawi, Mali, Mozambique, Nigeria, Senegal, South Africa, Tanzania, Uganda and Zambia. The first phase of implementation was designed to serve as a learning phase based on the actual collection of R&D and innovation data through surveys. Participating countries undertook both the R&D and the innovation survey, or one of the two. The surveys were conducted between June 2009 and April 2010. The knowledge and experience gained will be consolidated to inform the roll-out of the surveys to further countries and increase the scope of the programme. Relevant STI statistics have been used to complement the outputs of the surveys conducted in this context, and the product is being published as the *African Innovation Outlook.*

This first edition of the *African Innovation Outlook* should be considered as the initial step in setting up a comprehensive series of STI indicators for Africa.

1.2 Genesis of the ASTII initiative

1.2.1 African Union Ministerial Conference in charge of Science and Technology

The African Union Ministerial Conference in charge of Science and Technology (AMCOST) is a policy and political forum at the highest level for ministers responsible for science and technology in all member states of the African Union. The forum is mandated to promote Africa's scientific and technological development and set continental priorities and policies pertaining to the development, harnessing and application of science and technology for Africa's socio-economic transformation. AMCOST functions through two subsidiary bodies: the AMCOST Bureau, which comprises five ministers responsible for science and technology, one from each of the five regional economic groupings of the African Union; and the AMCOST Steering Committee, which comprises ten permanent secretaries or their equivalents in the ministries responsible for science and technology, two from each of the five regional groupings in Africa. The following developments are worth noting:

- At the first AMCOST meeting (held in Johannesburg, South Africa in November 2003), African countries endorsed the compilation of indicators for scientific research, technological development and innovation activities. The meeting emphasised that, as a matter of priority, all countries should have comprehensive national STI policies with emphasis on the development of effective national systems of innovation (NSI) (NEPAD, 2003).

- The second Ministerial conference (held in Dakar, Senegal in September 2005) resolved that an intergovernmental committee be established to agree on a common framework for compiling STI indicators. The committee was mandated to oversee the development, adoption and use of common indicators to survey STI in Africa (NEPAD, 2005a). In response to that decision, the NEPAD (New Partnership for Africa's Development) Office of Science and Technology (OST) designed a programme for ASTII with the main goal of assisting AU member states to collect, analyse and use STI data. An experts' working group was created to provide intellectual support to the ASTII initiative.

- At its first meeting (held in Maputo, Mozambique in 2007), the Intergovernmental Committee on Science, Technology and Innovation Indicators resolved that: "African countries shall use the existing internationally recognised STI manuals and/or guidelines, particularly the Organisation for Economic Cooperation and Development's (OECD) *Frascati* (OECD, 2002) and *Oslo Manuals* (OECD/Eurostat, 2005) to undertake Research and Development (R&D) and Innovation surveys respectively. They may use these manuals, and experience gained in undertaking the surveys, to develop African STI manuals or guidelines." This decision paved the way for the implementation of the ASTII initiative (NEPAD, 2007). The intergovernmental committee has achieved its purpose, and the AMCOST Steering Committee now provides the initiative with a coherent course of action and direction for implementation.

- The third AMCOST meeting (held in Mombasa, Kenya in September 2007) urged NEPAD and the African Union Commission to work in collaboration and accelerate the implementation of ASTII.

- The fourth AMCOST meeting (held in Cairo, Egypt in March 2010) took stock of the progress that NEPAD had made in the first round in developing systems for collecting STI data in member states. AMCOST expressed its appreciation, noted the demand that the initiative had generated, and urged NEPAD to roll the programme out to countries that were not yet participating and to build on the lessons learnt from the work carried out.

1.2.2 Resource allocation

Support for the first phase of the ASTII Initiative came from various sources in both cash and in kind. In 2006, the Swedish International Development Cooperation Agency (Sida) provided a grant to the NEPAD Secretariat to cover the activities of a programme on "Governing Science, Technology and Innovation in Africa". This has thus far been the major financial contribution and has supported most of the activities carried out during the first phase. Kenya, South Africa and Ghana contributed to the initiative by providing their own resources for conducting national surveys. South Africa committed additional resources to the ASTII initiative, which were used to build the capacity of national survey teams in Malawi. All the countries that participated in the first phase contributed to ASTII by paying the salaries of the government personnel and employees of other national institutions who were involved in the national surveys. The countries also paid for the data infrastructure that was required at national level. The Chinese Academy of Sciences contributed by covering most of the in-country logistical costs of the ASTII team that visited China for a joint workshop on STI indicators.

In addition to the continued support of Sida for a three-year period and the commitment of member states to financing their surveys, it is also important to note the commitment by the Republic of Equatorial Guinea to hosting the African Observatory for STI (AU, 2009). These efforts demonstrate increased national ownership of ASTII.

1.3 Objectives of ASTII

As stated in the CPA, the overall goal of ASTII is to contribute to improving the quality of STI policies at national, regional and continental levels (NEPAD, 2005b). In order to achieve this goal, Africa's capacity to develop and use STI indicators needs to be strengthened. The initiative therefore focuses on the following four specific objectives:

- To develop and cause the adoption of internationally comparable STI indicators
- To build human and institutional capacities for developing and using STI indicators, as well as conducting related surveys
- To enable African countries to participate in international programmes for STI indicators
- To inform African countries on the state of STI on the continent.

1.4 Methodology

1.4.1 Scope of the first phase of ASTII

"Not every one who chased the zebra caught it, but he who caught it chased it", goes a famous African adage, conveying words of wisdom. The Inter-governmental Committee on STI Indicators (at its meeting in Maputo, Mozambique in October 2007) noted that a limitless number of indicators could be imagined and constructed in order to measure STI. However, the capacities to use the resources to collect relevant data, populate the indicators and interpret the results were very limited for the first round of a project of the magnitude of ASTII. This was the first time that a group of African countries had collectively embarked on the systematic collection of STI data. The committee therefore agreed to focus on well-established STI indicators (OECD, 2010) that could provide the basis for inter-country comparisons and for which well-defined methods of production were available.

NEPAD invited all member states of the AU that had completed, or were undertaking, political and economic governance reviews under the auspices of African Peer Review Mechanism (APRM) to submit statements of interest to participate in the project. The 19 participating countries already referred to submitted their statements of interest and were invited to establish national Focal Points to spearhead the indicator programme in their respective countries (NEPAD, 2007). The participating countries agreed to collect data and build the core indicators listed in the next section.

1.4.2 Core indicators

The following R&D indicators were selected as the core for the 2007 R&D surveys:

- Gross domestic expenditure on R&D (by source and sector of performance)
- R&D personnel by level of formal qualification and occupation, gender, headcount and full-time equivalent
- Researchers by gender and field of study/research
- Outputs: publications, patents.[3]

With respect to the innovation surveys, the countries agreed to adapt the Community Innovation Surveys (CIS) model with the following headings:

- Product innovation (goods or services)
- Process innovation
- Ongoing or abandoned innovation activities
- Innovation activities and expenditures
- Sources of information and cooperation for innovation activities
- Effects of innovation during the last two years

- Factors hampering innovation activities
- Intellectual property rights
- Organisation and marketing innovations.

1.4.3 Structures and functions of Focal Points

The organisation of survey processes in the context of ASTII required national coordination at each of the Focal Points. The Focal Points comprised those who were directly involved in administering the surveys, drafting national reports and developing inputs for the *African Innovation Outlook.* Each Focal Point therefore included experts from ministries in charge of STI, national statistical offices, local universities and research institutes, as well as the public sector. Close collaboration among national experts with diverse expertise was essential in order to enrich the debate leading to the surveys. The core functions of the Focal Points included the following:

- Being cross-sectoral, inter-ministerial and multidisciplinary
- Being able to convene meetings of all relevant stakeholders
- Having legislative, or at least administrative, authority to collect (or cause to be collected) statistics and to participate in national sectoral surveys of relevance to the ASTII initiative
- Possessing a critical mass of expertise for the development of STI indicators, or have the ability to mobilise such expertise from other institutions
- Being able to prepare (or cause to be prepared) national STI survey questionnaires
- Organising training for, and assembling, national teams to conduct surveys
- Entering into agreements with NEPAD on project-related matters
- Preparing and submitting to NEPAD authorised national STI surveys and/or indicators
- Participating in meetings of the Intergovernmental Committee on STI Indicators.

The Focal Points maintained strong links with their governments to ensure the relevance of the indicators in national policy formulation and implementation processes. The participation of the national statistical offices ensured the professional independence of the process and guaranteed the official character of the statistics (AU, 2007b).

1.4.4 Training for R&D and innovation surveys

A diversity of knowledge, skills and experiences is required to conduct R&D and innovation surveys effectively and provide policy-relevant advice. ASTII stresses the importance of the quality[4] of the survey statistics, which should be aligned with the African Charter on Statistics. To this end, NEPAD collaborated with competent institutions and organised four training workshops on various aspects of R&D and innovation indicators. The training sessions were based on the *Oslo* and *Frascati Manuals* as they relate to R&D and innovation surveys. Tutorials during the training sessions made use of the CIS questionnaires (OECD, 2008), the survey instruments developed by the Centre for Science, Technology and Innovation

Indicators (CeSTII) (2008) and a series of exercises prepared by the United Nations Educational, Scientific and Cultural Organisation's (UNESCO) Institute for Statistics (UIS) to compute full-time equivalents (FTE) (NEPAD, 2008). Participating countries agreed to adapt the South African survey instruments for their purposes as the questions were tested. The South African survey was also based on CIS, and the use of this model supported comparisons with countries outside Africa.

With regard to measuring R&D, the training focused, among other things, on problems of definition, sectoral classification and the measurement of R&D indicators; understanding R&D and related scientific activities; addressing challenges to measuring STI; and making sense of the input-output framework.

Participants were introduced to the methods used to achieve the following: profiling innovative firms, developing models to identify determinants of the decision to innovate, studying the relevance of particular factors that constrain or stimulate innovation at the firm level, relating firm-level performance to innovative behaviour, providing the basis for benchmarking innovative performance across sectors and countries, and analysing the impact of policies on such behaviour.

Relevant and practical statistical concepts that support R&D and innovation indicators were also introduced, including practical elements of sampling and sampling frames availability, weighting, sampling errors, the selection of unit of analysis, source of data, data collection, quality and storage of data, descriptive and inference statistics, matters of non-response, interpretation and reporting of results, and the metadata that underpin the construction of indicators.

At least two senior officials from each of the Focal Points attended the workshop. Afterwards, the trainees performed the role of trainers in their home countries. This training served as a forum for interaction between users and producers of R&D and innovation statistics.

Among the outcomes of the training workshops, the following are worth mentioning:

- R&D and innovation survey instruments were harmonised in order to ensure comparability of data among the participating countries.
- Data collected by the countries were discussed at the workshops in order to improve the flow of knowledge on R&D and innovation.
- A roadmap for the production of the *African Innovation Outlook* was agreed upon.
- Advice was provided on how to improve data quality.

Countries decided whether to conduct both the R&D and innovation surveys, or whether to undertake just one of the two surveys. The ASTII surveys were distributed as follows:

- Gabon, Ghana, Mozambique, Nigeria, South Africa, Tanzania, Uganda and Zambia decided to undertake both the R&D and innovation surveys.
- Cameroon, Kenya, Mali, Malawi and Senegal decided to conduct R&D surveys.
- Burkina Faso, Egypt, Ethiopia and Lesotho chose to conduct innovation surveys.

The results of the R&D surveys are presented in Chapter 3, and the results of the innovation surveys in Chapter 4. It should be noted that the results of the innovation surveys in Gabon and Nigeria were not ready at the time that this book went to press.

Challenges emerged during the implementation of the surveys, despite the training. The issues included the application of the guidelines recommended by the *Frascati* and *Oslo Manuals* to the context of the participating countries, the compilation of national aggregates for inter-country comparability and the limited available resources. Challenges with the R&D surveys are highlighted in Chapter 3, and challenges with the innovation surveys in Chapter 4. Overcoming these challenges and consolidating the experience gained will constitute the core business the forthcoming phases of the ASTII initiative.

1.4.5 ASTII faculty: a group of STI experts

During implementation, a group of dedicated STI experts, known as the ASTII faculty, provided ongoing advice to the Focal Points on various aspects of STI indicators. Among other things, the faculty participated in the design, selection and presentation of modules at the training workshops, and they served as resource persons on statistical methodologies and their application, which formed the basis for the construction of relevant R&D and innovation indicators.

1.4.6 Continental coordination

The structure for implementation of the project required national execution by the Focal Points. Continental collaboration for the formulation and coordination of the project was performed by NEPAD through the ASTII project office.

1.5 Why an *African Innovation Outlook?*

The *African Innovation Outlook* is an outcome of the ASTII programme. It presents R&D and innovation indicators on the basis of the surveys conducted by the national Focal Points. The indicators have been validated by the authorised national bodies. In addition, the *Outlook* contains complementary indicators extracted from STI and other relevant sources. In summary, the *Outlook* informs the people of Africa and other interested parties about STI activities in African countries.

Owing to the evident gap between the supply of, and the demand for, adequate STI statistics in Africa (NEPAD, 2005c), the *African Innovation Outlook* is an instrument that will assist African policy-makers to develop and implement evidence-based policies to advance STI for development. The *Outlook* will support the research community, the private sector and the African public at large in their decision-making processes. The *Outlook* will be available to the international donor community to optimise its investment in STI in Africa. An important sequel to the *Outlook* will be the establishment of an African Observatory for STI (AOSTI) (NEPAD, 2005d). As stated by Gault (2008, 2010), AOSTI will be the logical recipient of the aggregate data from the R&D and innovation surveys and a centre of analysis and publication.

The following examples (adapted from Gault, 2010) illustrate the use of the *Outlook* and the indicators it contains:

- The indicators could be used to monitor investment in STI by governments, businesses, development partners and civil society and to support the evaluation of public spending programmes.

- Benchmarking is an equally important use of the STI indicators, which could be used to set or monitor targets. An example is the target for AU member states to allocate 1% of gross domestic product (GDP) to R&D by 2010 (AU, 2007c). African countries could use the gross domestic expenditure on research and development (GERD) indicator provided by the *Outlook* (see Chapter 3) to benchmark their progress towards this target. It is important to note that benchmarking achieves the expected results if it is carried out within an appropriate context; an indicator taken out of context may be abused.
- STI indicators could be used to support strategic planning. This is a foresight undertaking, and African countries could use the *Outlook* in charting the trajectory of STI for development.

If the indicators are to be relevant, they must be embedded in the policy processes that they are meant to support. The production of indicators therefore requires continual dialogue between the users and producers of such indicators. In view of the differential stages of development of African countries, the local context must be taken into account in producing indicators. As stated by Freeman and Soete (2007): "indicators that served well in the past may be no longer as important as they were and they may even be misleading". The *Outlook* will provide African countries with the necessary tools to endogenise the development of STI indicators that are relevant to their socio-economic development.

1.6 Structure of the *African Innovation Outlook*

This first edition of the *African Innovation Outlook* contains six chapters.

Chapter 1 sets the scene and describes the genesis of the programme by stating its objectives and scope. The chapter also highlights the roles and structures of the national Focal Points that implemented the surveys, as well as outlining the essence of the *Outlook.*

Chapter 2 utilises the systems of innovation approach to development in an attempt to broaden the discussion of identified structural impediments to African economic growth and human development. The chapter argues that improving institutions, so that they become broadly participative, transparent and universal, is imperative in redressing the failures of the past and ending the inevitable continuities with path dependencies and trajectories. The chapter is structured around themes, including: demographics; economic sectors, diversity, growth and development; entrepreneurship; global competitiveness; industrialisation; the macro-economic environment; regional integration; STI institutions and policies; and the Millennium Development Goals.

Chapter 3 summarises the outcomes of R&D surveys conducted in Cameroon, Gabon, Ghana, Kenya, Mali, Malawi, Mozambique, Nigeria, Senegal, South Africa, Tanzania, Uganda and Zambia. The survey data were analysed and, where applicable, tables of relevant indicators were constructed. The indicators of interest include: gross domestic expenditure on R&D (by source and sector of performance); R&D personnel (by level of formal qualification and occupation, gender, headcount and full-time equivalent); and researchers (by gender and field of study/research). Shortcomings are highlighted with a view to improving the next round of surveys. Where data were not available or not compatible, a note to that effect was added.

Chapter 4 provides a view of what innovation is, for statistical purposes, and how it is measured. It then looks at the first results of surveys of innovation in selected countries.

Chapter 5 draws data from the Scopus database and presents a bibliometric analysis of scientific output in the 19 participating countries. It discusses the impact of historical influences, particularly colonial legacies, on science in many African countries and illustrates that the scientific effort in most of the countries reflects physical and material realities and challenges related to the three main areas of food security, disease control and industrialisation.

Chapter 6 provides an overview of the next steps for ASTII in its contribution to addressing the challenges to STI in Africa.

[3] Patents as R&D outputs are not discussed in this first *African Innovation Outlook*, but will be addressed in late editions.

[4] The African Charter on Statistics includes the following dimensions for the quality of data: relevance, sustainability, data sources, accuracy and reliability, continuity, coherence and comparability, timeliness, topicality, specificities and awareness-building.

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Chapter 2: Economic Growth and Human Development Challenges for Science, Technology and Innovation in Africa

2.1 Introduction

In virtually all economic development programmes across the globe, the primary objective is to improve the quality of life of the general population. Economic growth is generally assumed to fulfil that objective. In Africa, however, there is the increasingly widespread phenomenon of 'jobless growth' where economic growth rates have risen in recent years, unaccompanied by any significant improvement in most of the indicators of human development. In many cases, this phenomenon is associated with the natural resource trap that most of the countries on the continent seem to be locked in. The implications of increasing unemployment on human development, measured by the behaviour of human development indices across the continent, are obvious. The growing gap between Africa, and especially sub-Saharan Africa, and most of the rest of the world, not in growth rates but rather in the evolution of economic systems and the ensuing trading and investment patterns, is entrenching this decoupling of economic growth and human development within the structure of most African economies. The implications for development policy are still unclear. This chapter examines the relationship between growth and development from the perspective of systems of innovation and draws conclusions about the role of human development in economic development.

One of the possible reasons for the enduring low correlation between economic growth and human development is the divide between the goals and the instruments of the growth and development process. Most of the accepted measures of human development are usually couched solely as the objective of economic growth and development policy. Their attainment is seen as contingent on the successful deployment of conventional macroeconomic policy tools, along with industrial and trade policies. Where these objectives remain unattained for sustained periods of time, especially in developing contexts, remedial action is often designed outside the sphere of economic planning in order to alleviate extreme cases of human deprivation through social policy strategies.

It is generally acknowledged that economic policies across Africa, especially sub-Saharan Africa, have on the whole failed to address the human development challenge adequately. To a certain extent, the cause of this enduring failure can be traced to the lack of clarity about the underlying, contesting ideological bases of the various policy formulations. Given the deep divides in contending ideologies and the paradigmatic underpinnings of policies, it is quite important to be explicit about what we may term the various 'languages' of alternative sets of growth and development strategies. Failure to do so would result in a confusing Babel of paradigms within the same policy formulation, based on ad hoc and mostly unstated assumptions. When this happens, policy becomes fragmentary and ineffective in attaining its objectives.

In this chapter, a systems of innovation approach to development is used in an attempt to address these conceptual divides and propose a framework for the design of a new development path more conducive to human development in Africa. Most of the literature on innovation systems focuses on national systems of innovation, but we are acutely aware of the colonial definition of African nations that determined the post-colonial map of states across the continent. We are aware of the implications of this *ersatz* creation of political entities on the viability of national systems of innovation in Africa and hence of the need to transcend this construct and move to a continental system of innovation in the interests of creating a regional economy that is more feasibly conducive to people-oriented growth and development (Muchie, 2003; Scerri, 2003; Maharajh, 2008).

The concept of systems of innovation is subject to a range of definitions and interpretations. In the past, R&D surveys and, to a lesser extent, innovation surveys, restricted their analysis to formal institutional frameworks directly relevant to the production, diffusion and absorption of technological innovations. A more recent and broader approach has extended the definition of innovation to include organisational and institutional change (OECD/Eurostat, 2005) within an organic or evolutionary context of search under conditions of less than full and imperfect information. This broader approach brings to the analytical foreground the role of history in the particular systems that have evolved, and consequently highlights the specificity of individual systems (Lundvall, 1992; Cassiolato, Lastres & Maciel, 2003). The approach is broadened further according to the type of institutions that are considered to be relevant, which depends partly on the particular definition of innovation that is adopted. The narrower the definition, the more restricted the focus becomes to institutions that are directly relevant to technological innovation. The broader the definition of innovation, and hence of the system of innovation, the wider the range of institutions becomes that are considered as pertinent to the analysis of systems.

There is also a wide range of informal institutions, in the form of established routines, practices and social formations, which are brought into consideration when a broader definition of the system of innovation is adopted, especially in developing countries. In this context, history becomes strongly relevant to the analysis of systems of innovation. Informal institutions are defined in various ways, and it is certainly difficult to identify a particular practice or social formation as a valid object of analysis within an evolutionary analytical framework. The analysis of the effects of informal institutions on the evolution of national systems of innovation is also complex. Consequently, it is often difficult to formulate and deploy strategy to align informal institutions with national development objectives.

It is within the web of these informal and formal institutions that tacit knowledge is formed. In a world economy in which the effective cost of the mobility of resources is approaching zero and most codified knowledge is free and transferred virtually instantly and freely, it is ultimately tacit knowledge that defines the competitive advantage of nations and the specificity of their systems of innovation. We also need to keep in mind that the absorption and use of the freely available codified knowledge presumes human capital development, which is strongly influenced by context-specific pools of tacit knowledge.

2.2 Population and economic growth

From an innovation systems perspective, human capital forms the core of technological capabilities, broad-based absorptive capacity for innovation, core competencies and the competitive advantage of nations. In its original formulation, the concept of 'human capital' was presented as a means of placing the human element within a production framework. Within this construct, human beings are owners of their own capital, which essentially consists of knowledge and skills, which they proceed to 'rent' out on the market for a return. The stock of human capital is not regarded as constant, but may change due to investment and depreciation. Within the original formulation, education is considered to be the main determinant of the human capital formation process and to a certain, and possibly largely implicit, extent, the onus of human capital formation falls on the individual, or at most on the family unit.

However, the concept of human capital has evolved beyond its original simple neoclassical formulation. We therefore need to explore the various approaches to human capital development, paying special attention to the possible ideological underpinnings of this concept that could possibly have conflicting implications for development policy. Conventionally, the concept of human capital has been adopted, and perhaps even appropriated, by neoliberal ideology to shift the responsibility for human capital formation, and the appropriation of the returns on it, to the individual. From this perspective, human capital becomes almost indistinguishable from other types of capital, and every individual is consequently transformed into an owner of capital (in other words, a capitalist). However, human capital cannot be easily equated with other forms of capital (see Bowles & Gintis, 1975).

If we move away from a fully determinate production function construct, human capital formation becomes a social construct. The nature of its ownership, even in a democratic political economy, bears little relevance to the control over its deployment and over the returns on it. In other words, there is a substantive difference between wage employment and portfolio investment. The restrictive neoclassical and recent neoliberal appropriation of the concept of human capital has led to its repudiation by the more progressive schools of political economy and the proposal of 'human capabilities' (Sen, 1999) as an alternative contending construct. However, we feel that the original formulation of the concept of human capital is sufficiently malleable to extend its formulation to incorporate a whole gamut of social conditions as the determinants of the formation of human capital. We could further enhance the analytical tractability of this concept by considering it in conjunction with network capital and social capital in order to better capture the role of human capital, in its extended formulation, in the functioning and evolution of the national system of innovation. Considerations of class formations and other historical and cultural determinants of the inequality of access can thus be introduced to the analysis of human capital formation. This approach serves to fundamentally shift the ideological basis of the concept of human capital and hence render its application more appropriate in a development context.

We also need to differentiate between the various levels at which this concept applies. This depends primarily on the specific definition of the national system of innovation that is adopted. The further we move away from a narrow definition (usually reflecting the system of science and technology) to a broader one, the wider our definition of the concept becomes, both in terms of the range and levels of skills and knowledge that we consider and the determinants that we include. This introduces framework conditions such as the provision of education, healthcare and government support for training and life-long learning, as well as culture and history. Throughout the rest of the chapter, framework conditions, human capital and their role in development will be a recurring theme.

Our approach to the relationship between populations and economic growth stems from the adoption of what we have come to call ‘the knowledge economy’. In a number of respects, we are sceptical about the way in which the term is currently used, which often implies that this is a recent phenomenon. Instead we propose that knowledge has always formed the basis of economies. What may be specific to the modern age is the increasingly rapid acceleration of change in the knowledge base of economies and the increasing rapidity of techno-economic paradigm shifts (Freeman and Perez, 1988; Perez, 2009). Given the social and cultural grounding of systems of innovation, this also implies a rapidly changing web of informal institutions, as societies and cultures strain to adapt to rapidly shifting global environments. Again, culture and history act as framework conditions that influence human development.

An initial attempt at mapping the human capital contour of specific innovation systems would use demographics to provide the age segmentation and education profile of populations and then perhaps use these in a preliminary comparative study. The analysis could then become the basis for an assessment of the potential pool of human capital within a system, although it would not necessarily indicate the role of human capital in the functioning of the system. For that, an analysis would be required of the institutions that mediate between human capital and the specific system of innovation.

The African continent has one of the youngest populations in the world. Annex 1 lists the most recent Human Development Index (HDI) statistics for Africa, clearly indicating the weak HDI rank positions of all African countries. The continent hosts 19 of the lowest-scoring countries in the sample of 182 countries. The combination of the age distribution in Africa with the composite of life expectancy, education and per capita gross domestic product (GDP) provides a stark indication of the challenges, and simultaneously of the possibilities for the development of broad-based human capital on the continent.

The challenges are obvious: African countries have among the lowest life expectancies in the world; participation rates in schools are low; and, while GDP per capita may be high in a number of countries, this is often offset by the inequality illustrated by high Gini coefficients. The reasons for these constraints are numerous, but, whatever the historical origins, the result has been widespread institutional failure that has become self-reinforcing and self-perpetuating. From the perspective of the systems of innovation approach, this enduring shortfall in human capital poses the foremost obstacle to achieving a sustainable development process. It is here that the goals and the strategic instruments of development policy conflate and the apparent paradox arises that the achievement of the long-term objective of poverty reduction in its various facets depends upon the alleviation of the conditions of poverty in the short term.

It is impossible to imagine that development can occur without first addressing most of the factors used to determine the Human Development Index. At the same time, however, Africa’s young population of just over a billion (Ashford, 2007) could, given appropriate conditions for the guaranteed development of human and social capital, provide an impressive base for the development of economies within the continent and for the continent as a whole. Such a population would provide a strong stimulus to the development of the national and continental systems of innovation from both the supply side and the demand side. On the supply side, a young population with years of productive employment and learning ahead of it would provide the human capital base for the evolution of long-term viable systems of innovation, whether national or continental. On the demand side, a large internal population with rising incomes and quality of life would provide the scale of an internal market that has typically provided the basis for inward industrialisation as the precursor to the emergence of new, highly competitive economies, starting with Japan and the Asian Tigers, and more recently Brazil, China and India.

2.3 Science, technology and innovation: Institutions and policies

Within an economic context, science, technology and innovation (STI) usually refers to various aspects of technology and technological innovations. As long as the term is restricted to technology, the definition of STI institutions would be limited to formal institutions that are directly engaged in the production of technological innovations, such as R&D divisions within enterprises, the public sector and the tertiary education sector, as well as institutions that support technological innovation through incentives and training. On that basis, the definition of 'the national system of innovation' tends to be synonymous with 'the system of science and technology'. However, the consideration of systems of innovation as economic systems rather than technological systems has considerably widened the range of institutions, as well as the related policy terrains, that should now be included in the STI category.

The consideration of which institutions to consider as relevant to STI depends to a large extent on the definition of the national system of innovation that is adopted, and whether innovation is considered to be sectoral or broadly systemic. If the grounding of innovation (even if restricted to technological innovation) is seen as lying within the broad context of the political economy, the category of STI institutions widens to include aspects of policy that are ancillary to the S&T sector. If the concept of innovation is broad enough to encompass all change, and if systems are seen as being in a permanent state of flux, then it is difficult to set limits on what could be included as an STI policy or STI institution. Thus, for example, a decision to review state support for single-parent households has implications for the welfare and education of children, which in turn has inter-generational effects on the development of the broad human capital base, which in turn determines the long-term development of technological capabilities, core competencies and the competitive advantage of nations. This approach to planning is more difficult than segmenting the planning framework into clearly defined, and implicitly separate, sectors. However, we could also propose that the failure of development planning can often be traced to the inability to draw out the complex interdependencies of all the facets of national systems of innovation and consequently to predict comprehensively the effects of particular policy initiatives.

The common focus on the higher end of the capability spectrum (namely, scientists and engineers, R&D laboratories, technological creativity and scientific output) tends to reflect the system of science and technology more than the system of innovation. The range of institutions considered in innovation surveys reflects those that are directly engaged in one way or another with formal R&D (OECD, 1992; OECD/Eurostat, 1997, 2005). It is therefore possible for a distorted picture of the system of innovation to emerge. In developed industrialised countries, this distortion may not necessarily be problematic, since we can reasonably assume that the requisite institutional context is stable and suited for the translation of science and technology (S&T) activity into economic prosperity. In the case of developing economies, however, we cannot so easily make similar assumptions about the transmission mechanisms linking technological performance with economic development. Thus, for example, the pursuit of some goal regarding expenditure on R&D as a proportion of GDP as the benchmark for STI planning might, in the absence of appropriate sets of complementary policies, have little or no effect on the development process. In fact, the isolated pursuit of such an objective might set up a misleading diagnostic of the health of a particular system of innovation. It could also prove to be a poor indicator of the nature and extent of innovation in developing economies. The relationship between innovation activity that is captured by formal institutions, such as R&D laboratories and universities, and informal innovation might, for example, be such that too excessive a focus on formal institutions could seriously underestimate innovation activity. This is illustrated by the higher propensity to innovate than to conduct R&D in firms in most member countries of the Organisation for Economic Cooperation and Development (OECD) and in African countries covered in the *African Innovation Outlook* (see Chapter 4).

It was partly for this reason that the *Oslo Manual,* in its third revision (OECD/Eurostat, 2005), expanded the definition of innovation from one dealing only with products, and the transformation of inputs to products, to include industrial organisation, including the use of management practices and strategies, and market development. The word 'technological' was dropped from the definition. The *Manual* also made reference to the importance of framework conditions such as those resulting from regulation, history and culture. This change provided an explicit role for institutions of all kinds in the analysis of innovation and systems of innovation.

The spread of STI institutions across Africa is quite uneven, and probably becomes more so as the category of institutions that we consider as relevant widens. We can therefore map this distribution at various levels of inclusivity, until possibly we end up mapping the entirety of economic institutions of specific countries. As the complexity of our institutional mapping increases, so would the probability of unevenness in the institutional map of the continent. The same applies to STI policies. As the definition of policies that are relevant to the evolution of systems of innovation grows, so does the level of complexity of the interaction among policies and the degree of differentiation among systems of innovation across Africa.

2.4 Role of science, technology and innovation in development

Broadly interpreted, STI is now accepted as the foundation of economic change (Dosi *et al.*, 1988; Freeman, 1993; Lundvall, 1992; Nelson, 1993; OECD, 1997; Cassiolato *et al.*, 2003; Muchie, Lundvall and Gammeltoft, 2003; Maharajh, 2008; among others). This is, however, a relatively recent development in economic theory. The focus on innovation as the engine for economic change had its heyday with Schumpeter's extensive incorporation of innovation, defined to include considerably more than technological innovation, in his theory of economic cycles. This was the culmination of the positioning of technological change among a number of classical economists, including Adam Smith, Friedrich List and Karl Marx. However, with the emergence of the neoclassical model as the dominant economic paradigm, the analysis of innovation and its role in economic dynamics was considerably impoverished. This was due to the extremely restrictive assumptions of neoclassical economics, particularly with respect to the full and perfect information context within which economic agents made their constrained optimisation decisions.

Given the obsession of this paradigm with finding determinate and unique solutions to fully specified models, there was little scope for the analysis of technological change in any but the most stylistic but analytically empty fashion.

The resurgence of interest in the nature of innovation and its role in economic change came about in the late 1960s and 1970s due to the rapid growth in Japanese productivity, which on many fronts was outstripping the USA (Freeman, 1987). This gave rise to a wave of research aimed at pinning down the residual thrown up by Solow's (1956) analysis of US productivity based on production function. The re-emergence of evolutionary economics and the national systems of innovation stemming from that began with the works of Nelson and Winter (1982) and culminated in the collection of works edited by Dosi *et al.* (1988) towards the end of the 1980s and the work of Lundvall (1992) and Freeman (1993) in the early 1990s. Since then, the concept has led to the expansion of R&D surveys based on the *Frascati Manual* (OECD, 2002) to innovation surveys guided by the *Oslo Manual* (OECD, 1992, 1997; OECD/Eurostat, 1997, 2005), which led to the first Eurostat Community Innovation Surveys (CIS). The CIS template has been revised several times since the early 1990s. Five CIS surveys have been carried out since 1992, and adaptations have been suggested to extend the capturing of innovation activities, incorporating service innovations, organisational change, management practices, design and marketing.

Attempts have also been made to render this instrument more appropriate to the conditions of developing economies (see Blankley *et al.*, 2006, for some of the debates on the relevance of the CIS in developing country contexts). The adoption of innovation surveys and of STI indicators measured in these surveys has been rapid across industrialised economies but relatively slow in developing economies, although we must be careful not to lump developing economies into a single category. Generally speaking, the propensity to survey innovation in specific countries depends on the countries' state resources and administrative capacity, as well as on the extent to which innovation is prioritised in the national policy framework. In poorer countries, the combination of these two factors usually militates against surveying. A possible way of addressing this would be to make innovation more prominent in the policy-makers' environment through a comprehensive re-articulation of the nature of innovation and its role in the development process. In that way, the adoption of the broad definition of innovation assumes added pragmatic and strategic value beyond its theoretical rationale.

In the relatively sudden rush to adopt the national systems of innovation concept in economic planning, however, there has been a tendency to fail to distinguish adequately between different categories of economies and to forget that development implies more than simply growth along a given trajectory. Almost by definition, development also requires changes in structures that are seen to be unsuitable for the requirements of raising the quality of life of populations to acceptable and sustainable levels. From this perspective, there is always the possibility, and perhaps even the probability, that STI, while being a stimulus to economic growth, may serve to entrench current structures that are not conducive to the requirements of the development process, especially in cases of strong knowledge and technology dependence. It is in such cases, where the adoption of the national system of innovation concept reflects primarily the system of science and technology, that the phenomenon of jobless growth is usually encountered. STI can only be used as the lever for structural transformation if it is engaged within a planning context designed to alter historically determined structures. This, in turn, can only be done through the recognition of the historical and structural specificities that form the basis of the concept of national systems of innovation.

2.5 Diversification of African economies

The foundation for a successful process of economic integration lies in the degree of diversity of the economy and the production base of the prospective participant countries. The relationship of diversity may lie across several axes. These could be primary producer economies with manufacturing-based economies; manufacturing economies among themselves; service sector-based economies with both primary and secondary sector-based economies; as well as with other service-based economies. The rationale underlying this base for integration lies in the requirement for the existence of different reciprocal markets for trade and investment among the prospective partner countries, as well as for the flow of knowledge and human capital. The relationship between primary producers is the least likely of all the possible partnership combinations among trading and investment partners to exhibit diversity and complementarities. A group of primary producers is most likely to trade with and draw investment from countries outside the group.

The neo-colonial experience and the post-colonial heritage of the African continent have, as already indicated, locked most African economies into the natural resource trap. Relatively speaking, South Africa has a national innovation system with a structurally different base from the rest of the sub-continent and the continent as a whole. However, the relationship of the South African economy with the non-African global economy still positions it as a peripheral trader, with a competitive advantage in the primary sector, but importing commodities that require a high intensity of skills and knowledge to produce. The degree of diversification among African economies is low (see Table 2.1) and affords limited opportunities for intra-African trade in comparison with trade flows between the continent and the rest of the world. This is mitigated to some extent by the entry of the post-apartheid South African economy as a legitimate member of the African Union. South African investment across Africa has risen remarkably since 1994, as have its exports of skills and knowledge-intensive goods and services to the rest of the continent. Within the sub-continent and Africa as a whole, South Africa has therefore assumed a central economic position. However, this asymmetry creates problems for the integration of economies in Africa, as will be discussed further on.

Table 2.1: Sector share of change in real GDP for Africa (2002–2007)

Sector	Percentage
Resources*	24
Wholesale and retail	13
Agriculture	12
Transport, communication	10
Manufacturing	9
Financial intermediation	6
Public administration	6
Construction	5
Real estate, business services	5
Tourism	2
Utilities	2
Other services (education, health, household services and social services)	6

Note:
100% = US$235 billion
* Government spending from resource-generated revenue contributed an additional eight percentage points.

This similarity in economic structures, in the narrow export base and in competitive capabilities based on natural-resource endowments, limits the scope for complementarities in production and consumption. This explains how South Africa, the new arrival on the continent, with its relatively highly diversified production base, has rapidly assumed its dominant role as the major exporter across Africa, particularly in sub-Saharan Africa. The general similarity of economic structures in most African states thus severely constrains the potential for trade and cross-border investment, except for a small group of economies. Leke *et al.* (2010) identify four countries on the continent as having diversified economies and regard these as 'Africa's growth engines', namely, Egypt, Morocco, South Africa and Tunisia, stating that these countries:

> … are already broadly diversified. Manufacturing and services together total 83 percent of their combined GDP. Domestic services, such as construction, banking, telecom, and retailing, have accounted for more than 70 percent of their growth since 2000. They are among the continent's richest economies and have the least volatile GDP growth. With all the necessary ingredients for further expansion, they stand to benefit greatly from increasing ties to the global economy. (Leke *et al.* (2010: 7)

These countries, with structures that demonstrate several of the conditions for take-off into sustained growth and development, represent just over 17% of the population of Africa (calculated from the demographic statistics in the *African Statistical Yearbook* [AfDB, 2010]).

The oil producers on the African continent are Algeria, Angola, Chad, Republic of the Congo, Equatorial Guinea, Gabon, Libya and Nigeria. The share of manufacturing and services in the GDP of these countries is not only considerably lower than in the diversified economies on the continent, but also significantly lower than in other major oil exporters across the world. The economic fortunes of these countries are therefore strongly tied to the global market price for oil. Other countries that are virtually single-commodity producers are Zambia (copper) and Mozambique (aluminium). Some countries (such as Cameroon, Ghana, Kenya, Senegal, Tanzania and Uganda) are at different stages of early economic diversification. Other economies (such as the Democratic Republic of the Congo, Ethiopia, Mali and Sierra Leone) are still caught in an extreme poverty trap.

The proportion of diversified economies on the continent (four out of 52) is worryingly low and will have to rise significantly and rapidly to provide the basis for a feasible programme of continental integration. The geographic distribution of the 'growth engines' on the continent is also particularly perturbing, since it reinforces the divide between Northern Africa and sub-Saharan Africa, which will be discussed further. Effectively, if the continent is divided into two regions, radically different development trajectories can be observed, with only one diversified economy within sub-Saharan Africa, certainly not enough to act as the base for the intra-regional, multidirectional trade and investment flows that would form the fabric of an integrated regional system of innovation.

Tables 2.2 and 2.3 depict Africa's export and import flows with itself as a proportion of its total export flows. In both cases, the intra-African trade is miniscule compared with its trade with the rest of the world. The averages for the period 2000–2007 are 8.5% for intra-African exports as a share of the continent's total exports, and an average of 9% for the equivalent indicator for imports. These figures have remained quite stable over the eight-year period under consideration.

Table 2.2: African exports (US$ millions) (2000–2007)

	2000	2001	2002	2003	2004	2005	2006	2007	Average 2001–2007
A	12 044	11 438	13 130	15 603	19 196	23 215	28 050	35 573	19 781
B	153 435	134 841	141 167	173 467	222 532	286 063	347 875	400 906	232 536
C	2.4	2.2	2.2	2.3	2.4	2.7	2.9	2.9	2.5
D	7.8	8.5	9.3	9.0	8.6	8.1	8.1	8.9	8.5

Source: ECA (2009)

Note:

A=Intra-African exports

B=African exports to the world

C=Africa's share of total world exports (%)

D=Intra-African exports as a share of African exports to the world (%)

Table 2.3: African imports (US$ millions) (2000–2007)

	2000	2001	2002	2003	2004	2005	2006	2007	Average 2001–2007
A	11 631	12 466	13 224	15 572	20 994	24 854	31 660	39 565	21 246
B	133 416	129 508	144 445	176 929	232 189	273 509	329 785	418 931	229 839
C	9	10	9	9	9	9	10	9	9
D	6 653 669	6 414 806	6 664 703	7 771 121	9 462 990	10 776 488	1 237 928	14 056 584	9 267 286
E	2	2	2	2	2	3	3	3	2

Source: ECA (2009)

Note:

A=Intra-African imports

B=African imports from the world

C=Share of intra-African imports to Africa's total imports (%)

D=World imports

E=Share of Africa's imports in world imports (%)

The diversification of African economies away from the primary sector is therefore not only required for the structural transformation of the internal economy, but is also a pre-requisite for the development of an integrated regional market for goods and services, as well as for financial and physical capital, and labour (human capital). In turn, we may argue that the absence of an integrated economic region poses one of the more formidable obstacles to the diversification of the bases of individual national systems of innovation. We thus find ourselves in a double bind, and specific policies are required to break the mutually constraining forces of local structures and regional contexts. These include policies to encourage diversification, trade and mobility, coupled with human resource development to provide the skilled labour required for diversification and the market for the resulting goods and services, which could lead to increased trade within Africa.

Table 2.4: Intra-African trade by economic grouping (2008)

Economic grouping	AMU	CAEMC	COMESA	ECCAS	ECOWAS	FRANC ZONE	SADC	WAEMU	Africa	World
Imports from (%)	(% of total imports)									
AMU	4.8	0.2	1.7	0.2	0.9	0.8	0.1	0.6	6.7	100.0
CAEMC	1.2	2.6	0.6	3.2	2.6	3.7	1.0	1.1	7.6	100.0
COMESA	1.8	0.1	3.7	1.0	0.2	0.2	2.7	0.1	7.4	100.0
ECCAS	0.5	0.9	1.2	1.3	0.9	1.3	7.8	0.4	10.5	100.0
ECOWAS	0.5	1.3	0.2	1.5	7.4	5.6	2.0	4.3	11.2	100.0
FRANC ZONE	1.1	1.5	0.5	1.9	9.8	6.5	0.9	5.1	13.3	100.0
SADC	0.2	0.1	6.0	1.9	1.2	0.4	9.8	0.2	12.4	100.0
WAEMU	1.0	1.0	0.5	1.4	12.9	7.8	0.9	6.8	15.9	100.0
Africa	1.6	0.5	3.0	1.2	2.3	1.7	3.7	1.2	9.3	100.0

Economic grouping	AMU	CAEMC	COMESA	ECCAS	ECOWAS	FRANC ZONE	SADC	WAEMU	Africa	World
Exports to (%)	(% of total exports)									
AMU	2.5	0.1	1.2	0.1	0.6	0.5	0.1	0.4	3.9	100.0
CAEMC	0.3	0.8	0.2	1.0	0.9	1.3	0.3	0.5	2.4	100.0
COMESA	1.6	0.1	4.3	1.1	0.2	0.2	3.1	0.1	8.0	100.0
ECCAS	0.1	0.3	0.4	0.5	0.4	0.5	2.9	0.2	4.0	100.0
ECOWAS	0.3	1.4	0.2	1.6	8.0	5.9	2.1	4.6	11.7	100.0
FRANC ZONE	0.7	1.2	0.4	1.5	7.9	5.3	0.7	4.1	10.5	100.0
SADC	0.3	0.1	6.1	1.9	1.2	0.4	9.9	0.2	12.7	100.0
WAEMU	1.9	2.1	1.1	3.1	28.3	17.1	2.0	14.9	34.4	100.0
Africa	1.2	0.4	2.8	1.2	2.3	1.6	3.5	1.2	8.5	100.0

Source: *African Statistical Yearbook* (AfDB, 2010)

Note:

AMU (Arab Maghreb Union)

CAEMC (Central African Economic and Monetary Community)

COMESA (Common Market for Eastern and Southern Africa)

ECCAS (Economic Community of Central African States)

ECOWAS (Economic Community of West African States)

FRANC ZONE (Communauté Financière Africaine)

SADC (Southern African Development Community)

WAEMU (West African Economic and Monetary Union)

Table 2.4 shows intra-African trade flows by regional economic communities and provides a useful picture of the enduring lack of a sufficiently sound trading base for economic integration on the continent. Conversely, the existing trading patterns within the internal African market, which show that less than 10% of all trade requirements are catered for internally, provide a strong indication of the possibilities for internal trade, given a coherent drive towards the diversification of the production base across the continent.

The investment linkages among African economies, compared to those with the rest of the world, are also still weak. As Page and De Velde (2004: 20) point out:

> Most investment in Africa does not come from other African countries, because of the important shares of the EU and the US. Total inward stocks are $167 billion, dwarfing total African outward investment of $40 billion. Perhaps more surprisingly, most African investment does not go to other African countries because of the very high share of South African investment which goes to the EU. This was $15 billion in 2002, i.e. over 40% of total African outward stock. In addition, $2.3 billion of South African investment was in the US and 0.7 billion in Australia, another 10%. Only $1.4 billion of South African outward stocks were in other African countries, accounting for 3.6% of total African outward stock, and under 1% of total African inward stock.

To a large extent, intra-African foreign direct investment (FDI) is limited by the investment constraints of relatively undiversified economies, but there is still scope for an expanded set of investment linkages, given the low proportion of Africa-directed FDI within Africa's total outward FDI. The promise of the large internal market for economies of both scale and scope applies also to innovation and the possibilities of developing appropriate innovation for large internal markets.

2.6 Macroeconomic conditions and policy

If the theoretical base for understanding economies and the development process shifts from orthodox neoclassical economics to political economy framed within an evolutionary articulation, the identification of the economic 'fundamentals' shifts accordingly. Following Nelson (1993), Freeman (1993) and Lundvall (1992), the fundamental determinants of the long-term structural transformation process required for sustainable development that equitably enhances the quality of life of the population relate more to the appropriate conditions for improving learning outcomes and capability formation at the base of the economy. From this perspective, fiscal and monetary policies become the supporting policy tools for this long-term process. In this case, it may well be decided that appropriately conceived and implemented redistribution would take precedence over growth-driven policy options. The development of sound governance and a healthy and participatory civil society, and the fostering of an economic as well as constitutional democracy, would be brought to the fore of the planners' canvas, drawn in as legitimate tools of economic policy instead of being relegated to the spheres of social and administrative policy.

The post-colonial state is often referred to with the implication of commonalities, or even homogeneity, among previously occupied territories, which is at odds with the range of diversity among the nation states that emerged after 1945. This diversity is reflected in the examples of successful development of various types and to several degrees as well as those of failed development, mostly within Africa and Western Asia. The examples of successful development have been associated, almost inevitably, with those cases where the support of human capital development, in its various forms, was at the centre of policy. In such cases, sustainable international competitiveness was based on productivity gains rather than overtly cheap labour. The conventional tools of economic policy in such countries have consistently been used in a supportive manner in a long-term programme of sustainable development.

The requirements of the modern learning economy, as the foundation for the successful evolution of the system of innovation, include a shift in policy focus away from the standard macroeconomic policy tools. The focus has to move to those areas of policy that directly affect the conditions of the institutional context in which human and social capital growth can be secured. In this sense, distribution issues and sustainable programmes of poverty alleviation assume a high level of priority in the ranking of policy tools.

2.7 Economic sectors and priorities

One of the earliest debates in development economics concerned the priorities assigned to economic sectors in investment allocation and the application of stimulus packages. The debate related essentially to the two camps of balanced and unbalanced growth approaches to the 'big push' theory of economic development (see Rosenstein-Rodan, 1943 and Hirschman, 1958). While both sides of the debate agreed that an incremental policy was unlikely to lift underdeveloped economies out of low-level equilibrium poverty traps, their proposals for the deployment of resources to implement the 'big push' were diametrically opposed.

The balanced growth proponents focused on the interdependence of sectors, especially in terms of consumption power, within a closed-economy framework. Those who advocated the unbalanced approach departed from the assumption of limited resources, not least of which was decision-making capabilities, or Hirschman's 'ability to invest' (Hirschman, 1958), and advocated the 'big push on a narrow front' with priorities assigned on the basis of industrial linkages, and potential spillover and multiplier effects. This early approach to the prioritisation of state intervention has been refined to reflect the increasing rapidity of techno-economic paradigm shifts, which make it increasingly difficult to predict future states on the basis of current ones. Moreover, there is growing realisation that over-reliance on existing inter-industry linkages, which has led to the increasing popularity of cluster analysis, may sometimes lock economies into the industrial development paths that reproduce current structures. Often what is needed when assigning development priorities is an exercise in 'imagining the future', as exemplified in foresight planning.

2.8 Attainment of the Millennium Development Goals

From an innovation system approach, the Millennium Development Goals (MDGs) are a mix of development goals and instruments, and it would be useful to couch them as part of the array of development instruments. There is, however, scope for an elaboration of the possible inter-linkages among the eight MDG sets, possible sequencing chains, and the strata of the national system of innovation with which they are most likely to engage.

From a system of innovation perspective, the first of the eight MDGs (to eliminate poverty and hunger) can be seen as the overriding objective, with most of the others as policy instruments. Thus, education, gender equality and the three goals referring to various aspects of health can be considered essential prerequisites for the development of a sustainable human capital base on which a viable innovation system can be built. The goal referring to global partnerships relates to aspects of the globally integrated economy that can be brought to bear to ease some of the crippling constraints of the global economic order on the development of poor economies. Social or network capital is also an issue here in addition to the development of human capital. Finally, the goal on environmental sustainability reflects the increasing concern of the world economy over the need to decouple economic growth and development from environmental degradation. This goal does not have a direct effect on the development prospects for poor nations, but may even, from several perspectives, be regarded as a constraint. Alternatively, addressing the environmental implications of industrialisation offers a strong incentive for the development of appropriate technologies, thereby enhancing local systems of innovation.

The progress chart for selected MDG targets in Northern Africa and sub-Saharan Africa is depicted in Table 2.5.

Table 2.5: Progress chart for Africa towards the Millennium Development Goals: Selected targets and indicators (2009)

Goal	Objective	Indicators/Targets for 2015	Northern Africa	Sub-Saharan Africa
1	Eradicate extreme poverty and hunger	*Reduce extreme poverty by half*	Low poverty	Very high poverty
		Productive and decent employment	Very large deficit in decent work	Very large deficit in decent work
		Reduce hunger by half	Low hunger	Very high hunger
2	Achieve universal primary education	*Universal primary schooling*	High enrolment	Low enrolment
3	Promote gender equality and empower women	*Equal girls' enrolment in primary school*	Close to parity	Close to parity
		Women's share of paid employment	Low share	Low share
		Women equally represented in national parliaments	Very low representation	Low representation
4	Reduce child mortality	*Reduce mortality of under five-year-olds by two-thirds*	Low mortality	Very high mortality
		Measles immunisation	High coverage	Moderate coverage
5	Improve maternal health	*Reduce maternal mortality by three-quarters**	Moderate mortality	Very high mortality
		Access to reproductive health	Moderate access	Low access
6	Combat HIV/AIDS, malaria and other diseases	*Halt and reverse spread of HIV/AIDS*	Low prevalence	High prevalence
		Halt and reverse spread of tuberculosis	Low mortality	High mortality
7	Ensure environmental sustainability	*Reverse loss of forests*	Low forest cover	Medium forest cover
		Halve proportion without improved drinking water	High coverage	Low coverage
		Halve proportion without sanitation	Moderate coverage	Very low coverage
		Improve lives of slum dwellers	Moderate proportion of slum dwellers	Very high proportion of slum dwellers
8	Develop a global partnership for development	*Internet users*	Moderate usage	Very low usage

Sources: Derived from ECA, AUC & AfDB (2009) and Statistics Division, Department of Economic and Social Affairs, United Nations

Notes:
The words in each box indicate the present degree of compliance with the target. The colours show progress towards the target according to the legend:

- Green: Already met the target or very close to meeting the target
- Light blue: Progress sufficient to reach the target if prevailing trends persist
- Orange: Progress insufficient to reach the target if prevailing trends persist
- Red: No progress, or deterioration

* The available data for maternal mortality do not allow a trend analysis. Progress in the chart has been assessed by the responsible agencies on the basis of proxy indicators.

The trends in the movement of selected variables towards the specified MDGs, as shown in Table 2.5, highlight two immediate points. The first is that in terms of dynamics, the two regions of Northern Africa and sub-Saharan Africa are markedly different, to the extent that structural differences in the base of the national systems of innovation between the two regions may be deduced. There is a historical rationale for the treatment of the two regions as separate and distinct, related to the nature of their colonisation and the ensuing post-colonial states. The colonisation of Northern Africa was primarily driven by the strategic imperatives of the various colonial powers. That of sub-Saharan Africa was motivated more by the resource requirements of the empires. This possible structural difference poses a serious challenge to an effective programme of regional integration across the African continent. At the same time, however, if systematically addressed, it also offers the possibility of increasing the complementarities of systems of innovation across the continent.

The second point is that the current trends indicate that sub-Saharan Africa will not achieve any of the MDGs along the current trajectory paths for reasons that relate to some extent also to the differences in the colonial histories of the two African regions. In a dynamic world, this implies an ever-growing gap between sub-Saharan Africa and the rest of the world. The linkages between a sound STI policy and the attainment of the MDGs are quite evident, especially if the definition of STI is extended to the institutional and technological domains. The attainment of most of the MDGs requires innovation at the technological level; it also requires innovation on the institutional front in education, health and international partnerships. It is obvious that these innovations, especially at the institutional level, have to be radical, given the current deficit of the existing development trajectories with respect to the MDGs.

2.9 Global competitiveness

In the era of unprecedented global liberalisation of trade, investment, human capital and knowledge flows, the drive for nations to be globally competitive has novel implications for the evolution of national systems of innovation. Prior to the current globally integrated economic regime, the typical successful development path was generally based on the policy prescriptions of List's (1848) infant industry model. The successful adoption of this policy accounted for the emergence of the Asian Tigers and the newly industrialised economies in the 1970s. The sheer size and economic power of the Chinese economy and its steady process of reform since the late 1970s is a specific case of development on the basis of local competence-building as the platform for global competitiveness. The case of India provides a similar example of the emergence of a globally competitive giant with the liberalisation of the economy since the 1990s, preceded by a long period of protected inward industrialisation. The Indian case is especially interesting because of its implications for the potential to develop technological capabilities, core competencies and competitive advantages on the basis of the internal market.

This option is now closed for most African economies. Their poorly developed industrial base, small populations with limited purchasing power and an impoverished reproductive base for human capital development strongly militate against their chances of developing sufficient local competence in the free trade era. Individually, the internal economies of most African economies are far too small and their institutions too poorly developed and unstable to offer much hope for development. If, however, we look at the continent as a whole from an innovation systems perspective, possibilities for escaping the poverty trap arise, in spite of the formidable political and institutional obstacles to viable integration. This is a case where the necessary overrides the improbable, as argued by Muchie *et al.* (2003).

2.10 Industrialisation and entrepreneurship

The issue of entrepreneurship and its relationship to the industrialisation process has occupied the attention of development planners, but the lack of debate on the meaning of the concept and an understanding of its role in the evolution of systems of innovation is often the source of grave mistakes in policy-making. Entrepreneurship has been one of the main areas of focus of the debates on growth and development strategies, which have often assumed certain market conditions that have not always been supported by evidence. Often, this excessive focus on entrepreneurship is used in the drive for the development of the small, medium and micro enterprise (SMME) sector and even of the informal sector as the panacea for countries' development problems. Such an approach can be quite dangerous, and we need to unpack the various shades of meaning of this term and the role of this factor in industrialisation and development.

In the first place, the term 'entrepreneurship' is often used synonymously with the enterprising and innovative qualities, whether actual or latent, of virtually all human beings. When linked with the neoliberal formulation of human capital, an all-embracing definition of entrepreneurship is brought into service in advocating the predominance of individual over public responsibility in the economic growth and development process.

Innovation does indeed happen within enterprises and is the outcome of entrepreneurial activity, but the foundation for the translation of entrepreneurship into innovation and sustainable industrialisation lies in the existence of a broad base of highly skilled, enterprising, but risk-averting employees (see Coase, 1937). Given this prerequisite, history, including very recent history, has also taught us that the translation of entrepreneurship into general welfare also requires a comprehensive and effectively enforced regulatory framework supporting human resource development and value creation.

Africa does not lack entrepreneurs or individual enterprise. Of course, most of those who behave as entrepreneurs do so because of the lack of alternatives, forced by economic circumstances, political instabilities and general institutional failure. It is not so much entrepreneurship that needs to be promoted in sub-Saharan Africa as the solid institutional foundation within which entrepreneurship can be leveraged to stimulate the type of industrialisation process required for structural transformation and development.

2.11 Regional integration

Given the history of Africa, the specificities of sub-Saharan Africa, and the congruence of factors which, in the post-colonial period, now render most autonomous national systems of innovation non-viable, there is a need to reflect more deeply on the possible benefits of integrating African economies on a systemic basis. From an innovation systems approach, this implies the need to transform the region from a set of disparate national systems of innovation into a continental (or at least sub-continental) agglomeration. The first stage of this transformation requires the mobility of people and resources, as well as information across current national borders. Beyond this, however, a sustainable continental system of innovation requires the integration of the particular national legal frameworks in sectors such as finance, labour, industry and the environment.

Article 1 of the African Economic Community Treaty of 1991 recognises the importance of regional integration in order to increase economic self-reliance and promote endogenous, self-sustainable development of the African continent. This is complemented by Article 51, which urges institutions to strengthen their capabilities and cooperation in order to use science and technology to improve the quality of life of the citizens of their countries (OAU, 1991). These processes, if applied appropriately, are essential for a more functional system of innovation. The essence of this Treaty has been captured in sub-regional and continental agreements. The African Union (AU) Strategic Plan 2010–2012 is aimed at strengthening continental integration through measures such as the harmonisation of the regional economic communities and free movement of people, goods, capital and service (AUC, 2009).

The current strategic transition from the NEPAD (New Partnership for Africa's Development) Secretariat to the NEPAD Agency has brought about a revised *modus operandi* whereby sectoral approaches have been enhanced by programmatic and results-based management. While the NEPAD-identified sectors[5] have remained unchanged, the new approach requires the Agency to ensure delivery in a more integrated manner on five themes[6] linked to the four pillars of the AU Strategic Plan (AU/NCPA, 2010).

NEPAD's new approach is well aligned with the MDGs and establishes a sound foundation for the development of regional systems of innovation, which are now recognised as essential to enabling structural transformation and economic development. It also poses challenges to all continental institutions to translate policy directives into meaningful programmes with positive outcomes.

Equally important has been the recognition of the role of science and technology in the context of regional economic integration. This has been spelt out in the SADC Science and Technology Protocol (SADC, 2008), by the Commission of the Economic Community of West African States responsible for Human Development and Gender (ECOWAS, 2007) and in the Treaty for the Establishment of the East African Community (EAC, 2007), among other initiatives. Much work has still to be done in creating and capacitating these bodies, which are the essential building blocks of the African Union.

Notwithstanding these initial efforts towards regional integration, most of the African economies remain largely resource-based. In the current geopolitics of world trade, most African countries export their natural resources to the more industrialised world with minimal value-added content, while simultaneously importing capital goods and consumer products. This inequitable scenario does not enhance the prospects for regionally integrated systems of innovation. It is of paramount importance that better intra-system flows of trade, investment and, more especially, technological upgrading must serve to benefit all participants. This virtuous cycle becomes possible through improvements in the generation, adoption, diffusion and contextually relevant transformation of knowledge to meet local demands and address domestic challenges. The breaking of this particular development trajectory rests crucially on effective strategy to integrate the systems of innovation across Africa. We have already seen the marked differences in economic performance between Northern Africa and sub-Saharan Africa. These differences offer the possibility of enlarging the internal trading and investment base of the eventual continental system of innovation.

The issues of scope and scale on both the supply and the demand sides of the system of innovation within Africa suggest that the various national systems of innovation on the continent should move as rapidly as possible to an integrated continental system of innovation. This is an area for further research in subsequent phases of the ASTII initiative.

The arguments in this chapter support the development of Africa's continental system of innovation as a feasible, long-term strategy to attain a sustainable dynamic of development. In this context, improving the functioning of national systems of innovation should serve to radically enhance human capabilities and improve production processes. Regional integration offers the prospect of quantitatively expanding competencies towards the continental system of innovation though policy experimentation and learning by doing.

2.12 Conclusions

Africa, in 2010, is host to a significant share of the world's human population. In the millennia since Africa acted as the cradle of humanity, the continent has suffered through protracted periods of dependence and underdevelopment. While the yoke of colonial and imperial subjugation has largely been overcome, contemporary Africa remains divided into 54 sovereign national entities. It is home to the largest number of least-developed countries and, while certain of the Millennium Development Goals will be achieved, over half its population struggles to survive in conditions of abject poverty. However, the sustained growth over the last decade and a half has started to generate positive outcomes for the continent.

Structural impediments such as low levels of infrastructure, adverse economic participation rates and the lack of regional economic integration remain worrying features of the current growth trajectory. Moreover, the continued external demand for commodities tends to reinforce distorted markets. Unless deliberate efforts are made to encourage and expand endogenous economic growth by improving the framework conditions for innovation, Africa may not be able to harvest the potential of the demographic boom represented by its young population. Approaching the relationship of economic development from the systems of innovation perspective accentuates the critical role of institutions and human capabilities as drivers of change.

Improving institutions, so that they become broadly participative, transparent and universal, is imperative in redressing the failures of the past and ending the inevitable continuities with path dependencies. This chapter has argued in favour of a form of structural transformation that has, at its core, the progressive dynamics of Schumpeter's creative destruction. This necessitates the stimulation of technological progress, the improvement of human capabilities and the promotion of framework conditions that support the entry and exit of activities. Given the appropriate institutional context, entrepreneurship at all scales (in micro, small, medium and large enterprises) has the potential to meet the huge demands of the continent and its population of over one billion. Legitimate, participative governance, strengthened through an innovation systems policy perspective, will also improve social cohesion by reducing uncertainties and enabling evolutionary change. In combination, these discrete components of policy-making and coordination offer the continent the opportunity to escape the vicious cycles of underdevelopment.

[5] The sectors identified by NEPAD are agriculture and food security; environment and tourism; infrastructure (transport, water and sanitation; energy; and information and communication technologies [ICT]); education and health; trade, market access, investment and private sector; science and technology; governance; and gender, youth and civil society.

[6] The NEPAD Agency must deliver its programmes according to the following five themes: Food Security; Climate Change and Sustainable Development; Regional Integration and Infrastructure; Human Capital Development; and Economic and Corporate Governance.

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Annex A: Human Development Index

High human development			
Rank	**Country**	**HDI**	**World rank**
1	Libya	0.847	55
2	Seychelles	0.845	57
3	Mauritius	0.804	82

Medium human development			
Rank	**Country**	**HDI**	**World rank**
4	Tunisia	0.769	98
5	Gabon	0.755	103
6	Algeria	0.754	104
7	Equatorial Guinea	0.719	118
8	Cape Verde	0.708	121
9	Egypt	0.703	123
10	Botswana	0.694	125
11	Namibia	0.686	128
12	South Africa	0.683	129
13	Morocco	0.654	130
14	São Tomé and Príncipe	0.651	131
15	Republic of the Congo	0.601	136
16	Comoros	0.576	139
17	Swaziland	0.572	142
18	Angola	0.564	143
19	Madagascar	0.543	146
20	Kenya	0.541	147
21	Sudan	0.531	150
22	Tanzania	0.530	151
23	Ghana	0.526	152
24	Cameroon	0.523	153
25	Mauritania	0.520	154
26	Djibouti	0.520	155
27	Lesotho	0.514	156
28	Uganda	0.514	157
29	Nigeria	0.511	158

Low human development			
Rank	**Country**	**HDI**	**World rank**
30	Togo	0.499	159
31	Malawi	0.493	160
32	Benin	0.492	161
33	Côte d'Ivoire	0.484	163
34	Zambia	0.481	164
35	Eritrea	0.472	165
36	Senegal	0.464	166
37	Rwanda	0.460	167
38	Gambia	0.456	168
39	Liberia	0.442	169
40	Guinea	0.435	170
41	Ethiopia	0.414	171
42	Mozambique	0.402	172
43	Guinea-Bissau	0.396	173
44	Burundi	0.394	174
45	Chad	0.392	175
46	Democratic Republic of the Congo	0.389	176
47	Burkina Faso	0.389	177
48	Mali	0.371	178
49	Central African Republic	0.369	179
50	Sierra Leone	0.365	180
51	Niger	0.340	182

Unavailable data
Somalia
Zimbabwe

Source: UNDP (2009)

Chapter 3: Research and Experimental Development

3.1 Introduction

The R&D indicators presented in this chapter are all based on R&D surveys conducted for the year 2007 (or 2007/08) in 13 of the countries participating in the African Science, Technology and Innovation Indicators (ASTII) initiative: Cameroon (only partial data), Ghana, Gabon, Kenya, Malawi, Mali, Mozambique, Nigeria, Senegal, South Africa, Tanzania, Uganda and Zambia. The indicators are summaries of the country data, arranged for inter-country comparisons (for country details, see Annex A). The initiative to collect data and build R&D indicators by African countries is rooted in the resolutions of the Second African Ministerial Conference on Science and Technology held in Dakar, Senegal in September 2005. Ministers agreed to establish an inter-governmental committee comprising relevant national authorities to develop, adopt and use common indicators to survey and prepare an African science, technology and innovation (STI) report (NEPAD, 2005).

The surveys are the first of their kind in Africa, and it is expected that they will pave the way for systematic and periodical R&D data collection in all member states of the African Union. R&D indicators are nowadays collected all over the world. The awareness of the importance of collecting R&D indicators for policies and analyses was awakened at the Organisation for Economic Cooperation and Development (OECD) in the 1960s, when the first steps were taken to arrive at common practices and definitions. The first *Manual on Research and Experimental Development Indicators* saw the light of day at an OECD expert group meeting in Frascati, Italy, in 1962. Since then, new editions have followed (OECD, 2002). ASTII has decided to follow the practices and definitions laid down in the sixth edition of the *Frascati Manual* (NEPAD, 2007). The OECD collects and publishes annual R&D indicators for its 33 member countries (OECD, 2010c; see also OECD, 2007, 2008, 2009). For European Member states, the data-collection process is coordinated with Eurostat, the statistical office of the European Union.

The collection and publication of R&D indicators for African countries will be an important step not only in providing the means for policy-makers and analysts to monitor African development in this field, but also to allow for regional and international comparisons. The United Nations Educational, Cultural and Scientific Organisation (UNESCO) already publishes regular R&D statistics through its Institute for Statistics (UIS). Recently, UIS attempted to present a global perspective on R&D activities, enumerating a series of indicators by regions and selected countries (UNESCO, 2009). Sadly, many African countries were absent in this presentation.

There are many other reasons why other R&D indicators are important for African countries (see Gault, 2008). R&D indicators are also increasingly used in the analysis of the so-called 'national systems of innovation', and the roles played by the various actors, such as universities (see Brundenius, Lundvall and Sutz 2009). This work is undertaken at the same time as the OECD is reviewing its measurement agenda (OECD, 2010a) as part of its Innovation Strategy (OECD 2010b) and supports the contribution of NEPAD to that discussion.

3.2 Gross domestic expenditure on research and experimental development (GERD)

One of the most common, and most often quoted, R&D indicators is how much a country dedicates to research and experimental development as a percentage of its GDP. The 'one per cent goal for African countries' was endorsed by the Executive Council of the African Union in the Khartoum Decision (EX.CL/Dec.254 (VIII) on Science and Technology) (AU, 2006). This indicator is gross domestic expenditure on research and experimental development (GERD). In order to estimate how much is actually spent on R&D in any country, it is necessary to have reasonably reliable data not only on GERD, but also on its components of R&D spending in different sectors of the economy. In the *Frascati Manual* (OECD, 2002), it is recommended that such data be collected for four sectors: the business enterprise sector (irrespective of ownership), the government sector, the higher education sector and private non-profit organisations (PNP). The sum of expenditure in the four sectors is thus equal to GERD. Ten of the countries participating in the ASTII programme have collected data (through surveys) on R&D expenditure. However, three of these countries have not yet collected data for the business enterprise sector, while two countries have no data for the PNP sector, and one lacks data for the higher education sector.

Business sectors in developing countries are often not very strong in R&D, but it is nevertheless important to collect and monitor trends in this sector, since its R&D potential is considerable. The PNP sector is frequently of less importance (in both developed and developing countries), so omissions may not be as critical. However, as will be shown, there are African countries where non-profit organisations play an important role (for instance, in Malawi, Mozambique and Senegal), and it is therefore strongly recommended that such institutions be included in future surveys in other countries.

Thirteen of the countries participating in the ASTII initiative have carried out R&D surveys, although some have done so only partially. The countries appear in the Box, in which the respective survey year(s) and information about the sectors are covered.

Country	Survey year(s)	Sectors covered
Cameroon	2008	BERD, GOVERD, HERD (no data on R&D expenditure)
Gabon	2007, 2008 and 2009	Totals only, no sector specific
Ghana	2007/2008	BERD, GOVERD, HERD, PNP
Kenya	2007/2008	BERD, GOVERD, HERD, PNP
Malawi	2007/2008	BERD, GOVERD, HERD, PNP
Mali	2007	BERD, HERD
Mozambique	2007/2008	GOVERD, PNP
Nigeria	2007	GOVERD, HERD
Senegal	2008	BERD, GOVERD, HERD, PNP
South Africa	2007	BERD, GOVERD, HERD, PNP
Tanzania	2007/2008	GOVERD, HERD, PNP
Uganda	2007/2008	BERD, GOVERD, HERD
Zambia	2008	BERD, GOVERD, HERD, PNP

Note:
BERD=Business enterprise sector
GOVERD=Government sector
HERD=Higher education sector
PNP=Private non-profit organisations

Source: ASTII R&D Surveys

3.3 GERD as an indicator of R&D activities

GERD is a measure of the R&D activities in a country, or of how dedicated the country is to conducting research. The data on GERD and its components are collected in national surveys and are, of course, measured in national currency. However, in order to allow for inter-country and international comparisons, the GERD data are translated into an international currency that could be used in inter-country comparisons. The practice is to use US purchasing power parity (PPP) dollars, which are dollars adjusted for their purchasing power in the country being represented (OECD, 2010c, General Methodology, A. Definitions and Coverage, Section 8). Table 3.1 shows some of the results for the countries in the ASTII initiative that have collected data on GERD (for detailed country data, see Annex A).

Table 3.1: Gross domestic expenditure on R&D (GERD) (2007/08)

	Year	GERD million PPP$	GERD per capita PPP$	GERD as % of GDP
Gabon	2008	78.7	58.3	0.47
Ghana	2007	120.1	5.0	0.38
Kenya	2007	277.8	7.4	0.48
Malawi	2007	180.1	12.9	1.70
Mali†	2007	37.4	3.0	0.28
Mozambique*‡	2007	42.9	2.0	0.25
Nigeria*†	2007	583.2	3.9	0.20
Senegal	2008	99.0	8.0	0.48
South Africa	2007	4 976.6	102.4	1.05
Tanzania*	2007	234.6	5.8	0.48
Uganda†	2007	359.8	11.6	1.10
Zambia	2008	55.3	4.6	0.37

Sources: ASTII R&D Surveys; PPP data from UNDP (2010); population and GDP data from AfDB (2010)

Note:

* Data do not include the business enterprise sector

† Data do not include private non-profit institutions/organisations

‡ Data do not include the higher education sector

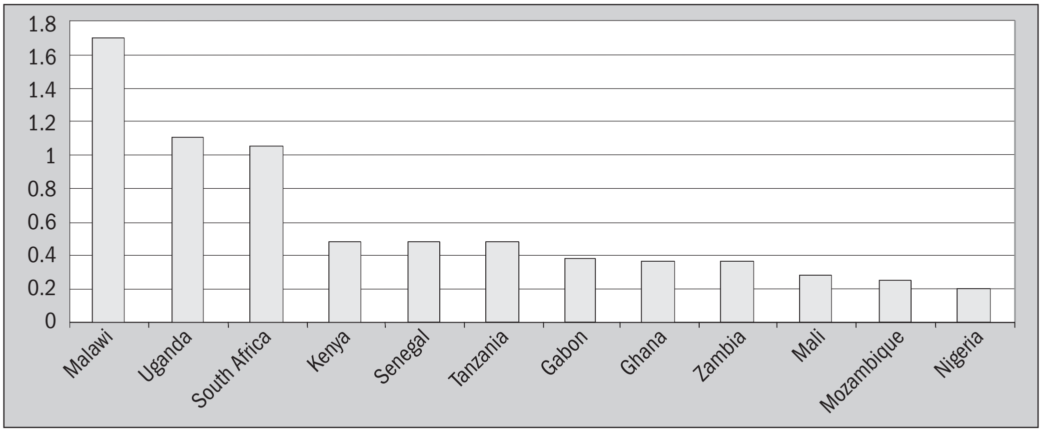
Caution is urged in interpreting these data. Some countries have not covered all sectors. Thus the business sector has not been surveyed in some cases, which is a serious omission. According to the data in Table 3.1, South Africa is, perhaps not surprisingly, the country that devotes most resources to R&D. With GERD of almost five billion PPP$, South Africa spends 8.5 times more on R&D than Africa's most populous country, Nigeria. On a per capita basis, the gap is 26 times. It should, however, be borne in mind that the Nigerian survey did not cover the business enterprise sector, so the gap is probably smaller. Apart from South Africa, there are two countries that stand out in this comparison: Malawi and Uganda. Both countries have an R&D density (GERD/GDP ratio) of over 1% (1.70% and 1.10%, respectively). For the other countries, the percentages range from 0.20% to 0.48% (Figure 3.1).

In the case of Malawi (the country with the lowest GDP in the group), this might seem surprising However, Malawi hosts many international research institutions, especially in the health sector, including the

Wellcome Trust, Global AIDS Research Initiative and many others. There have also been important capital equipment investments in this field. Another sector in which international research institutions are represented in Malawi is agriculture, including the Consultative Groups on International Agricultural Research (CGIAR) centres, many of which have relocated to Malawi. Another reason is that Malawi receives considerable donor funding for R&D activities (see Table 3.4).

In the case of Uganda, in addition to providing resources for public goods and services, the government has also provided funds for scientific research. The government prioritised the provision of support to scientists undertaking research and innovation related to the production process, especially research in banana development and fruit-juice processing, but also in malaria. In addition, the government negotiated a five-year US$30 million project in terms of the Millennium Science Initiative funded by the World Bank to support research, education and training in science and technology with linkages to industry. Some of the funds were geared towards strengthening the Uganda Industrial Research Institute (UIRI) and the Uganda National Council for Science and Technology. In order to support agriculture as a priority sector, funding was also provided for agricultural research through the National Agricultural Research Organisation (NARO) and for the provision of extension services through the National Agricultural Advisory Services (NAADS). In the 2009/10 fiscal year, the government gave extended funding to support the UIRI in becoming a centre of excellence, especially in value addition, business incubation, innovation, product and process design, and technology transfer. The focus on industrial technology continued to call for the creation of agroprocessing facilities, which will form a foundation for industrialisation in Uganda.

Figure 3.1: GERD as a percentage of GDP



Source: ASTII R&D Surveys

3.4 GERD by sector of performance

An important aspect of GERD is how it is spent across the four sectors (Tables 3.2 and 3.3). With the exception of South Africa and Malawi, the government sector and/or the higher education sector account for the lion's share of all R&D expenditure in all of the countries surveyed. In relative terms, the business enterprise sector is considerable in South Africa, but also in Kenya and Malawi. However, it should be recalled that the sector has not been surveyed in some countries, and hence the process of interpreting the data should be treated with caution, especially in the case of Nigeria, where R&D in the business sector might be significant.

The government and higher education sectors combined account for over 50% of GERD in the countries surveyed, with the exception of South Africa (41.1%). The private non-profit sector accounts for a rather small share of total R&D activities, including in South Africa, although there are some noteworthy exceptions: Malawi (25.7%), Senegal (24.9%), Mozambique (15.0%) and Kenya (12.9%).

Table 3.2: Gross domestic expenditure on R&D (GERD) by sector of performance (million PPP$)

	GERD	Business sector (BERD)	Government sector (GOVERD)	Higher education (HERD)	Private non-profit organisations
Gabon	78.7	NA	NA	NA	NA
Ghana	120.1	5.9	111.4	2.8	-*
Kenya	277.8	6.8	193.3	41.9	35.8
Malawi	180.1	42.7	33.3	57.8	46.3
Mali	37.4	1.1	0	36.3	0
Mozambique	42.9	-*	36.5	-*	6.4
Nigeria	583.2	-*	205.3	377.9	-*
Senegal	99.0	0.9	33.2	40.3	24.6
South Africa	4 976.6	2 871.5	1 079.9	965.5	59.7
Tanzania	234.6	-*	98.8	126.9	8.9
Uganda	359.8	14.8	165.5	179.5	-*
Zambia	55.3	1.1	10.7	43.2	0.3

* Sector not surveyed

Source: ASTII R&D Surveys

Table 3.3: GERD by sector of performance (percentage)

	GERD	BERD	GOVERD	HERD	PNP
Gabon	100.0	NA	NA	NA	NA
Ghana	100.0	4.9	92.8	2.3	-*
Kenya	100.0	2.4	69.6	15.1	12.9
Malawi	100.0	23.7	18.5	32.1	25.7
Mali	100.0	3.0	-*	97.0	-*
Mozambique	100.0	-*	85.0	-*	15.0
Nigeria	100.0	-*	35.1	64.9	-*
Senegal	100.0	0.9	33.5	40.7	24.9
South Africa	100.0	57.7	21.7	19.4	1.2
Tanzania	100.0	-*	42.1	54.1	3.8
Uganda	100.0	4.1	46.0	49.9	-*
Zambia	100.0	2.0	19.3	78.2	0.5

* Sector not surveyed

Source: ASTII R&D Surveys

3.5 GERD by source of funding

The financing of R&D does not necessarily come from the same source as where it is performed. Although it is no doubt the case that R&D expenditure in the business enterprise sector as a rule comes from the same sector, and the same is true for the government sector, it is not unusual for the government to finance part of the R&D expenditure in the business enterprise sector, and *vice versa.* Large amounts of the higher education expenditure on R&D usually come from the government but may also be financed by the business sector and private non-profit institutions. Table 3.4 shows the results for the 12 countries.

Table 3.4: GERD by source of funding (percentage)

	GERD	Business sector	Government sector	Higher education sector*	Private non-profit institutions	Funds from abroad
Gabon	100.0	NA	NA	NA	NA	NA
Ghana	100.0	50.9	36.3	0.9	0	11.9
Kenya	100.0	16.8	26.1	26.2	13.3	17.6
Malawi	100.0	22.8	32.9	0.6	10.6	33.1
Mali	100.0	10.1	40.9	0	0	49.0
Mozambique	100.0	0	27.7	0	15.0	57.3
Nigeria	100.0	0.2	96.4	0.1	1.7	1.0
Senegal	100.0	4.0	57.1	0.3	0.3	38.3
South Africa	100.0	42.7	36.4	9.4	0.9	10.7
Tanzania	100.0	0	60.6	0	1.0	38.4
Uganda	100.0	4.2	37.1	46.0	0	12.8
Zambia	100.0	3.2	77.1	17.7	0.3	1.7

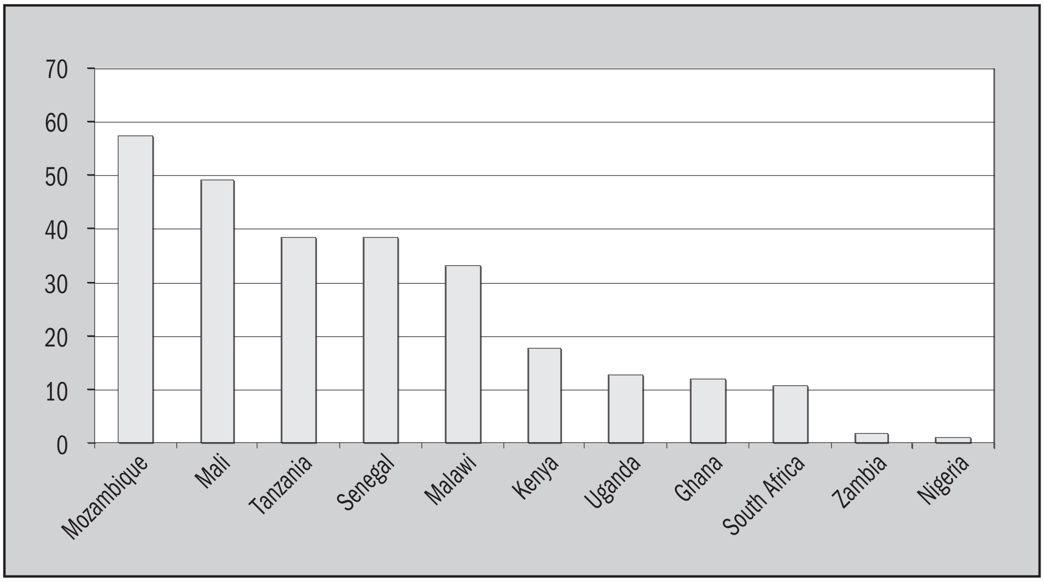
Source: ASTII R&D Surveys

* Including General University Funds

The government is the most important funding source of R&D activities, especially if higher education is lumped together with government. It is sometimes difficult to separate these two sectors in R&D accounting, and the experience of the ASTII surveys is no exception. In addition to financing its own research institutes, government also finances R&D at public universities, but universities sometimes finance R&D from their own funds. It is thus sometimes difficult to determine and distinguish financial sources. This is evident from the data in Table 3.4. Kenya and Uganda (and to some extent Zambia) stand out as the only countries where the higher education sector itself accounts for a considerable share of R&D spending. However, a substantial part of that spending is indirectly financed by government. So, in order for a more realistic comparison of the role of governments, one might rather look at the sum of expenditure by the government and higher education sectors.

R&D activities in Africa are to a large extent financed by international donors and other foreign sources, as recorded in the last column of Table 3.4. This support is important to register, since the dependency should be expected to decrease over time, despite the fact the international support is important at a capacity-building stage. Recording this should thus be part of the monitoring exercise, which should also include information on the leading funding institutions.[7]

Figure 3.2: Share of foreign funding in R&D activities (percentage)



Source: ASTII R&D Surveys

Among the countries surveyed, Mozambique is currently the most dependent on foreign donors, in that more than 50% of its R&D is financed from abroad, followed by Mali (49.0%), Tanzania (38.4%), Senegal (38.3%) and Malawi (33.1%). Nigeria and Zambia show very low dependence on foreign funding of only about 1.0% (Figure 3.2).

The business enterprise sector accounts for a considerable share of the funding of R&D activities in some countries (Ghana 50.9%, South Africa 42.7% and Malawi 22.8%), while in most countries, its share of funding is less than 10%. The Ghanaian business sector stands out because it funds ten times more R&D than it performs.

3.6 GERD by type of R&D

It is important to analyse R&D expenditure not only from the perspective of the sectors in which expenditure occurs, but also to look at types of expenditure – in other words, to analyse the role of basic research in relation to applied research and experimental research. Six countries collected data in this regard, and the results are presented in Table 3.5.

Nigeria stands out as devoting relatively more resources to basic research (36.1%) than the other countries, although the share is also relatively high in South Africa and Tanzania (20.6% and 19.2% respectively). This could be seen in contrast to Malawi, Mozambique and Uganda, where basic research accounts for only about 10% of GERD. It should, however, be recalled that higher education has not yet been surveyed in Mozambique.

Table 3.5: GERD by type of R&D (2007) (percentage)

	GERD	Basic research	Applied research	Experimental research	Not elsewhere classified
Malawi	100.0	10.0	60.0	30.0	0
Mozambique	100.0	9.5	83.2	7.2	0.2
Nigeria	100.0	36.1	37.8	26.1	0
South Africa	100.0	20.6	34.2	45.2	0
Tanzania	100.0	19.2	58.6	22.1	0.1
Uganda	100.0	10.2	59.3	30.5	0

Source: ASTII R&D Surveys

3.7 R&D human resources

Estimating the extent to which a country devotes its financial resources to research and experimental development, and how these resources are allocated among sectors, is perhaps the most visible, and internationally compared, STI indicator. However, it is also important to estimate the human resources that are available, and actually utilised, to do research in a country. If such resources are not available in sufficient quantities, then it does not matter how much a country is prepared to spend on research and experimental development. It may also be possible that human resources are available but not sufficiently qualified. There are thus many reasons why it is important to carry out human resource surveys and to follow up with continuous monitoring in order to detect possible deficiencies timeously so that they can be corrected by sending signals to policy-makers and educational planning agencies (as well as ministries of finance and donors).

3.8 Deployment of R&D human resources

All ten countries carried out human resource surveys in conjunction with the R&D surveys. One additional country – Cameroon – also supplied some general information on R&D human resources, which is reported in Table 3.6.

It should be stressed that ‘research personnel’ and ‘researchers’ are not the same thing. Researchers are, of course, necessary for conducting research, but researchers also need human and physical infrastructure. Researchers are thus part of the larger concept of research personnel, which, in addition to researchers, also includes R&D technicians, and other support staff linked to the researcher, or to a research project.

In surveys of human resources devoted to R&D, it is sometimes difficult to determine who is a researcher and who is not. Sometimes this is determined by the educational achievement of the person. Thus, it is often considered that a researcher should have a PhD, or equivalent, but this is not necessarily the case. A person with a PhD in a research project could mainly be doing administration and spend little time on the project as a researcher. A person in the project with no PhD (yet) may be doing a considerable amount of qualified research. The survey teams in the countries participating in the ASTII project have been well aware of these problems.

Table 3.6 reveals some interesting information. Among the countries surveyed, South Africa has by far the highest number of human resources available for R&D activities, with a researcher density of 825 per million inhabitants. Senegal is not far behind with a researcher density of 635 per million inhabitants. At the other end of the scale, Mozambique (with a researcher density of 24.4), Uganda (25.4) and Ghana (27.1) lag quite far behind. It is not clear if these huge differences are real or just reflect different definitions of 'researcher', as discussed. This issue warrants further investigation.

Table 3.6: R&D personnel and researchers (headcount)

	R&D personnel	Researchers	Researchers as a % of R&D personnel	Population in million	Research personnel per million inhabitants	Researchers per million inhabitants
Cameroon	5 600	4 562	81.5	18.660	300	244
Gabon	834	527	63.2	1.422	586	371
Ghana	2 115	636	30.1	22.871	92	28
Kenya	6 799	3 794	55.8	37.755	180	100
Malawi	2 884	733	25.4	14.846	194	49
Mali	2 414	877	36.3	12.409	195	71
Mozambique	2 082	522	25.1	21.869	95	24
Nigeria	32 802	17 624	53.7	147.722	222	119
Senegal	10 207	7 859	77.0	11.893	858	661
South Africa	59 344	40 084	67.5	49.173	1 207	815
Tanzania	3 593	2 755	76.7	41.276	87	67
Uganda	1 768	785	44.4	30.638	58	26
Zambia	2 219	612	27.6	12.314	180	50

Source: ASTII R&D Surveys

The share of researchers among the R&D personnel is as a rule between 55% and 75% in most OECD countries (OECD 2010c). In the case of South Africa, the share is 67.5%. Among the countries surveyed, there are only a few countries with ratios in the same range. In some countries the ratio is as low as 25% (Malawi and Mozambique) and around 30% (Ghana and Zambia).

This could be interpreted in different ways. If it is assumed that the 'normal' researcher/research personnel ratio would lie between 55% and 75%, what would then explain the fact that the ratio is far lower in some countries? It could mean that researchers in some countries are supported by a much larger staff than in other countries, and this is not necessarily a bad thing. However, it could also indicate that there is an inefficiency problem in such countries. Another – rather simple explanation – is that 'researcher' has been defined differently in the surveyed countries.

3.9 The role of women in research and experimental development

Women can and should play an important role in research and experimental development. As Table 3.7 shows, the participation of women in R&D activities is surprisingly high in the surveyed countries. In two of the countries, Tanzania and South Africa, the participation ratio is over 40%, and it is close to the same ratio in Mozambique and Uganda. An encouraging feature is that there is no big difference between female participation ratios, whether they are employed as researchers or as support staff. This means that there has been important growth in the participation of women in scientific careers in Africa, although the low ratio in Mali should be the subject of further analysis and reflection.

Table 3.7: Female R&D personnel and researchers and shares of total (headcount)

	Female R&D personnel	Female researchers	Female share of total research personnel	Female share of total researchers
Cameroon	994	994	17.8	21.8
Gabon	239	118	28.7	22.4
Ghana	449	114	21.2	17.9
Kenya	1 515	723	22.3	19.1
Malawi	610	170	21.2	23.2
Mali	256	93	10.6	10.6
Mozambique	784	174	37.7	33.3
Nigeria	8 891	4 106	27.1	23.3
Senegal	2 669	1 890	26.1	24.0
South Africa	24 251	16 154	40.9	40.3
Tanzania	1 555	558	43.3	20.3
Uganda	677	302	38.3	38.5
Zambia	818	188	36.9	30.7

Source: ASTII R&D Surveys

3.10 Where do the researchers do research?

As shown in Table 3.8, most researchers in the surveyed countries are employed in government research institutes or public university laboratories. As a rule, over 90% of the researchers work in the public sector. The business enterprise sector plays an important role in Mali, South Africa and Ghana, although it is no doubt also potentially important in the other countries. Private non-profit institutions thus far play a very modest role in R&D activities in the surveyed countries, with the noteworthy exception of Malawi.

Table 3.8: Researchers by sector of employment (headcount) percentage shares

	Total	Business sector	Government sector	Higher education sector	Private non-profit organisations
Cameroon	100.0	3.4	6.5	90.0	-*
Gabon	100.0	NA	NA	NA	NA
Ghana	100.0	13.8	61.8	24.4	-*
Kenya	100.0	3.1	30.7	63.0	3.2
Malawi	100.0	3.7	33.7	47.6	15.0
Mali	100.0	53.8	-*	46.2	-*
Mozambique	100.0	-*	97.3	-*	2.7
Nigeria	100.0	-*	10.7	89.3	-*
Senegal	100.0	0.2	2.1	96.4	1.3
South Africa	100.0	20.8	9.3	69.2	0.7
Tanzania	100.0	-*	21.8	72.6	5.6
Uganda	100.0	4.7	50.2	45.1	-*
Zambia	100.0	5.7	32.4	59.8	2.1

* Sector not surveyed

Source: ASTII R&D Surveys

3.11 Qualifications of researchers and support staff

In order to do research, it is, of course, desirable that the researcher has a solid and adequate educational background. All the participating countries collected information on this important aspect of R&D human resources. Details for researchers are not available, but data are available for R&D personnel as a group, and the results are shown in Tables 3.9 and 3.10 and Figure 3.3.

Table 3.9: R&D personnel by level of education (headcount)

	GERD	PhD level	Theoretically based university studies	Other higher education	Subtotal Tertiary education	Other
Gabon*	527	321	163	22	506	21
Ghana	2 115	166	305	414	885	1 230
Kenya	6 799	1014	1 202	2 464	4 680	2 119
Malawi	2 884	208	436	350	994	1 890
Mali	2 414	164	653	155	972	1 442
Mozambique	2 082	36	349	104	489	1 593
Nigeria	32 802	6 498	18 782	0	25 280	7 522
Senegal*	7 859	2 003	5 840	16	7 859	0
South Africa	59 344	19 008	21 712	18 624	59 344	0
Tanzania	3 593	399	919	913	2 231	1 362
Uganda	1 768	156	947	0	1 103	665
Zambia	2 219	316	625	735	1 676	543

* Researchers only

Source: ASTII R&D Surveys

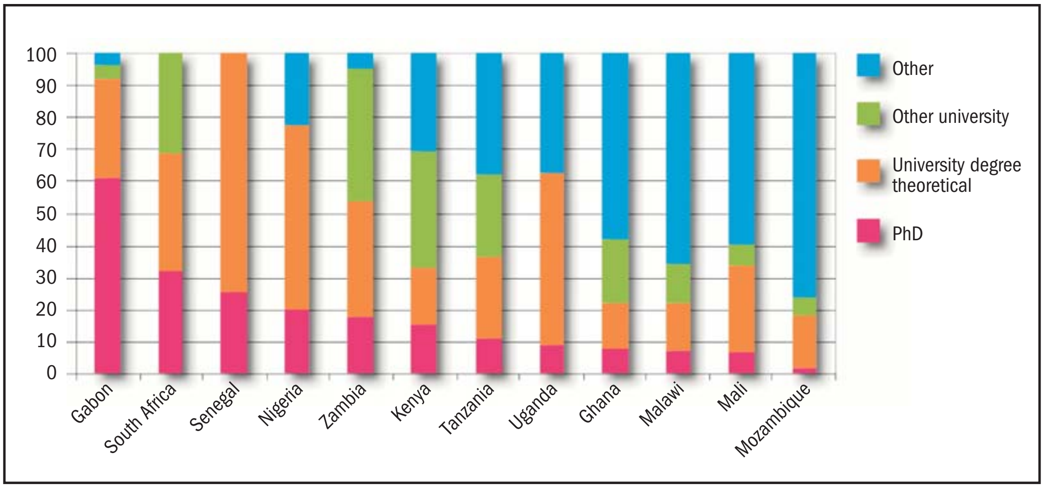
There are striking differences between countries. Those with PhDs range from 60.9% in Gabon to 1.7% in Mozambique. This, of course, again raises the question of definitions of researcher and R&D personnel. Gabon is an extreme case, but there are also three countries – South Africa (32%), Senegal (25.5%) and Nigeria 19.8% – that have high percentages of PhDs among their R&D staffs. It is interesting that these are also the countries with the highest researcher densities (*cf.* Table 3.6). On the other extreme, there are several countries with low percentages of PhDs and high percentages of R&D personnel with non-tertiary education. This is particularly the case with Ghana, Malawi, Mali and Mozambique. Although this is a fact that requires attention, it does not necessarily mean that research projects in these countries are staffed by less competent R&D personnel.

Table 3.10: R&D personnel by level of education (headcount) percentage shares

	GERD	PhD level	Theoretically based university studies	Other higher education	Subtotal Tertiary education	Other
Gabon	100.0	60.9	30.9	4.2	96.0	4.0
Ghana	100.0	7.8	14.4	19.6	41.8	58.2
Kenya	100.0	14.9	17.8	36.2	68.8	31.2
Malawi	100.0	7.2	15.1	12.1	34.4	65.6
Mali	100.0	6.8	27.1	6.4	40.3	59.7
Mozambique	100.0	1.7	16.8	5.0	23.5	76.5
Nigeria	100.0	19.8	57.3	0	77.1	22.9
Senegal	100.0	25.5	74.3	0.2	100.0	0
South Africa	100.0	32.0	36.6	31.4	100.0	0
Tanzania	100.0	11.1	25.6	25.4	62.1	37.9
Uganda	100.0	8.8	53.6	0	62.4	37.6
Zambia	100.0	14.2	28.2	33.1	75.5	24.5

Source: ASTII R&D Surveys

Figure 3.3: Qualifications of R&D personnel (percentage)



3.12 When is a researcher doing research?

An important issue was raised earlier. Who is a researcher and when and how should he/she be counted as doing research? First, there is the mentioned distinction between the researcher and support staff. So far, only so-called ‘headcounts’ (HC) have been recorded, but the *Frascati Manual* also recommends that surveys should try to estimate full-time equivalents (FTE). In other words, it is useful to have an estimate of how much time the researchers and support staff headcounts actually spend doing research or involved in research projects. This is important to know since, for obvious reasons, many are not working on research projects all the time. This is the case with researchers, but is perhaps even more so with support staff as part of research personnel.

Six countries have made estimates of full-time equivalents, and the results are presented in Tables 3.11 and 3.12. Table 3.11 shows the FTE percentage for both total R&D personnel and researchers (total and females). Table 3.12 shows the FTE percentage of HC (*cf*. Tables 3.6, 3.7 and 3.11).

The average ratio between FTE and HC is around 50%, with South Africa as a case in point. Malawi and Senegal are in the same range, with Ghana following with a slightly higher ratio. Nigeria and Uganda are both considerably below the average, although – interestingly – the FTE status of women employed in researchers in Uganda seems to be higher than for men. In interesting evidence that it could be worthwhile studying more closely, Zambia shows an exceptionally high correspondence between FTE and HC, which leads to questions about the conversion of HC into FTE. It should be pointed out, however, that the conversion is one of the most difficult exercises in this kind of survey.

Table 3.11: R&D personnel and researchers (FTE) (total and females)

	R&D personnel total	R&D personnel females	Researchers total	Researchers female
Ghana	1 431	310	392	69
Malawi	1 638	331	406	89
Nigeria	11 330	3 015	5 677	1 326
Senegal	5 540	1 347	4 527	1 078
South Africa	31 352	12 105	19 320	7 349
Uganda	635	267	352	185
Zambia	2 130	803	536	184

Source: ASTII R&D Surveys

Table 3.12: Relationship between full-time equivalents and headcounts (FTE as a percentage of HC)

	R&D personnel total	R&D personnel females	Researchers total	Researchers female
Ghana	67.7	69.0	61.6	60.5
Malawi	56.7	54.3	55.4	52.4
Nigeria	34.5	33.9	32.2	32.3
Senegal	54.3	50.5	57.6	57.0
South Africa	52.8	49.9	48.2	45.5
Uganda	35.9	39.4	44.8	61.2
Zambia	96.0	98.2	87.6	97.9

Source: ASTII R&D Surveys

3.13 Science background of the researchers

Do the researchers have an adequate educational background? It is clear that a researcher with an advanced university degree is, as a rule, a better qualified researcher than one with a lower university degree, or with no university education at all. However, the field of science is also an important factor in this regard. In Africa, many countries would find it desirable that a majority of researchers have a background in, for instance, agricultural sciences, and medicine and health, because of priorities set by governments. Not all the countries surveyed have such information. However, six countries have such data, as presented in Table 3.13 and Figure 3.4.

Table 3.13: Researchers by field of science (headcount) percentage shares

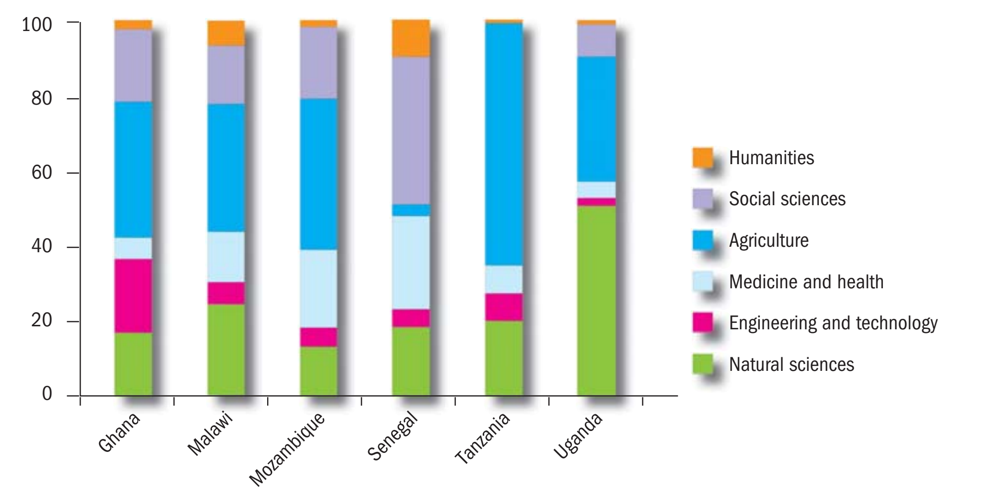
	Total	Natural sciences	Engineering and technology	Medicine and health	Agricultural sciences	Social sciences	Humanities
Ghana	100.0	17.1	19.4	5.8	36.0	19.3	2.2
Malawi	100.0	24.6	6.0	13.3	33.9	16.0	6.2
Mozambique*	100.0	13.3	4.8	21.1	40.0	19.4	1.4
Senegal	100.0	18.6	4.4	24.9	3.2	39.1	9.8
Tanzania*	100.0	20.0	7.4	7.5	65.1	0	0
Uganda†	100.0	50.7	1.9	4.5	33.4	9.1	0.4

Source: ASTII R&D Surveys

* Does not include the business enterprise sector

† Higher education sector only

Figure 3.4: Researchers by field of science (2007) (percentage)



Source: ASTII R&D Surveys

3.14 Conclusion

This is the first time that a publication of this kind has been produced in which it has been possible to compare African countries on the basis of recent R&D data collected by themselves through R&D surveys conducted within their countries. While the intention was to include 19 countries in this endeavour, it has nevertheless been a great achievement that 13 of these countries were able to participate. Some countries had to undertake an R&D survey for the very first time. It has never been an easy task to undertake the first R&D survey in a country. There is no institutional memory to fall back on; the survey unit has to deal with unfamiliar concepts and methodology; and respondents are moreover uninformed about what is required of them. However, by continuing with the R&D surveys on a regular basis, the survey will tend to grow in its cover and accuracy. Respondents will also grow to realise the value of the exercise and the data that it produces; for example, they can build a proper record of their R&D activities, which helps with the management and organisation of their future R&D. If the R&D survey efforts are maintained, they will lead to better surveys and data over time as more experts, respondents and organisations become familiar with the exercise. It is hoped that this has been the start of a positive move towards better recording of R&D activities in African countries, as well as reporting on such activities.

[7] A review of R&D funds from abroad for OECD countries shows that the magnitude varies significantly and can be large. However, for OECD countries, a large magnitude represents the ability of the country to sell its R&D services abroad and to derive income as a consequence. This is quite different from donor funding for capacity building in developing countries. That is why information on the leading funding institutions should be recorded so that any change from donor institutions to institutions that are purchasing R&D services can be observed.

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Annex A: Country tables

Table 3A.1: Cameroon: R&D personnel headcount by occupation (2008)

R&D personnel headcount (HC) by occupation	Total	Business sector	Government	Higher education	Private non-profit organisations*
Total (HC)	**5 600**	**156**	**1 336**	**4 108**	**NA**
Researchers	4 562	156	298	4108	NA
Technicians	338	-	338	-	NA
Other	700	-	700	-	NA
Females (HC)	**994**	**17**	**361**	**616**	**NA**
Researchers	994	17	361	616	NA
Technicians	-	-	-	-	NA
Other	-	-	-	-	NA

* Sector not surveyed

Table 3A.2: Gabon: R&D personnel headcount by occupation (2008)

R&D personnel headcount (HC) by occupation	Total	Business sector	Government	Higher education	Private non-profit organisations*
Total (HC)	**834**	**NA**	**NA**	**NA**	**NA**
Researchers	527	NA	NA	NA	NA
Technicians	142	NA	NA	NA	NA
Other	165	NA	NA	NA	NA
Females (HC)	**239**	**NA**	**NA**	**NA**	**NA**
Researchers	118	NA	NA	NA	NA
Technicians	55	NA	NA	NA	NA
Other	66	NA	NA	NA	NA

* Sector not surveyed

Table 3A.3: Gabon: Researchers by level of education and field of science (2008)

Researchers by level of education	Total	Business sector	Government	Higher education	Private non-profit organisations
Total	**527**	**NA**	**NA**	**NA**	**NA**
ISCED 6	321	NA	NA	NA	NA
ISCED 5A	163	NA	NA	NA	NA
ISCED 5B	22	NA	NA	NA	NA
Other	21	NA	NA	NA	NA
Female	**118**	**NA**	**NA**	**NA**	**NA**
ISCED 6	55	NA	NA	NA	NA
ISCED 5A	52	NA	NA	NA	NA
ISCED 5B	5	NA	NA	NA	NA
Other	6	NA	NA	NA	NA
Total researchers by field of science	**527**	**NA**	**NA**	**NA**	**NA**
Natural sciences	70	NA	NA	NA	NA
Engineering & Technology	25	NA	NA	NA	NA
Medicine and Health	24	NA	NA	NA	NA
Agricultural sciences	43	NA	NA	NA	NA
Social sciences	119	NA	NA	NA	NA
Humanities	69	NA	NA	NA	NA
Other/unknown	177	NA	NA	NA	NA
Female	**118**	**NA**	**NA**	**NA**	**NA**
Natural sciences	22	NA	NA	NA	NA
Engineering and Technology	5	NA	NA	NA	NA
Medicine and Health	14	NA	NA	NA	NA
Agricultural sciences	13	NA	NA	NA	NA
Social sciences	18	NA	NA	NA	NA
Humanities	14	NA	NA	NA	NA
Other/unknown	32	NA	NA	NA	NA

Table 3A.4: Gabon: Gross expenditures on R&D in CFA Francs XAF by sector and source of funds (2008)

Gross expenditures on R&D (GERD) *Million national currency*	Total	Business sector	Government	Higher education	Private non-profit organisations
GERD by sector and source of funds	**35 481**	**NA**	**NA**	**NA**	**NA**
Business enterprises	NA	NA	NA	NA	NA
Direct government	27 144	NA	NA	NA	NA
General university funds	-	-	-	NA	-
Higher education	NA	NA	NA	NA	NA
Private non-profit organisations	NA	NA	NA	NA	NA
Funds from abroad	1 153	NA	NA	NA	NA
Other	7 184	NA	NA	NA	NA

Table 3A.5: Ghana: R&D personnel headcount by occupation and level of education (2007)

R&D personnel headcount (HC) by occupation	Total	Business sector	Government	Higher education	Private non-profit organisations
Total HC	**2 115**	**271**	**1 634**	**210**	**0**
Researchers	636	88	393	155	0
Technicians	509	95	387	27	0
Other	970	88	854	28	0
Female HC	**449**	**50**	**357**	**42**	**0**
Researchers	114	18	67	29	0
Technicians	102	14	80	8	0
Other	233	18	210	5	0
Total R&D personnel by level of education	**2 115**	**271**	**1 634**	**210**	**0**
ISCED 6	166	6	105	55	0
ISCED 5A	305	28	205	72	0
ISCED 5B	414	99	256	59	0
Other	1 230	138	1 068	24	0
Female	**449**	**50**	**357**	**42**	**0**
ISCED 6	24	1	11	12	0
ISCED 5A	57	4	43	10	0
ISCED 5B	75	2	59	14	0
Other	293	43	244	6	0

Table 3A.6: Ghana: Researchers by level of education and by field of science (2007)

Researchers by level of education	Total	Business sector	Government	Higher education	Private non-profit organisations
Total	**636**	**88**	**393**	**155**	**0**
ISCED 6	159	6	102	51	0
ISCED 5A	429	63	274	92	0
ISCED 5B	36	19	17	0	0
Other	12	0	0	12	0
Female	**114**	**18**	**67**	**29**	**0**
ISCED 6	20	1	11	8	0
ISCED 5A	75	11	55	9	0
ISCED 5B	7	6	1	0	0
Other	12	0	0	12	0
Total researchers by field of science	**636**	**88**	**393**	**155**	**0**
Natural sciences	109	NA	NA	NA	0
Engineering and Technology	124	NA	NA	NA	0
Medicine and Health	37	NA	NA	NA	0
Agricultural sciences	229	NA	NA	NA	0
Social sciences	123	NA	NA	NA	0
Humanities	14	NA	NA	NA	0
Female	**114**	**18**	**67**	**29**	**0**
Natural sciences	28	NA	NA	NA	0
Engineering and Technology	16	NA	NA	NA	0
Medicine and Health	14	NA	NA	NA	0
Agricultural sciences	22	NA	NA	NA	0
Social sciences	32	NA	NA	NA	0
Humanities	2	NA	NA	NA	0

Table 3A.7: Ghana: R&D personnel full-time equivalents (2007)

R&D personnel full-time equivalent (FTE)	Total	Business sector	Government	Higher education	Private non-profit organisations
Total R&D personnel by occupation	**1 430.6**	**116**	**1 251.7**	**62.9**	**0**
Researchers	392.3	38.2	307.1	47.0	0
Technicians	342.8	41.2	293.9	7.7	0
Other	695.5	36.6	650.7	8.2	0
Female	**310.2**	**21.7**	**274.7**	**13.8**	**0**
Researchers	69.0	7.4	52.6	9.0	0
Technicians	70.2	6.1	61.7	2.4	0
Other	171.0	8.2	160.4	2.4	0

Table 3A.8: Ghana: Gross expenditures on R&D in Ghanaian Cedi by sector and source of funds (2007)

Gross expenditures on R&D (GERD) *Million national currency*	Total	Business sector	Government	Higher education	Private non-profit organisations
GERD by sector and source of funds	**53 619.0**	**2 648.0**	**49 739.0**	**1 232.0**	**0**
Business enterprises	27 268.0	2 470.0	24 773.0	25.0	0
Direct government	19 472.0	34.0	18 359.0	1 079.0	0
General university funds	124.0	-	-	124.0	-
Higher education	349.0	0	349.0	-	0
Private non-profit organisations	0	0	0	0	0
Funds from abroad	6 406.0	144.0	6 258.0	4.0	0
GERD by sector and type of costs					
Labour costs	28 723	344	27 947	432	0
Other current costs	10 662	675	9 966	21	0
Land and buildings	1 338	501	792	45	0
Instruments and equipment	12 218	774	11 134	310	0
Total intramural costs by type of R&D	**52 940**	**1 247**	**15 886**	**35 807**	**0**
Basic research	15 088	679	14 182	226	0
Applied research	22 870	343	1 029	21 498	0
Experimental development	14 982	225	674	14 083	0
Not elsewhere classified	0	0	0	0	0

Table 3A.9: Kenya: R&D personnel headcount by occupation and level of education (2007/08)

R&D personnel headcount (HC) by occupation	Total	Business	Government	Higher education	Private non-profit organisations
Total HC	**6 799**	**266**	**1 730**	**4 336**	**467**
Researchers	3 794	54	805	2 684	251
Technicians	2 786	183	866	1 569	168
Other	219	29	59	83	48
Females	**1 515**	**131**	**288**	**874**	**222**
Researchers	723	26	118	444	135
Technicians	739	94	166	398	81
Other	53	11	4	32	6
R&D personnel by level of education	**6 799**	**266**	**1 730**	**4 336**	**467**
ISCED 6	1 014	12	83	878	41
ISCED 5A	1 202	80	312	762	48
ISCED 5B	2 464	132	819	1 402	111
Other	2 119	42	516	1 294	267

Table 3A.10: Kenya: Gross expenditures on R&D in Kenyan Shilling (2007/08)

Gross expenditures on R&D (GERD) *Million national currency*	Total	Business sector	Government	Higher education	Private non-profit organisations
GERD by sector and source of funds	**7 641.6**	**892.1**	**2 702.3**	**2 280.2**	**1 767**
Business enterprises	1 286.1	769.3	479.9	0	36.9
Direct government	1 998.3	11.9	994.7	928.4	63.3
General university funds	0	-	-	0	-
Higher education	1 998.8	0	757.9	1 240.9	0
Private non-profit organisations	1 012	0	232.9	0	779.1
Funds from abroad	1 346.4	110.9	236.9	110.9	887.7
GERD by sector and type of costs	**6 295.4**	**1 286.1**	**1 998.4**	**1 998.9**	**1 012**
Labour costs	3 685.2	892.9	998.8	999.1	794.4
Other costs	2 610.2	393.2	999.6	999.8	217.6

Table 3A.11: Malawi: R&D personnel headcount by occupation and level of education (2007/08)

R&D personnel headcount (HC)	Total	Business sector	Government	Higher education	Private non-profit organisations
Total R&D personnel by occupation	**2 884**	**153**	**1 751**	**661**	**319**
Researchers	733	27	247	349	110
Technicians	1 022	39	830	76	77
Other	1 129	87	674	236	132
Female	**610**	**28**	**276**	**204**	**102**
Researchers	170	4	33	104	29
Technicians	115	4	89	9	13
Other	325	20	154	91	60
Total R&D personnel by level of education	**2 884**	**153**	**1 751**	**661**	**319**
ISCED 6	208	9	76	89	34
ISCED 5A	436	13	128	221	74
ISCED 5B	350	26	193	81	50
Other	1 890	105	1 354	270	161
Female	**610**	**28**	**276**	**204**	**102**
ISCED 6	35	0	6	22	7
ISCED 5A	107	3	14	66	24
ISCED 5B	77	5	21	27	24
Other	391	20	235	89	47

Table 3A.12: Malawi: R&D personnel full-time equivalent by occupation (2007/08)

R&D personnel full-time equivalent (FTE)	Total	Business sector	Government	Higher education	Private non-profit organisations
Total R&D personnel by occupation	**1 637.8**	**39.6**	**1 140.2**	**247.4**	**210.6**
Researchers	405.7	7.0	172.9	146.6	79.2
Technicians	790.7	19.5	664.0	41.8	65.4
Other	441.4	13.1	303.3	59.0	66.0
Female	**331.1**	**6.0**	**163.6**	**99.6**	**61.9**
Researchers	88.7	1.0	23.1	43.7	20.9
Technicians	89.1	2.0	71.2	4.9	11.0
Other	153.3	3.0	69.3	51.0	30.0

Table 3A.13: Malawi: Gross expenditures on R&D in Malawian Kwacha (2007/08)

Gross expenditures on R&D (GERD) *Million national currency*	**Total**	**Business sector**	**Government**	**Higher education**	**Private non-profit organisations**
GERD by sector and source of funds	**7 164.5**	**1 698.8**	**1 322.1**	**2 299.3**	**1 844.3**
Business enterprises	1 631.3	852.1	244.0	297.6	237.6
Direct government	2 354.3	594.4	860.9	867.5	31.5
General university funds	45.8	-	-	45.8	-
Higher education	0	0	0	0	0
Private non-profit organisations	761.7	182.8	186.9	0	392.0
Funds from abroad	2 371.4	69.5	30.3	1 088.4	1 183.2

Table 3A.14: Mali: R&D personnel headcount by occupation and by level of education (2007)

R&D personnel headcount (HC)	**Total**	**Business sector**	**Government***	**Higher education**	**Private non-profit organisations***
Total R&D personnel by occupation	**2 414**	**1 171**	**NA**	**1 243**	**NA**
Researchers	877	472	NA	405	NA
Technicians	1 085	671	NA	414	NA
Other	452	28	NA	424	NA
Female	**256**	**93**	**NA**	**163**	**NA**
Researchers	93	52	NA	41	NA
Technicians	109	40	NA	69	NA
Other	54	1	NA	53	NA
Total R&D personnel by level of education	**2 414**	**1 171**	**NA**	**1 243**	**NA**
ISCED 6	164	1	NA	163	NA
ISCED 5A	653	415	NA	238	NA
ISCED 5B	155	77	NA	78	NA
Other	1 442	678	NA	764	NA
Female	**256**	**93**	**NA**	**163**	**NA**
ISCED 6	8	0	NA	8	NA
ISCED 5A	44	23	NA	21	NA
ISCED 5B	34	19	NA	15	NA
Other	170	51	NA	119	NA

* Sector not surveyed

Table 3A.15: Mali: Researchers headcount by level of education (2007)

R&D personnel headcount (HC) by level of education	Total	Business sector	Government*	Higher education	Private non-profit organisations*
Total HC	**874**	**472**	**NA**	**402**	**NA**
ISCED 6	146	1	NA	145	NA
ISCED 5A	427	253	NA	174	NA
ISCED 5B	121	101	NA	20	NA
Other	180	117	NA	63	NA
Female	**93**	**52**	**NA**	**41**	**NA**
ISCED 6	7	0	NA	7	NA
ISCED 5A	34	14	NA	20	NA
ISCED 5B	20	16	NA	4	NA
Other	32	22	NA	10	NA

Table 3A.16: Mali: Gross expenditures on R&D CFA Franc XOF (2007)

Gross expenditures on R&D (GERD) *Million national currency*	Total	Business sector	Government*	Higher education	Private non-profit organisations*
GERD by sector and source of funds	**8 532.1**	**253.8**	**NA**	**8 278.3**	**NA**
Business enterprises	861.8	213.8	NA	648.0	NA
Direct government	3 486.0	40.0	NA	3 446.0	NA
General university funds	0	-	-	0	NA
Higher education	0	0	NA	0	NA
Private non-profit organisations	0	0	NA	0	NA
Funds from abroad	4 184.3	0	NA	4 184.3	NA

* Sector not surveyed

Table 3A.17: Mozambique: R&D personnel headcount by occupation and by level of education (2007/08)

R&D personnel Headcount (HC)	Total	Business sector*	Government	Higher education*	Private non-profit organisations
Total R&D personnel by occupation	**2 082**	**NA**	**2 002**	**NA**	**80**
Researchers	522	NA	508	NA	14
Technicians	935	NA	886	NA	49
Other	625	NA	608	NA	17
Female	**784**	**NA**	**742**	**NA**	**42**
Researchers	174	NA	170	NA	4
Technicians	374	NA	345	NA	29
Other	236	NA	227	NA	9
Total R&D personnel by level of education	**2 082**	**NA**	**2 002**	**NA**	**80**
ISCED 6	36	NA	36	NA	0
ISCED 5A	349	NA	339	NA	10
ISCED 5B	104	NA	102	NA	2
Other	1 593	NA	1 525	NA	68
Female	**784**	**NA**	**742**	**NA**	**42**
ISCED 6	12	NA	12	NA	0
ISCED 5A	122	NA	118	NA	4
ISCED 5B	36	NA	36	NA	0
Other	614	NA	576	NA	38

* Sector not surveyed

Table 3A.18: Mozambique: Researchers headcount by level of education (2007/08)

Researchers Headcount (HC)	Total	Business sector*	Government	Higher education*	Private non-profit organisations
Total HC by level of education	**522**	**NA**	**508**	**NA**	**14**
ISCED 6	36	NA	36	NA	0
ISCED 5A	349	NA	339	NA	10
ISCED 5B	104	NA	102	NA	2
Other	33	NA	31	NA	2
Female	**174**	**NA**	**170**	**NA**	**4**
ISCED 6	12	NA	12	NA	0
ISCED 5A	122	NA	118	NA	4
ISCED 5B	36	NA	36	NA	0
Other	4	NA	4	NA	0

* Sector not surveyed

Table 3A.19: Mozambique: Gross expenditures on R&D in New Meticais (2007/08)

Gross expenditures on R&D (GERD) *Million national currency*	**Total**	**Business sector***	**Government**	**Higher education***	**Private non-profit organisations**
GERD by sector and source of funds	**427.21**	**NA**	**407.77**	**NA**	**19.44**
Business enterprises	0	NA	0	NA	0
Direct government	132.97	NA	132.97	NA	0
General university funds	0	NA	-	NA	0
Higher education	0	NA	0	NA	0
Private non-profit organisations	19.44	NA	0	NA	19.44
Funds from abroad	274.8	NA	274.8	NA	0
Total intramural expenditure by type of R&D	**361.7**	**NA**	**361.7**	**NA**	**NA**
Basic research	39	NA	39	NA	NA
Applied research	294.5	NA	294.5	NA	NA
Experimental development	26.3	NA	26.3	NA	NA
Not elsewhere classified	1.9	NA	1.9	NA	NA
Expenditure on R&D by field of science	**361.7**	**NA**		**NA**	**NA**
Natural sciences	54.9	NA	54.9	NA	NA
Engineering and Technology	34.4	NA	34.4	NA	NA
Medicine and Health	55.6	NA	55.6	NA	NA
Agricultural sciences	140	NA	140	NA	NA
Social sciences	37.1	NA	37.1	NA	NA
Humanities	39.7	NA	39.7	NA	NA

* Sector not surveyed

Table 3A.20 Nigeria: R&D personnel headcount by occupation and by level of education (2007)

R&D personnel headcount (HC)	Total	Business sector*	Government	Higher education	Private non-profit organisations*
Total R&D personnel by occupation	**32 802**	**NA**	**8 089**	**24 713**	**NA**
Researchers	17 624	NA	1 885	15 739	NA
Technicians	4 647	NA	1 668	2 979	NA
Other	10 531	NA	4 536	5 995	NA
Female	**8 891**	**NA**	**2 384**	**6 507**	**NA**
Researchers	4 106	NA	450	3 656	NA
Technicians	1 026	NA	411	615	NA
Other	3 759	NA	1 523	2 236	NA
Total R&D personnel by level of education	**32 802**	**NA**	**8 089**	**24 713**	**NA**
ISCED 6	6 498	NA	438	6 060	NA
ISCED 5A	18 782	NA	3 235	15 547	NA
ISCED 5B	0	NA	0	0	NA
Other	7 522	NA	4 416	3 106	NA
Female	**8 891**	**NA**	**2 384**	**6 507**	**NA**
ISCED 6	1 257	NA	83	1 174	NA
ISCED 5A	5 165	NA	947	4 218	NA
ISCED 5B	0	NA	0	0	NA
Other	2 469	NA	1 354	1 115	NA

* Sector not surveyed

Table 3A.21: Nigeria: Researchers headcount by level of education (2007)

Researchers headcount (HC)	Total	Business sector*	Government	Higher education	Private non-profit organisations*
Total researchers by level of education	**17 624**	**NA**	**1 885**	**15 739**	**NA**
ISCED 6	6 311	NA	354	5 957	NA
ISCED 5A	11 020	NA	1 390	9 630	NA
ISCED 5B	0	NA	0	0	NA
Other	293	NA	141	152	NA
Female	**4 106**	**NA**	**450**	**3 656**	**NA**
ISCED 6	1 214	NA	67	1 147	NA
ISCED 5A	2 799	NA	347	2 452	NA
ISCED 5B	0	NA	0	0	NA
Other	93	NA	36	57	NA

* Sector not surveyed

Table 3A.22: Nigeria: R&D personnel full-time equivalents by occupation and level of education, and total researchers by level of education (2007)

R&D personnel full-time equivalent (FTE)	Total	Business sector*	Government	Higher education	Private non-profit organisations*
Total R&D personnel by occupation	**11 329.6**	**NA**	**4 343.0**	**6 986.6**	**NA**
Researchers	5 676.5	NA	1 112.2	4 564.3	NA
Technicians	1 840.9	NA	917.4	923.5	NA
Other	3 812.2	NA	2 313.4	1 498.8	NA
Female	**3 014.9**	**NA**	**1 268.3**	**1 746.6**	**NA**
Researchers	1 325.7	NA	265.5	1 060.2	NA
Technicians	353.5	NA	226.1	127.4	NA
Other	1 335.7	NA	776.7	559.0	NA
Total R&D personnel by level of education	**11 401.5**	**NA**	**4 342.9**	**7 058.6**	**NA**
ISCED 6	2 006.9	NA	251.9	1 755.0	NA
ISCED 5A	6 266.8	NA	1 785.9	4 480.9	NA
ISCED 5B	0	NA	0	0	NA
Other	3 127.8	NA	2 305.1	822.7	NA
Total researchers by level of education	**5 676.5**	**NA**	**1 112.2**	**4 564.3**	**NA**
ISCED 6	1 936.4	NA	208.9	1 727.5	NA
ISCED 5A	3 612.8	NA	820.1	2 792.7	NA
ISCED 5B	0	NA	0	0	NA
Other	127.3	NA	83.2	44.1	NA

* Sector not surveyed

Table 3A.23: Nigeria: Gross expenditures on R&D in Nigerian Naira (2007)

Gross expenditures on R&D (GERD) *Million national currency*	**Total**	**Business sector***	**Government**	**Higher education**	**Private non-profit organisations***
GERD by sector and source of funds	**45 852.6**	**NA**	**16 135.1**	**29 717.5**	**NA**
Business enterprises	72.8	NA	0	72.8	NA
Direct government	44 182.2	NA	16 090.2	28 092.0	NA
General university funds	0	-	-	0	NA
Higher education	37.5	NA	36.3	1.2	NA
Private non-profit organisations	791.6	NA	0	791.6	NA
Funds from abroad	474.6	NA	7.1	467.5	NA
Other†	293.9	NA	1.5	292.4	NA
GERD by sector and type of costs	**45 852.6**	**NA**	**16 135.1**	**29 717.5**	**NA**
Labour costs	31 702	NA	8 445.1	23 256.9	NA
Other current costs	2 406.8	NA	1 200.0	1 206.8	NA
Land and buildings	2 431.9	NA	1 650.0	781.9	NA
Instruments and equipment	9 311.9	NA	4 840.0	4 471.9	NA
Current intramural costs by type of R&D	**34 108.6**	**NA**	**9 645.0**	**24 463.6**	**NA**
Basic research	12 937.6	NA	1 929.0	11 008.6	NA
Applied research	12 606.0	NA	4 533.0	8 073.0	NA
Experimental development	8 565.0	NA	3 183.0	5 382.0	NA
Not elsewhere classified	0	NA	0	0	NA
Total intramural expenditure by type of R&D	**45 953.5**	**NA**	**16 135.1**	**29 817.5**	**NA**
Basic research	16 599.9	NA	3 227.0	13 372.9	NA
Applied research	17 390.8	NA	7 584.0	9 806.8	NA
Experimental development	11 962.8	NA	5 325.0	6 637.8	NA
Not elsewhere classified	0	NA	0	0	NA
Expenditure on R&D by field of science	**4 852.4**	**NA**	**16 135.1**	**29 717.3**	**NA**
Natural sciences	15 150.9	NA	5 760.2	9 390.7	NA
Engineering and Technology	11 152.0	NA	4 421.0	6 731.0	NA
Medicine and Health	4 740.3	NA	2 258.9	2 481.4	NA
Agricultural sciences	8 312.8	NA	2 226.7	6 086.1	NA
Social sciences	5 007.6	NA	1 468.3	3 539.3	NA
Humanities	1 488.8	NA	0	1 488.8	NA

* Sector not surveyed
† Donations from individuals

Table 3A.24: Senegal: R&D personnel headcount by occupation (2008)

R&D personnel headcount (HC)	Total	Business sector	Government	Higher education	Private non-profit organisations
Total R&D personnel by occupation	**10 207**	**48**	**840**	**9 020**	**299**
Researchers	7 859	13	167	7 573	106
Technicians	831	35	345	264	187
Other	1 517	0	328	1 183	6
Female	**2 669**	**7**	**196**	**2 383**	**83**
Researchers	1 890	3	16	1 846	25
Technicians	211	4	93	56	58
Other	568	0	87	481	0

Table 3A.25: Senegal: Researchers by level of education and by field of science (2008)

R&D personnel headcount (HC)	Total	Business sector	Government	Higher education	Private non-profit organisations
Total researchers by level of education	**7 859**	**13**	**167**	**7 573**	**106**
ISCED 6	2 003	0	134	1 822	47
ISCED 5A	5 840	13	33	5 751	43
ISCED 5B	16	0	0	0	16
Other	0	0	0	0	0
Female	**1 890**	**3**	**16**	**1 846**	**25**
ISCED 6	314	0	10	294	10
ISCED 5A	1 571	3	6	1 552	10
ISCED 5B	5	0	0	0	5
Other	0	0	0	0	0
Total researchers by field of science	**7 859**	**13**	**167**	**7 573**	**106**
Natural sciences	1 461	0	8	1 453	0
Engineering and Technology	346	0	22	324	0
Medicine and Health	1 957	0	0	1 938	19
Agricultural sciences	250	13	114	75	48
Social sciences	3 072	0	23	3 020	29
Humanities	773	0	0	763	10
Female	**1 890**	**3**	**16**	**1 846**	25
Natural sciences	223	0	0	223	0
Engineering and Technology	54	0	4	50	0
Medicine and Health	626	0	0	619	7
Agricultural sciences	35	3	7	20	5
Social sciences	767	0	5	754	8
Humanities	185	0	0	180	5

Table 3A.26: Senegal: R&D personnel full-time equivalents by occupation, level of education and field of science (2008)

R&D personnel full-time equivalent (FTE)	Total	Business sector	Government	Higher education	Private non-profit organisations
Total R&D personnel by occupation	**5 539.8**	**48**	**840**	**4 352.8**	**299**
Researchers	4 526.9	13	167	4 240.9	106
Technicians	619.8	35	345	52.8	187
Other	393.1	0	328	59.1	6
Female	**1 346.6**	**7**	**196**	**1 060.6**	**83**
Researchers	1 077.7	3	16	1 033.7	25
Technicians	157.8	4	93	2.8	58
Other	111.1	0	87	24.1	0
Total researchers by level of education	**4 527**	**13**	**167**	**4 241**	**106**
ISCED 6	1 201	0	134	1 020	47
ISCED 5A	3 310	13	33	3 221	43
ISCED 5B	16	0	0	0	16
Other	0	0	0	0	0
Total researchers by field of science	**4 526.9**	**13**	**167**	**4 240.9**	**106**
Natural sciences	821.7	0	8	813.7	0
Engineering and Technology	203.4	0	22	181.4	0
Medicine and Health	1 117.3	13	0	1 085.3	19
Agricultural sciences	204	0	114	42	48
Social sciences	1 743.2	0	23	1 691.2	29
Humanities	437.3	0	0	427.3	10

Table 3A.27: Senegal: Gross expenditures on R&D in CFA Franc XOF (2008)

Gross expenditures on R&D (GERD) *Million national currency*	**Total**	**Business sector**	**Government**	**Higher education**	**Private non-profit organisations**
GERD by sector and source of funds	**22 080.5**	**189.4**	**7 393.6**	**8 976.6**	**5 520.6**
Business enterprises	892.0	177.4	714.6	0	0
Direct government	12 599.7	0	3 304.1	8 976.6	319.0
General university funds	0	0	0	0	0
Higher education	67.4	0	67.4	0	0
Private non-profit organisations	59.4	0	59.4	0	0
Funds from abroad	8 449.7	0	3 248.1	0	5 201.6
GERD by sector and type of costs	**22 079.9**	**189.4**	**7 393.3**	**8 976.7**	**5 520.5**
Labour costs	9 685.4	75	2 598.3	6 852.1	160
Other current costs	11 653.3	114.4	4 367.1	2 124.6	5 047.2
Land and buildings	31.3	0	31.3	0	0
Instruments and equipment	709.9	0	396.6	0	313.3

Table 3A.28: South Africa: R&D personnel full-time equivalents by occupation (2007)

R&D personnel headcount	**Total**	**Business sector**	**Government**	**Higher education**	**Private non-profit organisations**
Total R&D personnel by occupation	**59 344**	**17 951**	**8 782**	**3 2109**	**502**
Researchers	40 084	8 336	3 732	27 752	264
Technicians	9 476	5 303	2 090	2 006	77
Other	9 784	4 312	2 960	2 351	161
Female	**24 251**	**5 954**	**3 581**	**14 433**	**283**
Researchers	16 154	2 412	1 514	12 098	130
Technicians	3 441	1 688	945	775	33
Other	4 656	1 854	1 122	1 560	120
Total R&D personnel by level of education	**59 344**	**17 951**	**8 782**	**32 109**	**502**
ISCED 6	19 008	1 258	968	16 738	44
ISCED 5A	21 712	8 444	3 614	9 341	313
ISCED 5B	18 624	8 249	4 200	6 030	145
Other	0	0	0	0	0
Female	**24 251**	**5 954**	**3 581**	**14 433**	**283**
ISCED 6	7 553	388	296	6 860	9
ISCED 5A	9 250	2 903	1 671	4 502	174
ISCED 5B	7 448	2 663	1 614	3 071	100
Other	0	0	0	0	0

Table 3A.29: South Africa: Researchers by level of education (2007)

R&D personnel headcount (HC)	Total	Business sector	Government	Higher education	Private non-profit organisations
Total researchers by level of education	**40 084**	**8 336**	**3 732**	**27 752**	**264**
ISCED 6	18 500	1 032	902	16 528	38
ISCED 5A	16 762	5 770	2 387	8 404	201
ISCED 5B	4 822	1 534	443	2 820	25
Other	0	0	0	0	0
Female	**16 154**	**2 412**	**1 514**	**12 098**	**130**
ISCED 6	7 320	269	285	6 760	6
ISCED 5A	6 869	1 763	1 054	3 950	102
ISCED 5B	1 965	380	175	1 388	22
Other	0	0	0	0	0

Table 3A.30: South Africa: R&D personnel full-time equivalents (2007)

R&D personnel full-time equivalent (FTE)	Total	Business sector	Government	Higher education	Private non-profit organisations
Total R&D personnel by occupation	**31 352.5**	**12 461.3**	**7 008.9**	**11 503.2**	**379.1**
Researchers	19 320.3	6 047.5	3 057.8	9 999.4	215.6
Technicians	6 060.5	3 796.4	1 594.8	612.8	56.5
Other	5 971.7	2 617.4	2 356.3	891.0	107.0
Female	**12 105.3**	**3 834.3**	**2 854.4**	**5 216.1**	**200.5**
Researchers	7 349.1	1 671.4	1 219.7	4 353.7	104.3
Technicians	2 109.5	1 126.4	731.7	231.5	19.9
Other	2 646.7	1 036.5	903.1	630.9	76.3

Table 3A.31: South Africa: Gross expenditures on R&D in Rand (2007)

Gross expenditures on R&D (GERD) *Million national currency*	**Total**	**Business sector**	**Government**	**Higher education**	**Private non-profit organisations**
GERD by sector and source of funds	**18 624.1**	**10 738.5**	**4 040.5**	**3 621.9**	**223.2**
Business enterprises	7 945.9	7 133.9	268.4	519.8	23.8
Direct government	6 775.2	2 326.7	3 388.4	1 026.7	33.4
General university funds	1 734.9	-	-	1 734.9	-
Higher education	15.3	1.8	3.4	7.0	3.1
Private non-profit organisations	165.7	95.8	25.3	13.2	31.4
Funds from abroad	1 987.1	1 180.2	355.1	320.3	131.5
GERD by sector and type of costs	**18 624.1**	**10 738.5**	**4 040.5**	**3 621.9**	**223.2**
Labour costs	8 171.2	4 881.1	1 714.6	1 466.4	109.1
Other current costs	8 398.5	4 412.1	2 019.7	1 859.7	107.0
Land and buildings	367.8	263.0	50.1	51.7	3.0
Instruments and equipment	1 686.6	1 182.3	256.1	244.1	4.1

Table 3 A.32: South Africa: Gross expenditures on R&D in Rand (2007)

Gross expenditures on R&D (GERD) *Million national currency*	**Total**	**Business sector**	**Government**	**Higher education**	**Private non-profit organisations**
Total intramural expenditure by type of R&D	**18 624.1**	**10 738.5**	**4 040.5**	**3 621.9**	**223.2**
Basic research	3 830.8	929.1	1 127.0	1 709.3	65.3
Applied research	6 373.7	3 077.3	1 913.9	1 262.4	120.0
Experimental development	8 419.6	6 732.0	999.6	650.1	37.9
Not elsewhere classified	0	0	0	0	0
Expenditure on R&D by field of science	**18 624.1**	**10 738.5**	**4 040.5**	**3 621.9**	**223.2**
Natural sciences	6 037.4	3 774.2	1 269.6	980.0	13.6
Engineering and Technology	6 387.8	5 003.3	920.4	464.1	0
Medicine and Health	2 616.4	1 268.6	532.7	785.6	29.6
Agricultural sciences	1 264.6	311.3	775.2	159.8	18.3
Social sciences	1 809.4	380.6	473.3	796.3	159.2
Humanities	508.5	0.5	69.3	436.1	2.6

Table 3A.33: Tanzania: R&D personnel headcount by occupation and level of education (2007/08)

R&D personnel headcount	Total	Business sector*	Government	Higher education	Private non-profit organisations
Total R&D personnel by occupation	**3 593**	**NA**	**1 287**	**2 089**	**217**
Researchers	2 755	NA	601	2 000	154
Technicians	782	NA	686	89	7
Other	56	NA	0	0	56
Female	**1 555**	**NA**	**684**	**807**	**64**
Researchers	558	NA	130	393	35
Technicians	117	NA	99	14	4
Other	880	NA	455	400	25
Total R&D personnel by level of education	**3 593**	**NA**	**1 287**	**2 089**	**217**
ISCED 6	399	NA	99	274	26
ISCED 5A	919	NA	407	403	109
ISCED 5B	913	NA	401	446	66
Other	1 362	NA	380	966	16
Female	**1 555**	**NA**	**684**	**807**	**64**
ISCED 6	184	NA	123	38	23
ISCED 5A	82	NA	37	36	9
ISCED 5B	212	NA	76	114	22
Other	1 077	NA	448	619	10

* Sector not surveyed

Table 3A.34: Tanzania: Gross expenditures on R&D in Tanzanian Shilling (2007/08)

Gross expenditures on R&D (GERD) *Million national currency*	Total	Business sector*	Government	Higher education	Private non-profit organisations
GERD by sector and source of funds	**91 003.5**	**NA**	**38 308.0**	**49 249.7**	**3 445.8**
Business enterprises	NA	NA	NA	NA	NA
Direct government	55 127.2	0	23 611.2	30 363.8	1 115.2
General university funds	0	-	-	0	-
Higher education	0	0	0	0	0
Private non-profit organisations	967.1	0	0	0	967.1
Funds from abroad	34 909.2	0	14 696.8	18 885.9	1 326.5
Total intramural expenditure by type of R&D	**56 094.27**	**NA**	**23 611.17**	**30 363.8**	**2 119.3**
Basic research	10 747.6	NA	4 523.9	5 817.7	406.0
Applied research	32 899.27	NA	13 847.97	17 808.4	1 242.9
Experimental development	12 384.3	NA	5 239.3	6 737.7	407.3
Not elsewhere classified	63.1	NA	0	0	63.1

* Sector not surveyed

Table 3A.35: Uganda: R&D personnel headcount by occupation and level of education (2007/08)

R&D personnel headcount (HC)	Total	Business sector	Government	Higher education	Private non-profit organisations*
Total R&D personnel by occupation	**1 768**	**89**	**889**	**790**	**NA**
Researchers	785	37	394	354	NA
Technicians	281	20	172	89	NA
Other	702	32	323	347	NA
Female	**677**	**28**	**335**	**314**	**NA**
Researchers	302	13	162	127	NA
Technicians	95	2	67	26	NA
Other	280	13	106	161	NA
Total R&D personnel by level of education	**1 768**	**89**	**889**	**790**	**NA**
ISCED 6	156	1	45	110	NA
ISCED 5A	947	50	495	402	NA
ISCED 5B	0	0	0	0	NA
Other	665	38	349	278	NA
Female	**677**	**28**	**335**	**314**	**NA**
ISCED 6	45	1	13	31	NA
ISCED 5A	337	14	192	131	NA
ISCED 5B	0	0	0	0	NA
Other	295	13	130	152	NA

* Sector not surveyed

Table 3A.36: Uganda: Researchers headcount by level of education and field of science (2007/08)

R&D personnel headcount (HC)	Total	Business sector	Government	Higher education	Private non-profit organisations*
Total researchers by level of education	**785**	**37**	**394**	**354**	**NA**
ISCED 6	121	1	35	85	NA
ISCED 5A	548	23	296	229	NA
ISCED 5B	0	0	0	0	NA
Other	116	13	63	40	NA
Female	**302**	**13**	**162**	**127**	**NA**
ISCED 6	38	1	11	26	NA
ISCED 5A	195	7	117	71	NA
ISCED 5B	0	0	0	0	NA
Other	69	5	34	30	NA
Total researchers by field of science	**266**	**NA**	**NA**	**266**	**NA**
Natural sciences	135	NA	NA	135	NA
Engineering and Technology	5	NA	NA	5	NA
Medicine and Health	12	NA	NA	12	NA
Agricultural sciences	89	NA	NA	89	NA
Social sciences	24	NA	NA	24	NA
Humanities	1	NA	NA	1	NA
Female	**78**	**NA**	**NA**	**78**	**NA**
Natural sciences	49	NA	NA	49	NA
Engineering and Technology	1	NA	NA	1	NA
Medicine and Health	4	NA	NA	4	NA
Agricultural sciences	17	NA	NA	17	NA
Social sciences	7	NA	NA	7	NA
Humanities	0	NA	NA	0	NA

* Sector not surveyed

Table 3A.37: Uganda: R&D personnel full-time equivalents by occupation (2007/08)

R&D personnel full-time equivalent (FTE)	Total	Business sector	Government	Higher education	Private non-profit organisations*
Total R&D personnel by occupation	**634.75**	**58.79**	**357.52**	**218.44**	**NA**
Researchers	351.76	25.79	232.12	93.85	NA
Technicians	120.07	14.9	39.34	65.83	NA
Other	162.92	18.1	86.06	58.76	NA
Female	**267.48**	**8.86**	**192.69**	**65.9**3	NA
Researchers	184.8	6.11	139.32	39.37	NA
Technicians	27.19	0.14	4.69	22.36	NA
Other	55.49	2.61	48.68	4.2	NA

* Sector not surveyed

Table 3A.38: Uganda: Gross expenditures on R&D in Ugandan Shilling (2007/08)

Gross expenditures on R&D (GERD) *Million national currency*	**Total**	**Business sector**	**Government**	**Higher education**	**Private non-profit organisations***
GERD by sector and source of funds	**256 829.7**	**10 489.1**	**118 171.1**	**128 169.5**	**NA**
Business enterprises	10 714.1	9 061.9	1 652.3	0	NA
Direct government	95 226.2	32.0	86 400.4	8 793.8	NA
General university funds	3 284.6	-	-	3 284.6	NA
Higher education	114 796.2	0	0	114 796.2	NA
Private non-profit organisations	NA	0	0	0	NA
Funds from abroad	32 808.5	1 395.2	30 118.4	1 294.9	NA
GERD by sector and type of costs	**256 829.7**	**10 489.0**	**118 171.2**	**128 169.5**	**NA**
Labour costs	3 902.1	201.3	2 868.9	831.9	NA
Other current costs	208 829.7	1 356.0	90 792.9	116 680.8	NA
Land and buildings	44 097.9	8 931.7	24 509.4	10 656.8	NA
Instruments and equipment	†	†	†	†	†
Total intramural expenditure by type of R&D	**256 829.7**	**10 489.0**	**118 171.2**	**128 169.5**	**NA**
Basic research	26 190.6	3 384.5	10 004.2	12 801.9	NA
Applied research	152 359.0	3 128.2	97 619.7	51 611.1	NA
Experimental development	78 280.1	3 976.3	10 547.3	63 756.5	NA
Not elsewhere classified	-	-	-	-	-
Expenditure on R&D by field of science	**256 829.7**	**10 489.0**	**118 171.2**	**128 169.5**	**NA**
Natural sciences	13 031.6	791.5	1 567.7	10 672.4	NA
Engineering and Technology	793.5	767.5	0	26.0	NA
Medicine and Health	55 982.7	7 970.0	47 051.6	961.0	NA
Agricultural sciences	131 910.7	634.4	16 068.8	115 207.6	NA
Social sciences	46 613.1	314.4	45 905.0	393.6	NA
Humanities	3 743.4	2.1	3 658.7	82.5	NA
Other	4 754.7	9.1	3 919.2	826.4	NA

* Sector not surveyed
† Included in Land and Buildings

Table 3A.39: Zambia: R&D personnel headcount by occupation and level of education (2008)

R&D personnel headcount (HC)	Total	Business sector	Government	Higher education	Private non-profit organisations
Total R&D personnel by occupation	**2 219**	**141**	**774**	**1 246**	**58**
Researchers	612	35	198	366	13
Technicians	835	68	243	490	34
Other	772	38	333	390	11
Female	**818**	**49**	**372**	**367**	**30**
Researchers	188	11	67	106	4
Technicians	270	16	102	134	18
Other	360	22	203	127	8
Total R&D personnel by level of education	**2 219**	**141**	**774**	**1 246**	**58**
ISCED 6	316	17	71	219	9
ISCED 5A	625	50	239	323	13
ISCED 5B	735	58	331	331	15
Other	543	16	133	373	21
Female	**818**	**49**	**372**	**367**	**30**
ISCED 6	93	4	32	55	2
ISCED 5A	183	14	66	99	4
ISCED 5B	222	13	93	102	14
Other	320	18	181	111	10

Table 3A.40: Zambia: Researchers by level of education (2008)

R&D personnel headcount (HC)	Total	Business sector	Government	Higher education	Private non-profit organisations
Total researchers by level of education	**612**	**35**	**198**	**366**	**13**
ISCED 6	194	7	54	130	3
ISCED 5A	275	12	103	155	5
ISCED 5B	140	13	41	81	5
Other	3	3	0	0	0
Female	**188**	**11**	**67**	**106**	**4**
ISCED 6	54	3	13	38	0
ISCED 5A	80	4	35	37	4
ISCED 5B	54	4	19	31	0
Other	0	0	0	0	0

Table 3A.41: Zambia: R&D personnel full-time equivalents by occupation/level of education and field of science (2008)

R&D personnel full-time equivalent (FTE)	Total	Business sector	Government	Higher education	Private non-profit organisations
Total R&D personnel by occupation	**2 130**	**126**	**713**	**1 236**	**55**
Researchers	536	26	142	356	12
Technicians	829	65	241	490	33
Other	765	35	330	390	10
Female	**803**	**48**	**367**	**363**	**25**
Researchers	184	12	65	104	3
Technicians	265	15	101	133	16
Other	354	21	201	126	6
Total R&D personnel by level of education	**2 130**	**126**	**713**	**1 236**	**55**
ISCED 6	307	11	69	218	9
ISCED 5A	612	38	238	324	12
ISCED 5B	727	55	329	328	15
Other	484	22	77	366	19
Total R&D personnel by field of science	**2 130**	**126**	**713**	**1 236**	**55**
Natural sciences	238	0	55	176	7
Engineering and Technology	272	24	33	211	4
Medicine and Health	167	5	97	63	2
Agricultural sciences	321	21	146	138	16
Social sciences	762	56	287	399	20
Humanities	370	20	95	249	6

Table 3A.42: Zambia: Gross expenditures on R&D in Zambian Kwacha (2008)

Gross expenditures on R&D (GERD) *Million national currency*	Total	Business sector	Government	Higher education	Private non-profit organisations
GERD by sector and source of funds	**186 637**	**3 765**	**36 067**	**145 900**	**905**
Business enterprises	6 024	3 444	567	1 980	33
Direct government	143 990	0	33 990	110 000	0
General university funds	33 000	-	-	33 000	-
Higher education	0	0	0	0	0
Private non-profit organisations	602	0	80	0	522
Funds from abroad	3 021	321	1 430	920	350

Chapter 4: Innovation

4.1 Introduction

The activity of innovation has been linked to economic growth and is regarded as a potential creator of wealth and well-being. In Africa, innovation can contribute to moving towards achieving the Millennium Development Goals (MDGs) and strengthening economies by creating jobs for the young populations of Africa.

When economic systems, or markets, fail to provide the conditions needed to foster innovation, governments intervene and, to provide guidance for this intervention, they develop innovation strategies. High-level examples of innovation strategies are found in the Organisation for Economic Cooperation and Development (OECD, 2010) and the European Union (EU) (CEC, 2006, 2009). A current country example is the US Innovation Strategy (Executive Office of the President, 2009), and references to others can be found in Gault (2010).

Once governments develop an innovation strategy, statistical measures are required to monitor the progress of specific interventions and to support evaluation. It is principally through evaluation that policy learning occurs, leading to improvement of the intervention, or its abandonment if it is shown not to be working. The mix of interventions and measures can also support policy experiments (Lundvall *et al.* 2009), in regions or in industries, that inform policy implementations more broadly. Innovation strategies may be quite elaborate, but they may also be as simple as supporting the use by firms of information and communication technologies (ICTs) through tax policy.

If innovation is economically and socially important, and it is the subject of government policy, then statistical measures, leading to indicators, are steps towards providing evidence for policy development to ensure a better environment for innovation. This chapter provides a view of what innovation is, for statistical purposes, and how it is measured. It then looks at the initial results of innovation surveys in selected countries.

4.2 What is innovation?

Experts have been discussing the definitions of innovation for statistical purposes for at least 25 years in the OECD's Working Party of National Experts on Science and Technology Indicators (NESTI), and parallel discussions have taken place in working groups convened by Eurostat, the statistics office of the European Communities. The current codification of this ongoing discussion is the third edition of the *Oslo Manual* (OECD/Eurostat, 2005), which provides guidelines for the collection and interpretation of data on innovation in 31 OECD countries and 27 members of the European Union. This and earlier editions of the *Oslo Manual* have supported the EU Community Innovation Survey (CIS), which was first conducted for reference year 1992 and continues to be used in the EU and in other countries to gather information in support of innovation policy.

At the first Intergovernmental Meeting on Science, Technology and Innovation Indicators in Maputo in 2007, a decision was taken to adopt both the *Oslo Manual* and the *Frascati Manual* (OECD, 2002) for use in measuring innovation and R&D in Africa. The intention was to gain experience in African countries and then to prepare guidelines, or manuals, that would take account of this experience and codify the knowledge for use in subsequent African surveys (Gault, 2008). In parallel with this learning by doing, using and interacting,[8] the New Partnership for Africa's Development (NEPAD) Office of Science and Technology (OST) has been an observer at NESTI since 2007 and is able to participate in debates on the revision of any of the Frascati family of manuals (OECD, 2002), based on experience gained in Africa.

For the work reported on in this chapter, the definition of innovation comes from OECD/Eurostat (2005):

> 146.[9] An **innovation** is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organization method in business practices, workplace organization or external relations.

It is linked to the market through 'implementation':

> 150. A common feature of an innovation is that it must have been *implemented*. A new or improved product is implemented when it is introduced on the market. New processes, marketing methods or organizational methods are implemented when they are brought into actual use in the firm's operations.

In the *Oslo Manual*, innovation is connected to the market. The definition in the third edition includes marketing, organisational methods and business practices, whereas the definition in the second edition did not. The surveys that are reported on in this chapter measured product and process innovation, where process was confined to transformation activities. However, the surveys include questions on market development, organisational change and business practices, which provide a basis for assessing the importance of these aspects of innovation.

The activity of innovation is characterised by putting a product on the market. For there to be a product innovation, the product has to be new or significantly improved, and for there to be a process innovation, the means of producing the product, or of delivering the product to market, have to be new or significantly improved. The *Oslo Manual* also recognises degrees of novelty of innovation, the lowest of which is 'new to the firm', followed by 'new to the market'.

Process innovation that is new to the firm occurs if the firm has invested in machinery or equipment it has never used before, even though the use of such machinery or equipment may not have been uncommon in the industry in which the firm operated.

A distinction should be made between the activity of innovation and innovation activities. A partial list of innovation activities taken from the South African Innovation Survey questionnaire (Blankley and Moses, 2009) includes: R&D, whether continuous or occasional; outsourced R&D; the acquisition of machinery, equipment and software; acquisition of other external knowledge; training; market introduction of innovations; and other activities including design. An example of acquisition of external knowledge, in addition to the contracting out of R&D, is the purchase or licensing of intellectual property, and knowledge gained through international trade or from the consequences of foreign direct investment (FDI).

While the firm may engage in some or all of these activities with a view to innovation as the outcome, such activities, in and of themselves, do not constitute innovation. This means that without a market connection, R&D or patents are not innovation, they are innovation activities.

4.3 How is innovation measured?

Over the years, there have been attempts to measure innovation through proxy measures such as R&D performance and patenting. However, such proxies are just that, and they have some weaknesses. Not all firms that perform R&D or patent actually innovate. The propensity to conduct R&D is related to the size of the firm; smaller firms may innovate, but they may not necessarily have the resources to perform R&D. The same could be said of patenting, and the activity of patenting is also industry dependent. Some industries patent more than others (Scherer, 2005).

In the last 20 years, actual surveys of the activity of innovation have emerged, for example, the Community Innovation Survey (CIS) in the European Union,[10] which has been adopted by the Human Sciences Research Council in South Africa (Blankley and Moses, 2009) and by most of the participants in the surveys reported on in this chapter. In Europe, the results of the Community Innovation Surveys are compiled by Eurostat for use by the policy and research communities and the public. The results are available in print form (Eurostat, 2010) and electronically through the European Innovation Scoreboard (EIS) and the Innobarometer (Pro Inno Europe, 2010).

Not all survey questions work in all countries or in all industry sectors in any one country. The ideal situation for an initiative such as that of the NEPAD OST would be to have a set of core questions that have been shown to work in most countries and then to invite countries to add questions of specific interest to them. For example, a country with a large agricultural sector might wish to probe more deeply the activity of innovation in that sector, while still being able to report on the results of the core questions to support international comparisons.

The clients that will use the survey results have a particular interest in the responses to survey questions. Ministries or research institutes are examples of such clients, and the questions should ideally be developed in consultation with the client and then subjected to testing in the field.

The testing of questions and questionnaires raises an important issue for the organisation doing the testing. Apart from gathering information, a questionnaire can change behaviour if it is given to a firm that knows nothing about the topic, in this case innovation. The testing exercise becomes a learning process for the firm and a teaching opportunity for the testers of the questionnaire. The issue is the extent to which survey teams should be used to change the behaviour of their subjects.

Innovation surveys produce aggregate statistics that can be compared across countries; they can also be compared over time to observe trends. Surveys that are conducted once are referred to as cross-sectional surveys, and repeated cross-sectional surveys can be used to establish trends. However, they cannot be used for the analysis of cause and effect, such as the impact of the introduction of a tax credit for the purchase of capital equipment related to innovation. For this, panel surveys are required in which the participating firms are present for an agreed number of years. Panel surveys are expensive in terms of the costs of running them and maintaining the sample, as well as the burden to the respondent. The innovation surveys reported on here are the first in a series of cross-sectional surveys.

4.4 Participation and findings

Of the 19 countries involved in the NEPAD OST project, ten undertook innovation surveys as part of the project and provided results, namely: Burkina Faso, Egypt, Ethiopia, Ghana, Lesotho, Mozambique, Tanzania, South Africa, Uganda and Zambia.

As this was a pilot study, not all countries were able to use large samples, which would have allowed them to make population estimates for the variables that were being measured (Table 4.1). Some had samples that were quite small but still provided an indication of innovation in the country. Sector coverage also differed from country to country: all countries covered manufacturing; some also covered mining; some covered service industries; and there were cases of other sectors being included, such as higher education and research establishments. While the various ways in which the surveys were carried out make statistically sound country comparisons impossible, some deductions can be made from the results.

4.4.1 Innovation is pervasive

The first finding is that innovation was present in all the participating countries, in both small and large firms. The innovation included product and process innovation as well as organisational and marketing innovation. In all cases, some of the resulting goods and services from innovative firms were sold outside of the producing country. Trade is a means of connecting the firm not just to purchasers, but to knowledge of markets, technologies and practices in other countries. The connection of innovative firms was a clear result in all participating countries.

4.4.2 Innovation is a connected activity

The client or customer is the lead source of ideas for innovation outside the firm itself. This was the case for every country, but one, for which data were available. In the case of Mozambique, competitors were as influential as clients. Public institutions such as universities and technikons, governments and public research organisations were low on the list of external sources. CIS and CIS-like surveys in other parts of the world generate similar results (Eurostat, 2008: Tables 5.12 and 5.37).

Innovative firms collaborated, and their first choice of collaborator, within their own country, was the client or customer. Partners of choice varied in the case of collaboration outside the country.

Product innovation (including goods or services) was done principally by the firm, but there was significant evidence of collaboration with other enterprises or institutions. There was also evidence of product innovation being done by other institutions, which was particularly strong in the case of Lesotho.

Process innovation was also done principally by the firm, but there was also significant collaboration and some evidence of innovation by other institutions.

The lead innovation activity was the acquisition of machinery, equipment and software, followed by R&D conducted by the firm. This order was reversed in the case of Ghana and Tanzania.

4.4.3 Innovation had impact

Most countries considered the main impact of innovation to be the improved quality of the goods and services offered, followed by flexibility in production, an increased range of products, and increased capacity to produce. Tanzania and Zambia reported the importance of meeting government regulatory requirements as an impact of innovation.

4.4.4 There are barriers

The barrier most frequently cited was the lack of funds in the enterprise and the cost of innovation. Other barriers included the domination of the market by established enterprises and the lack of information on both technologies and markets. Burkina Faso found the lack of qualified personnel to be the most significant barrier.

4.4.5 Size matters

Innovation activities, such as R&D, as well as innovation itself, are related to the size of the firm. Innovation surveys in industrialised countries show a positive correlation with firm size for both variables. In the case of South Africa, size classes are determined by revenue size, and it is difficult to make the link to employment size (Blankley and Moses, 2009). However, the percentage of innovative firms is lowest in the smallest of the four class sizes, 4, (40.9%) and highest in the largest class, 1, (60.0%), but class 2 is higher (69.1%) than class 1 and class 3 (53.25). This variation warrants further research, but the difference between the propensity to innovate in class 1 and class 4 does make the point that size matters. This is confirmed by data from Ghana, which examined the propensity to innovate in small, medium and large firms and demonstrated a clear correlation between size and propensity to innovate.

Another characteristic of industrial populations is that there are many micro or small-sized firms, well over 90% of the population, which means that the employment size of the surveyed firms makes a difference to the results. For two equivalent countries, an innovation estimate based on sampling all firms with ten or more employees will be higher than a sample based on all firms with one or more employee. The variation in employment size cut-off for firms given in Table 4.1 is an argument against any attempt to compare countries on the basis of their propensity to innovate.

A final observation on firm size and innovation is that surveys of firms with large employment or turnover will yield a high estimate of the propensity to innovate.

4.4.6 In most countries, many firms that innovated did not perform R&D

Innovation can and does happen without the need for inhouse R&D within the firm, but this raises questions about the source of the knowledge supporting the creation of value in the firm. For those countries that reported this statistic, the percentage of firms that were innovative and performed R&D is given in Table 4.1. The difference between this number and 100 per cent is the percentage of innovative firms not doing R&D. This number is only indicative, as most countries reported the results of their sample, rather than population estimates.

Table 4.1 Characteristics of innovation surveys in participating countries and an example of a finding

Participating country	Reference period	Firms responding	Employment cut-off for firms in survey	Percentage of innovative firms performing R&D
	Years	Number of firms (range)	Number of employees	%
Burkina Faso	2006–2008	<500	NA*	30
Egypt**	2005–2007	>1000	1	74
Ethiopia†	2005–2007	<500	NA	11‡
Ghana	2006–2007	<500	5	NA
Lesotho	2006–2008	<500	1	53
Mozambique	2005–2007	<500	25	24
Tanzania	2005/06–2007/08	<500	10	42
South Africa#	2002–2004	>1000	Revenue§	52
Uganda	2006–2008	<500	Revenue§	25–26‡
Zambia	2006–2008	<500	0	NA

* Data were not available at the time of publication.
** Egypt used a representative sample (Egyptian Ministry of Scientific Research, 2009).
† Ethiopia used a questionnaire different from those of other participating countries.
‡ Non-responses were distributed in proportion to responses.
§ Revenue of the firm was used in the absence of employment data.
\# South Africa used a stratified sample and published population estimates (Blankley and Moses, 2009).

4.5 Interpreting the findings

Table 4.1 gives some of the reasons why the results of this first round of innovation surveys cannot be compared. While most countries used a standard questionnaire, based on that used in South Africa, which was in turn based on CIS 4, different size cut-offs, sample sizes and reference periods were used.

Countries with earlier reference periods would have observed different economic conditions from those seen by later ones.

Some of the more robust observations, such as the importance of the client and customer as both a source of ideas for innovation and as a collaborator, are given in the text. The example finding, with some variation from country to country, is the statistic showing the percentage of innovative firms that perform R&D. This statistic should not be used for country comparisons for reasons given in the previous paragraph. However, the message that should be taken from the example is that not all innovative firms performed R&D. This result is characteristic of surveys carried out by OECD countries (Gault, 2010; OECD 2009), and it raises policy questions about promoting entrepreneurship as well as R&D, especially in small firms.

The common results of the surveys provide a picture of an innovative firm in Africa, but with some gaps. The reader is encouraged to review the reports of the participating countries as they become available and raise questions that could contribute to future rounds of innovation surveys or surveys in new participating countries.

The present surveys, and their results, demonstrate that African countries are adopting the methods and standards needed to produce internationally comparable indicators of the activity of innovation, and in so doing, the participating countries are building the human and institutional capacities needed for such work.

4.6 Using the findings

While this round of surveys does not support comparable findings on the propensity to innovate in countries, industries or regions, there are findings that might attract policy interest.

The importance of the relationship of the innovative producer with the client, both as a source of ideas and as a collaborator, might suggest support for collaboration. The fact that the leading innovation activity is the acquisition of machinery and equipment could lead to discussion of tax incentives to encourage investment in certain classes of machinery and equipment, such as those related to information and communication technologies (ICTs). The tendency of innovative firms to trade abroad might suggest a role for an export development bank or other institution providing support for firms that are trying to enter the export market.

Human resources are a factor in all innovation activity. There is thus a link between innovation and policies on education, health, training and migration that governments use to create framework conditions through service provision, regulation and practice. This means, for example, that environmental regulation could be an incentive for some firms to meet the regulatory requirements, a result that was observed in Tanzania and Zambia.

One of the findings of the surveys was that process innovation was done mainly by the firm, but sometimes in collaboration with others. In fewer cases, process innovation was done by organisations outside the firm, an example of which was the sale of a new process technology to the firm, thereby making the purchasing firm innovative at the level of 'new to the firm' with respect to process innovation. Firms produce and sell products; they do not sell their production processes, so the fact that a firm is the leading actor in process innovation suggests it is solving its own problems in order to become better at what it does. Understanding what firms are doing, and how or whether government programmes support what they are doing, is an area for further research. In particular, better understanding is required of firms that innovate without performing R&D.

The surveys illustrate the need for capacity building throughout the innovation system, including conducting the surveys, processing the data and using the results in the policy process. This is an ongoing process of continual learning and improvement. The role of survey statistician as teacher also needs to be considered. Not every respondent has thought about innovation before, or of the potential impact of increased innovation activities on the firm.

The findings of the surveys reported on in this chapter will support the participation of African institutions in international forums at which innovation indicators are discussed and prepare the way for the creation of an African group of national experts on science and technology indicators comparable to the OECD NESTI. Such a group could bring African solutions to African problems and influence indicator work in the rest of the world. This is perhaps the most significant outcome of the survey activity reported on here.

[8] Lundvall *et al.* (2009:3) distinguish two modes of learning: (1) learning by doing, using and interacting (DUI) and (2) learning through science, technology and innovation (STI). The latter is more R&D based.

[9] This is the number of the paragraph in OECD/Eurostat (2005).

[10] The questionnaires for CIS 4 and for CIS 2006 are the same. A generic version in English can be found at www.oecd.org/dataoecd/37/39/37489901.pdf. The questions are discussed in Gault (2010).

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Chapter 5: Bibliometric Analysis of Scientific Output

5.1 Introduction

Although bibliometric scholarship on African scientific research is still relatively limited, there is evidence of recent growth in interest. Seminal studies were done by Blickenstaff and Moravcsik in the 1980s (Blickenstaff and Moravcsik, 1982; Moravcsik, 1985) and by a group of scholars (including Roland Waast and Jacques Gaillard) at the Institute for Development Research in Paris in the 1990s and later (Narva´ez-Berthelemot, Russell and Velho, 2002), as well as by Dahoun (1999). More recent studies on African science were conducted by Tijssen (2007) and Pouris and Pouris (2009). Country-specific bibliometric analyses are also on the increase: there is a significant body of scholarship on South Africa (by Jacobs and Ingwersen [2000], Mouton [2008, 2010], Pouris [2005] and others), Morocco (Bouabid and Martin, 2009), Nigeria, Algeria and countries in Central Africa (Boshoff, 2009). In addition to these country studies, there are also analyses of specific fields or interdisciplinary topics, such as the study by Onyancha and Ocholla (2009) on HIV/AIDS research in Africa, Nwagu's (2006) study of the productivity of biomedical scientists in Nigeria, a paper by Erftemeijer, Semesi and Ochieng (2001) on marine botanical research in East Africa and Farahat's paper (2002) on authorship patterns in agricultural sciences in Egypt.

Methodological issues have often been central in these studies. Various studies (Gaillard *et al*., 1997; Shrum, 1997), for example, have commented on the lack of representation of African journals in international bibliographic databases such as the Thomson Reuters Web of Science, with the result that African science is less 'visible' in these databases. One of the ways in which scholars have responded has been to consult a broader range of databases; for example, the group at the Institut de Recherche pour le Développement (IRD) Centre for Development Studies (in Montpellier, France) has consistently utilised the Pascal database, particularly because of its broader coverage of francophone countries in Africa. In a study of the social sciences, Narva´ez-Berthelemot and Russell (2001) consulted the DARE[11] database of the United Nations Educational, Scientific and Cultural Organisation (UNESCO), which has a much larger coverage of social science journals than the Web of Science. It is now well-documented and increasingly recognised by scholars working on African science that large numbers of 'local' African journals, especially from countries such as Nigeria and South Africa, but also journals from North African countries as well as some francophone countries (Côte d'Ivoire and Burkina Faso), are not indexed in any of the major international indexes.

This is one of the reasons for our decision to select SciVerse Scopus as the primary data source for the bibliometric analyses presented in this chapter. Various studies have shown (De Moya-Anegon *et al.*, 2007; Norris & Oppenheim, 2007) that not only is the overall coverage of journals in Scopus more comprehensive than the Web of Science (approximately 16 000 journals in Scopus compared with 9 500 in the Web of Science [WoS][12]), but its coverage of developing countries is superior. Having said this, it is clear from our analysis that the vast majority of local African journals remain excluded from Scopus. This 'under-coverage' is especially severe for disciplines in the humanities and social sciences. This means that figures reported for these fields in this chapter generally represent low estimates of actual output, especially for the larger countries.

5.2 Results of previous bibliometric studies

Bibliometric studies on African science have focused predominantly on the following four themes:

- Trends in scientific output over time, including shifts in Africa's share of world science (as measured in papers included in the ISI Science Citation Index).
- The differential contribution by individual countries to African science – and specifically the dominance by South Africa and Egypt (which together produce more than half of all output).
- The differential contribution by individual institutions within countries: in the most productive countries (South Africa, Algeria, Nigeria and Tanzania), there is a broad base of fairly 'robust' and significant institutions (universities and research institutes), whereas in the smaller countries (Angola, Malawi, Mali, Mozambique and others), science is usually produced by one or very few institutions (mostly universities).
- The 'shape of knowledge production' across different scientific fields, particularly the very large contribution made by agricultural and health sciences (especially in sub-Saharan Africa) to the overall output.

Various studies have shown that Africa's share of world science, as measured in papers published in the Thomson Reuters citation indexes, has been declining steadily over the past two decades. Earlier studies (Gaillard and Waast, 1993; Moravcsik, 1985) have looked at this issue, but arguably the most comprehensive bibliometric analysis of these trends is captured in Robert Tijssen's article in *Scientometrics* in 2007.

In his analysis, Tijssen shows how sub-Saharan Africa has fallen behind quite dramatically in its contribution to world science output: from 1% in 1987 to 0.7% in 1996. The diminishing shares of African science overall do not reflect a decrease in an absolute sense, but rather increasing publication output that has grown more slowly than the international growth rate. Africa has lost 11% of its share of global science since its peak in 1987; sub-Saharan science has lost almost a third (31%) of its output. The countries in North Africa – Egypt and the Maghreb countries (Algeria, Mauritania, Libya, Morocco and Tunisia) – accounted for the modest growth in the African share of worldwide output during the period 1998–2002. The decline of sub-Saharan science can partly be attributed to discarding African journals from the citation indexes. Notably, the number of South African journals dropped from 35 to 19 over the period 1993–2004.[13]

In a detailed analysis of the individual citation profiles of a selection of countries, Tijssen shows how unequal knowledge production is evident across the continent. It is also interesting to note that there are rather significant deviations between countries in the same size category or at the same development level. For example, within the group of the seven largest countries, South Africa and Kenya clearly outperform the other five in terms of average citation rates, the share of publications cited and the field-normalised citation scores. Tijssen argues that it seems reasonable to assume that this performance is partly due to the cultural heritage from the English-language science systems of these two countries, which helps to sustain or enhance their visibility in English-language dominated international research literature. The North African countries, traditionally more focused on the Arab world and the French-speaking scientific world, are at a disadvantage.

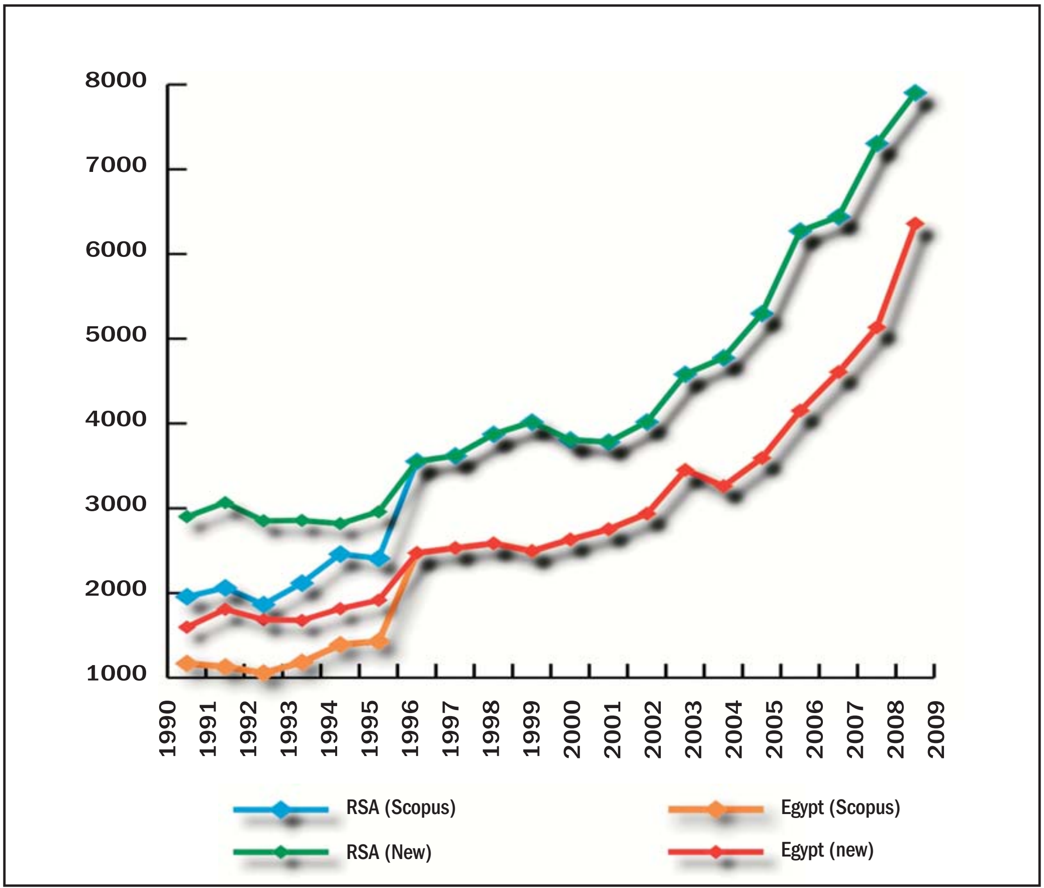
In the most recent assessment of Africa's contribution to world output, Pouris and Pouris (2009), utilising ISI Web of Science source data, show that Africa's share of world production of 3 768 434 scientific papers constituted only 1.8% between 2001 and 2004.

5.3 Statistical data: General trends

This section is devoted to a discussion of research output for the 19 countries in this study, as measured by the number of articles in the Scopus database. The analyses span a 20-year period from 1990 to 2009. Our focus is on: (1) trends in overall research output for the 19 countries; (2) a breakdown of the differential contribution of each country to the overall output; (3) a discussion of the average annual growth rate in output by country for the total period and for five-year window periods; (4) a comparison of research productivity across the 19 countries (as measured by the number of papers by million of the population for the earliest and the most recent five-year periods); and finally, (5) a discussion of the 'shape' of knowledge production (*i.e.* the distribution of output by scientific field or discipline).

Our decision to base the bibliometric analysis in this chapter on the records in the Scopus database (owned by Elsevier) was motivated by the larger coverage by Scopus of international peer-reviewed journals. However, on inspection of the data, and after comparing with the ISI files, we discovered a systematic under-coverage by Scopus of the earliest period (1990–1995). In correspondence with Dr Henk Moed, Chief Scientist at Elsevier, he indicated that Scopus does not, as a rule, cover documents published before 1996. There are exceptions to this rule, such as articles in *Nature* and *Science* and some material published by certain scientific societies. In order to achieve the best possible coverage, we therefore decided to replace the Scopus data for the period 1990–1995 with ISI data. For the remainder of the period (1996–2009), we used the Scopus data. This being said, combined ISI and Scopus data are mainly reported for the total number of paper counts per country. In cases where a finer breakdown of papers by field and institution is required, we relied on the Scopus database for the period 1990 to 2009, and, wherever possible, restricted such analyses to the most recent period of 2005 to 2009. The difference between the ISI and Scopus data for the initial period (1990–1995) is clearly illustrated in Figure 5.1, in which the Scopus and ISI data have been plotted separately for South Africa and Egypt. It is also important to point out that we have only included articles and review articles in the count of publications. We have therefore excluded editorials, letters, conference proceedings and other document types.

Figure 5.1: Comparison of papers in the ISI and Scopus databases: South Africa and Egypt (1990–2009)



5.3.1 Total research output (1990–2009)

The 19 countries discussed in this study produced 234 861 scientific papers over the period 1990–2009, as listed in the Scopus database. This constitutes more than 78% of the total output of all 54 African countries over this period. The only significant producers of scientific output among the remaining 35 African countries not included in our study are: Botswana (2 237 papers), Côte d'Ivoire (2 562); Morocco (17 319), Sudan (2 445), Tunisia (19 118) and Zimbabwe (4 383).

Figure 5.2 presents the differential contribution to total research output of the 13 most productive countries among the 19 countries in the study. The breakdown shows the dominance of South Africa (37%) and Egypt (27%), as well as the significant contributions of Nigeria (12%), Algeria (5%) and Kenya (5%).

Figure 5.2: Contribution share of individual countries (top 13) to total research output (n = 236 567 papers) (1990–2009)

5.3.2 Research output by country

More detailed breakdowns of all 19 countries are presented in Tables 5.1 and 5.2. For the sake of simplicity, the individual annual outputs have been collapsed into four intervals of equal length. The countries have been grouped into five main categories according to volume of output. Group 1 consists of the two major producers of output (South Africa and Egypt), which together produced 64% of all output. The next group consists of three countries that produced more than 10 000 papers each (Nigeria, Algeria and Kenya). Group 3 includes seven countries than produced more than 2 000 papers each; Group 4 list five countries that produced between 800 and 2 000 papers each; and Group 5 consists of two countries that produced just over 200 papers each.

Table 5.1: Scientific output by country (1990–2009)

Period	Group 1		Group 2			Group 3						
	South Africa	Egypt	Nigeria	Kenya	Algeria	Tanzania	Ethiopia	Cameroon	Uganda	Ghana	Senegal	Malawi
1990–1994	14 481	8 571	4 315	2 077	900	688	751	570	245	426	268	227
1995–1999	18 010	11 987	4 640	2 795	1 694	1 098	1 131	893	666	813	844	406
2000–2004	20 976	15 021	5 455	3 058	2 689	1 286	1 243	1 245	1 024	975	942	552
2005–2009	33 205	23 833	13 333	4 971	7 051	2 570	2 409	2 557	2 296	2 022	1 333	1 047
TOTAL	**86 649**	**59 412**	**27 743**	**12 784**	**12 334**	**5 642**	**5 534**	**5 265**	**4 231**	**4 236**	**3 387**	**2 232**

Table 5.2: Scientific output by country (1990–2009)

Period	Group 4					Group 5	
	Zambia	Burkina Faso	Gabon	Mali	Mozambique	Angola	Lesotho
1990–1994	242	180	161	106	73	26	48
1995–1999	403	289	240	228	151	35	34
2000–2004	383	416	266	267	195	56	48
2005–2009	798	751	453	508	462	120	100
TOTAL	**1 826**	**1 715**	**1 120**	**1 109**	**881**	**237**	**230**

5.3.3 Average annual growth rate in research output

The average annual growth rate in the output of scientific papers in Scopus (ISI included for the first five-year period) was calculated for the whole period 1990–2009. Because differential trends may be masked over a long time period such as this, the growth rates have also been calculated for shorter five-year periods (Table 5.3).

Of the five biggest science producers, Algeria recorded the highest annual growth rate of 14.0% between 1990 and 2009. In the medium-sized Group 3, Uganda (15.5%) recorded the highest and Ethiopia (7.5%) the lowest annual growth rates. In Group 4, Mozambique did somewhat better than the other countries in the group.

Close inspection of the most recent performance of countries during the five-year intervals yielded interesting results. In Group 1, Egypt's growth since 2005 (13.2%) is significantly higher than that of South Africa (9.0%). In Group 2, Algeria recorded a very commendable growth rate of 22.7%, confirming the findings of both Tijssen (2007) and Waast (2010) about the general improvement of the Maghreb countries in scientific output in recent years. It is also noteworthy that Nigeria, after recording a significant decline in output in the period 1990–1994, managed to turn this trend around and has recorded a very respectable 16.5% growth rate since 2005.

No country in Group 3 stands out, although Ghana and Malawi recorded good growth rates. However, the very poor performance of Senegal in the most recent five-year period must be of concern to the country, as will be the decline in annual growth rates of two of the other bigger countries, Tanzania and Cameroon. The performance of Burkina Faso (which is has been quite consistent over the whole period), and to a lesser extent Mozambique, in Group 4 are noteworthy. Conversely, the negative growth rate of Gabon in the most recent five-year period continues a trend that started in 2000. The annual output of Angola and Lesotho is too small to read much into the growth rates. In such small systems, rather large fluctuations in output are to be expected.

The reasons for some of the fluctuations are discussed in the thematic discussion, but it is clear that political instability and civil wars (and their long-standing effects), the continuing consequences of the brain drain (especially in a country such as Nigeria) and the debilitating effects of the structural adjustment policies of the World Bank, which led to cuts in donor funding for many African universities in the 1990s, would all account for these shifts.

Table 5.3: Average annual growth rate of scientific papers by country, for total period and five-year periods (1990–2009)

Country	Total period	Five-year periods (%)			
	1990–2009 (%)	1990–1994	1995–1999	2000–2004	2005–2009
Group 1					
South Africa	5.2	-1.3	7.2	6.7	9.0
Egypt	6.5	1.8	5.9	6.8	13.2
Group 2					
Nigeria	7.1	-10.3	8.0	8.3	16.5
Algeria	14.0	5.9	13.9	15.1	22.7
Kenya	5.5	4.7	2.4	7.3	11.6
Group 3					
Tanzania	8.5	7.5	2.8	13.0	9.0
Cameroon	10.2	11.3	9.9	17.3	7.5
Ethiopia	7.5	2.3	6.8	14.5	11.8
Uganda	15.5	16.5	21.8	16.0	13.3
Ghana	10.3	11.1	14.3	10.8	15.6
Senegal	10.7	13.1	21.9	11.1	3.6
Malawi	10.3	7.9	8.4	8.1	14.3
Group 4					
Zambia	7.2	-6.8	7.2	5.6	11.1
Burkina Faso	10.7	11.7	21.6	18.7	16.1
Mali	10.9	23.3	14.8	21.8	9.7
Mozambique	12.2	8.9	11.3	13.5	13.3
Gabon	6.8	-0.6	20.0	14.8	-1.5
Group 5					
Angola	11.3	13.5	17.3	-3.9	6.6
Lesotho	5.3	0.0	5.5	1.8	25.7

Note:
The average annual growth rate was estimated by fitting a linear regression trend line to the annual values after the values had been converted into logarithmic values and the exponents (number of years) of these values taken. Lesotho has no publications in the Scopus database for 1992, which resulted in an invalid logarithmic value for the total period (1990–2009) as well as for the first five-year period (1990–1994).

5.3.4 Scientific productivity: A comparison over time

International comparisons of scientific productivity are measured in two ways: (1) by calculating the number of papers in international databases (such as ISI or Scopus) per million of the population (for a particular year or time period), which is a rather ‘rough’ indicator; or (2) by dividing the number of scientific papers by 1 000 of the R&D workforce (either headcounts or full-time equivalents). The latter is generally regarded as a more refined measure, as it directly measures the productivity of the research workforce that produced the papers. However, for some of the countries in this study, the unreliability of the statistics on the research workforce would mean that such data would have to be interpreted with some caution.

Table 5.4 presents a comparison of research productivity (as measured by papers per million of the population) between the earliest and latest time periods and in descending order from highest (South Africa) to lowest (Angola).

The results show huge differences in research productivity. South Africa’s productivity (132 papers per million of the population) places it in a category of its own. A second cluster of three countries (Gabon, Egypt and Algeria) have similar productivity rates (between 40 and 70 papers per million). At the lower end of the scale are four countries (Mali, Ethiopia, Mozambique and Angola) with the lowest productivity scores (less than 10 papers per million of the population. The bulk of the countries in the study (11) all have productivity rates of between 10 and 26 papers per million of the population.

The results show that all the countries recorded significant increases in productivity. This is to be expected, as the total population of the 19 countries in the study increased by only 46% over the period 1990–2009, from 468 million to 684 million (representing an average annual growth of 2.3%), whereas scientific output grew by 186%, or an average of 9.3% per year (from an average of 6 870 papers per year for the first period to over 19 600 for the most recent period. Based on these differential growth rates, one would expect a country's research productivity to increase by a factor of approximately 3 (the difference between the growth rates in population and scientific output). Table 5.5 lists the countries in descending order of the increase in their productivity.

The analysis shows that Algeria, Uganda, Mozambique, Angola, Mali and Senegal increased their productivity by a factor of more than 3 (Table 5.5). The results for Mozambique, Mali and Angola are not particularly significant, given the small size of their science systems. The more interesting cases are Algeria (Group 2 country) and Uganda (Group 3). These two countries, compared to the other three countries, increased their productivity by a factor of more than 5 and also recorded higher productivity figures during the earlier period (1990–1994).

Table 5.4: Scientific papers per million population[14] (comparing the periods 1990–1994 and 2005–2009)

Country	Average annual output (1990–1994)	Population estimate (million) (1994)	Average annual papers per million population (1990–1994)	Average annual output (2005–2009)	Population estimate (million) (2009)	Average annual papers per million population (2005–2009)
South Africa	2 896	43.9	66	6 641	49.1	135
Gabon	32	1.1	29	91	1.5	60
Egypt	1 714	60.8	28	4 767	80.5	59
Algeria	180	27.9	6	1 410	34.6	41
Cameroon	114	13.1	9	511	19.3	26
Kenya	415	28.2	15	987	40.0	25
Senegal	54	8.7	6	267	14.1	19
Nigeria	863	98.1	9	2 667	152.2	18
Uganda	49	19.1	3	459	33.4	14
Malawi	45	9.7	5	209	15.4	14
Zambia	48	9.2	5	160	12.1	13
Tanzania	138	28.0	5	514	41.9	12
Ghana	85	17.2	5	404	34.3	12
Lesotho	10	1.9	5	20	1.9	11
Burkina Faso	36	10.1	4	158	16.2	10
Mali	21	9.1	2	102	13.8	7
Ethiopia	150	54.9	3	482	88.0	5
Mozambique	15	17.3	1	92	22.1	4
Angola	5	9.8	1	24	13.1	2

Table 5.5: Magnitude of increase in productivity of countries (comparing 1990–1995 with 2005–2009)

Country	Papers per million population (1990–1994)	Papers per million population (2005–2009)	Magnitude of increase in productivity (ratio: 2005–09/1990–94)
Algeria	6.5	41	6.3
Uganda	2.6	14	5.4
Mozambique	0.8	4	5.0
Angola	0.5	2	3.5
Mali	2.3	7	3.2
Senegal	6.2	19	3.1
Cameroon	8.7	26	3.0
Malawi	4.7	14	2.9
Burkina Faso	3.6	10	2.7
Zambia	5.3	13	2.5
Tanzania	4.9	12	2.5
Ghana	5.0	12	2.4
Lesotho	5.1	11	2.1
Gabon	29.3	60	2.1
Egypt	28.2	59	2.1
Ethiopia	2.7	5	2.0
South Africa	66.0	135	2.0
Nigeria	8.8	18	2.0
Kenya	14.7	25	1.7

A comparison with a number of similar-sized countries in other regions of the world shows that South Africa is the only country with comparable productivity ratings. Table 5.6 lists these countries, including three other African countries (Tunisia, Botswana and Morocco) not included elsewhere in this analysis.

Table 5.6: Comparison of research productivity (2005–2009)

Country	Average annual output (2005–2009)	Population (million) (2009)	Papers per million population
New Zealand	6 905	4.3	1 606
Greece	10 371	10.7	969
Portugal	7 188	10.7	672
South Korea	29 883	48.6	615
Chile	4 000	16.7	240
Tunisia	2 220	10.6	209
Malaysia	3 773	26.2	144
South Africa	6 475	49.1	135
Brazil	25 800	201.1	128
Botswana	214	2.0	107
Morocco	1 344	31.6	43

Table 5.7 presents information on research productivity for the most recent available years. Two sources of information were used for the number of researchers (for countries where such information was available), namely, the R&D Survey conducted for the African Science and Technology Indicators Initiative

(ASTII) programme and the United Nations Educational, Scientific and Cultural Organisation (UNESCO) Institute of Statistics. Needless to say, the underlying data for these statistics are not always equally credible. Because the annual output of scientific papers fluctuates (even at country level), the average annual output over the last five-year period has been included.

The results show that research productivity varies greatly by country, whether calculated as papers by headcount of researchers or by full-time equivalent (FTE) (which would be the more appropriate measure). Some of this variation can be attributed to the small sample sizes of certain countries and should therefore be interpreted with some caution. For the larger countries (more than 400 papers per year), the ratio varies between 0.19 (Algeria) and 1.31 (Uganda). In the largest country, South Africa, each FTE researcher produces an average of one paper every three years. In the second-largest country, Nigeria, productivity is higher, as each FTE researcher produces a paper almost every second year.

Table 5.7: Scientific papers per number of researchers per year (2005–2009)

Country	Average annual no. of papers (2005–2009)	Researchers (headcount)	Papers per researcher (headcount)	Researchers (FTE)	Papers per FTE researcher
South Africa	6 641	400 084*	0.02	19 320*	0.34
Nigeria	2 667	17 624*	0.15	5 677*	0.47
Kenya	987	3 477*	0.28	n.d.	n.d.
Algeria	1 410	n.d.	n.d.	7 331†	0.19
Tanzania	514	2 755*	0.19	n.d.	n.d.
Ethiopia	482	n.d.	n.d.	6 051†	0.30
Cameroon	511	454*	1.13	n.d.	n.d.
Gabon	91	527*	0.17	n.d.	n.d.
Ghana	404	636*	0.64	392*	1.03
Uganda	459	785*	0.58	352*	1.31
Senegal	267	7 859*	0.03	4 527*	0.06
Malawi	209	733*	0.29	406*	0.51
Mali	102	877*	0.12	672†	0.15
Mozambique	92	n.d.	n.d.	1 532†	0.06
Lesotho	20	n.d.	n.d.	51†	0.39

* R&D Survey conducted in 2007 for the ASTII programme (*cf.* Chapter 3)
† UNESCO Institute of Statistics (www.uis.unesco.org): (Algeria: estimate is for 2005; Ethiopia: estimate is for 2007; Mali: estimate is for 2006; Lesotho: estimate is for 2004)

5.3.5 The shape of knowledge production

Differences in the shape and distribution of scientific output across scientific fields in different countries and regions of the world are determined by many factors, including the changing research demands (particularly the demands of agrarian economies compared with industrialising economies) and the strengths of scientific establishments (taking historical and cultural influences into account), as well as the state of governance and funding of scientific research. National knowledge production is also steered and shaped by national policies and the social inscription of science, in other words, what kinds of science (basic and strategic science areas) are prioritised and whether the social sciences and humanities are appreciated and supported, or merely tolerated and even ignored. Ultimately, size matters – larger science systems have the capacity for more diversity and more coverage of the full scope of the sciences; small systems, by definition, are limited in their ability to invest in specific scientific domains. The detailed discussion of each country's research output across scientific fields is presented in the country-specific discussion (*cf.* Annex A, with Annex B containing the finer breakdown of scientific

Table 5.8: Shape of research output by group and country (2005–2009)

Country	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
Group 1					
South Africa (56%)	Medicine (19%)	Agriculture/ Biology (16%)	Social Sciences (10%)	Earth & Planetary Sciences (7%)	Environmental Sciences (6%)
Egypt (57%)	Medicine (17%)	Chemistry (14%)	Physics & Astronomy (9%)	Materials Sciences (9%)	Engineering (8%)
Group 2					
Nigeria (66%)	Medicine (25%)	Agriculture/Biology (18%)	Biochemistry/ Molecular Biology (12%)	Social Sciences (7%)	Environmental Sciences (5%)
Kenya (77%)	Agriculture/ Biology (27%)	Medicine (23%)	Immunology & Microbiology (11%)	Biochemistry/ Molecular Biology (10%)	Social Sciences (8%)
Algeria (62%)	Physics & Astronomy (17%)	Engineering (13%)	Materials Sciences (13%)	Mathematics (10%)	Chemistry (9%)
Group 3					
Tanzania (76%)	Medicine (31%)	Agriculture/Biology (19%)	Immunology & Microbiology (11%)	Environmental Sciences (8%)	Social Sciences (6%)
Ethiopia (66%)	Agriculture/ Biology (28%)	Medicine (18%)	Environmental Sciences (8%)	Immunology & Microbiology (6%)	Social Sciences (6%)
Cameroon (59%)	Agriculture/ Biology (20%)	Medicine (16%)	Physics & Astronomy (9%)	Biochemistry/Molecular Biology (7%)	Immunology & Microbiology (7%)
Ghana (73%)	Medicine (25%)	Agriculture/Biology (20%)	Social Sciences (10%)	Environmental Sciences (9%)	Immunology & Microbiology (9%)
Uganda (81%)	Medicine (37%)	Agriculture/Biology (16%)	Immunology & Microbiology (14%)	Environmental Sciences (7%)	Social Sciences (8%)
Senegal (70%)	Medicine (31%)	Agriculture/Biology (16%)	Immunology & Microbiology (12%)	Biochemistry/Molecular Biology (6%)	Social Sciences (5%)
Malawi (83%)	Medicine (47%)	Agriculture/Biology (13%)	Immunology & Microbiology (12%)	Social Sciences (8%)	Biochemistry/Molecular Biology (4%)
Group 4					
Zambia (79%)	Medicine (38%)	Immunology & Microbiology (17%)	Agriculture/Biology (12%)	Social Sciences (8%)	Veterinary (5%)
Burkina Faso (80%)	Medicine (44%)	Immunology & Microbiology (20%)	Veterinary (7%)	Social Sciences (6%)	Pharmacology & Toxicology (4%)
Gabon (83%)	Medicine (34%)	Immunology & Microbiology (21%)	Agriculture/Biology (17%)	Environmental Sciences (6%)	Biochemistry/Molecular Biology (5%)
Mali (79%)	Medicine (32%)	Agriculture/Biology (19%)	Immunology & Microbiology (13%)	Environmental Sciences (8%)	Biochemistry/Molecular Biology (7%)
Mozambique (79%)	Medicine (37%)	Agriculture/Biology (15%)	Immunology & Microbiology (12%)	Earth and Planetary Sciences (8%)	Social Sciences (7%)

Note:

The total value of the contribution of the top-five ranked fields is shown in brackets beside the country name.

papers by field for each country for the period 2005–2009). A comparative perspective on the shape of research output is presented in Table 5.8, which shows the percentage contribution of different fields to total research output.

There is a clear relationship between the size of the system and the range of fields covered. In most of the countries in Groups 3 and 4, the top five fields contribute between 70% and 83% of total output (the only exceptions are Cameroon and Ethiopia). The dominance of one field (or sometimes two) in some of the smaller systems is even more significant: in Group 4, medicine produces between 32% and 44% of all research output for these countries. Even in Group 3, medical research accounts for significant proportions of total output.

The predominance of medical and health sciences research is further illustrated if research outputs in immunology and microbiology are included with medicine. The combined output in these fields constitutes more than half the total output for Burkina Faso (64%), Malawi (59%), Zambia (55%), Gabon (55%) and Uganda (51%) and more than 40% for Mozambique (49%), Senegal (43%) and Tanzania (42%).

For most of the countries in Groups 3 and 4, the agricultural, biological and environmental sciences[15] produce the second-highest share of overall output. In the following countries these fields constitute more than a quarter of total output: Ethiopia (36%), Ghana (29%), Kenya (27%), Tanzania (27%) and Mali (27%).

Not only are the top countries less ‘dependent’ on research in a few fields, but there is better representation of fields traditionally associated with technological innovation: physics, chemistry, mathematics and engineering. This is certainly the case for Algeria, where the ‘exact sciences’ (physics, chemistry and engineering) contribute 62% of total output. These fields also contribute 40% of Egypt’s total output. The only other country where physics and chemistry feature in the top five fields is Cameroon (9%).

The social sciences feature in many countries, but usually as the fourth or fifth largest field: Ghana (10%), South Africa (8%), Nigeria (7%), Kenya (7%), Uganda (7%), Malawi (7%), Mozambique (7%), Zambia (7%), Tanzania (6%), Ethiopia (6%), Burkina Faso (6%) and Senegal (5%). It should be noted, however, that in many of these countries, there are significant numbers of local journals in the social sciences and humanities (this is certainly true for South Africa, Nigeria and Ethiopia) that are not included in Scopus. This means that the contribution of the social sciences (particularly the humanities) is undoubtedly underestimated in calculating the size of total country output.

Table 5.9: Research output by field of science and country grouping (1990–1997)

Areas/Zones	English-speaking (excluding South Africa)	French-speaking (excluding Maghreb)	North Africa	South Africa	Rest of Africa	Total
Agriculture	2 004 (22%)	809 (15%)	1 534 (10%)	1 161 (10%)	162 (21%)	5 670 (13%)
Medicine	4 201 (46%)	3 132 (63%)	4 351 (28%)	4 144 (35%)	433 (57%)	16 261 (39%)
Other sciences	2 950 (32%)	1 017 (21%)	9 657 (62%)	6 508 (55%)	164 (22%)	20 296 (48%)
TOTAL	9 155 (100%)	4 958 (100%)	15 542 (100%)	11 813 (100%)	759 (100%)	42 227 (100%)

Source: Arvanitis *et al.* (2000: 467)

Note:

The number of research publications is followed by the percentage share of science fields to total output in brackets.

In their 2000 study, Arvanitis, Waast and Gaillard (2000) made a detailed analysis of the differences in the 'shape' of knowledge production and how this differs across countries (Table 5.9). Countries in North Africa (Egypt, Tunisia and Morocco) and South Africa have similar profiles, with a predominance of output in the exact sciences as well as medicine. According to Arvanitis *et al.* (2000), however, the rest of Africa has a different profile. More specifically, the English-speaking zone has developed strengths in agriculture, whereas French-speaking countries publish more in health research. Arvanitis *et al.* (2000:468) explain these differences as follows:

> Such differences stem first of all from differences in industrialisation. Both North African countries and South Africa had had a much stronger industrial basis than the rest of Africa. The differences between the French and English-speaking zones reflect the colonial heritage, and the respective potential for co-operation of France and the Anglo-Saxon industrialized powers, whose intervention had had a strong bearing on the publication counts of the countries concerned. Finally, one could also see the influence of co-operation and aid policies in the last thirty years, which has certainly affected these sets of countries very differently.

This concludes the presentation and preliminary discussion of the broad bibliometric data. In the next section, some cross-cutting themes are discussed in more detail as they emerge from the analyses.

5.4 Thematic discussion

In interpreting the bibliometric trends presented in the previous section, we focus on three aspects of the African science landscape and indicate how these have influenced and continue to influence scientific production:

- Science as the mirror of nature
- The continuing legacy of colonial science in many African countries
- Destabilising influences on scientific production.

5.4.1 Science as the mirror of nature

With the exception of the scientific production of the larger countries in the study – South Africa, Egypt, Algeria and to a lesser extent Nigeria, Kenya and Tanzania – it is fair to say that the scientific endeavour in the majority of the other countries mirrors the natural and physical reality of these countries. Scientific research in these countries originated because of the need to study and consider ways of combating and controlling the often harsh realities, including widespread disease and pandemics, food security issues and drought-affected crops. The true reality for many of these countries is that they are located either in semi-desert regions, where water and food security present problems, or they are in tropical and sub-tropical geographies, where their human populations are severely affected and often decimated by a variety of tropical diseases, such as malaria, schistosomiasis, leprosy, filariasis, trypanosomiasis and leishmaniasis.

However, at the same time, a positive perspective on the 'fruits' of nature and the often very fertile natural resources in many African countries allows for a rich and wide variety of agricultural produce, including tea and cotton in East Africa, coffee in Ethiopia, cacao in Ghana and banana in Uganda. Mineral resources also occur in abundance (including oil in Angola, Equatorial Guinea, Nigeria, Uganda and several other countries).

Table 5.10: Scientific papers by country and main research institute (2005–2009)

Country	Institute (1)	Institute (2)	Institute (3)
Angola (120)	Instituto de Combate e Controle das Tripanossomíases (11)	Programa Nacional de Controle da Malária (3)	Instituto Nacional de Investigação Pesqueira (3)
Burkina Faso (1 057)	Centre Muraz (133)	Institut de l'Environnement et de Recherches Agricoles Ouagadougou (83)	Centre de Recherche en Santé de Nouna (49)
Cameroon (2 586)	Centre Pasteur du Cameroun (77)	Institute of Medical Research and Medicinal Plant Studies (56)	Organisation de Coordination pour la Lutte contre les Endémies en Afrique Centrale (35)
Ethiopia (2 397)	Ethiopian Institute of Agricultural Research (112)	International Livestock Research Institute (100)	Armauer Hansen Research Institute (62)
Gabon (459)	Centre International de Recherches Médicales de Franceville (120)	Medical Research Unit of the Albert Schweitzer Hospital (75)	Wildlife Conservation Society (12)
Ghana (2 031)	Crops Research Institute (58)	International Water Management Institute (52)	Food Research Institute (50)
Kenya (4 980)	Kenya Medical Research Institute (620)	International Livestock Research Institute Nairobi (294)	Kenya Agricultural Research Institute (229)
Malawi (1 045)	Malawi-Liverpool-Wellcome Trust Clinical Research Programme (78)	Chitedze Agricultural Research Station (44)	National Tuberculosis Control Programme (16)
Mali (548)	Institut d'Economie Rurale du Mali (47)	Institut National de Recherche en Santé Publique (35)	National Institute of Allergy and Infectious Diseases (29)
Mozambique (462)	Centro de Investigação em Saúde da Manhiça (37)	Instituto do Coração (16)	
Senegal (1 366)	Institut de Recherche pour le Développement (192)	Institut Pasteur de Dakar (111)	Institut Sénégalais de Recherches Agricoles (41)
Tanzania (2 569)	National Institute for Medical Research (186)	Ifakara Health Research and Development Centre (126)	Schweizerisches Tropeninstitut (83)
Uganda (2 308)	Uganda Virus Research Institute (155)	International Institute of Tropical Agriculture (86)	National Institute of Allergy and Infectious Diseases (46)
Zambia (792)	Centre for Infectious Disease Research (48)	Tropical Diseases Research Centre (34)	International Council for Research on Agro-Forestry project (12)

Note:
In the five countries excluded (South Africa, Egypt, Nigeria, Algeria and Lesotho), scientific endeavours appear to be less reflective of the natural and physical reality of the country.

Numbers of scientific papers from an institute are shown in brackets beside the institute name; total scientific papers from the country are shown in brackets beside the country name.

It is therefore not surprising that in many of these countries, the first research institutions were institutes of agronomy and forestry, or specific institutes for cotton, tea or coffee research. This is also true of the presence of many of the international research institutes with a presence in Africa, for example:

- International Livestock Research Institute (ILRI)
- International Council for Research on Agro-Forestry (ICRAF)
- International Centre for Insect Physiology and Ecology (ICIPE).

An overview of the scientific papers by these institutes and centres in each of the countries reveals how crucial their contributions are to the overall country research output. Table 5.10 focuses only on the output of the three most productive agricultural and health research institutes and centres over the period 2005–2009, ignoring for this purpose the output of the university sector.

Although Table 5.10 deliberately excludes the contribution of the higher education sector, this is not to ignore their contribution in the fields of medicine and agriculture. On the contrary, in many of the countries, the faculties and colleges of medicine (and perhaps to a lesser extent the faculties of agriculture) are often the main producers of scientific output in these fields. The point here is to emphasise how the original demand for interventions in the fields of disease control and food security necessitated the establishment of national and international centres and institutes in these countries.

5.4.2 The continuing legacy of colonial science

Many of the research institutes established during the colonial period still exist in African countries. The role of different colonial powers in the formation of scientific institutions varied greatly across continents. This is both a function of the nature of the institutions that were established as well as the model of colonial science pursued.

The British model of colonial science privileged the establishment of botanical gardens in many of the colonies as sites for botanical and related research. This model was shaped by the influence of the Royal Botanical Garden at Kew in London. A botanical garden was established in Lagos, Nigeria in 1887; the Royal Niger Company also founded a garden for the distribution of plants at Asaba, Nigeria in 1888 and established four other agricultural stations at various locations between 1889 and 1890 for experiments with coffee, cocoa and other crops. Ghana (then Gold Coast) also had a government botanical garden in 1890 at Aburi (McKelvey 1965).

Interestingly, the British over the years attempted to give more responsibility to the colonies in steering their own research agendas. According to Sir Charles Jeffries (1964), three main principles guided the development of scientific institutions and facilities in British colonial Africa: the facilities should be in the colonies rather than in Britain; research should be organised on a sub-regional rather than on a territorial basis; and colonial administrations should share in supporting the costs of research facilities and eventually bear complete responsibility for them (Eisemon, Davis and Rathgeber, 1985). To accomplish this regional approach to colonial science and technology, research councils were created in British Africa (in essence the model of the South African Council for Scientific and Industrial Research [CSIR]), which formulated regional research policies and priorities and then made recommendations on the allocation of research funds, as well as on projects assigned to institutes.

The French approach to colonial science was very different. Research in the colonies initially had to be conducted through the mediation of institutions based in Paris, such as the Muséum National d'Histoire Naturelle, which had a section devoted to tropical agriculture, and the École Supérieure d'Application d'Agriculture Tropicale, which provided training for colonial agricultural officers. It was only with the advent of the Pasteur Institute that a shift occurred and the organisation of research activities in the African region involved the establishment of local branches. According to Gaillard *et al*. (1997: 28), the major translocation of French science in francophone Africa from the late nineteenth century until the 1950s saw "institutional radiation", with, for example, the establishment of six local Pasteur institutes in Saigon (1890), Algiers (1894), Nha Trang (1895), Madagascar (1902), Tunis (1903), Brazzaville (1910) and Dakar (1913) (see also Eisemon *et al.*, 1985: 193). According to Eisemon *et al*. (1985: 193), these institutions performed extensive experimental research, produced vaccines and provided routine diagnostic services. Thus far the work sponsored by the Pasteur Institute in North Africa has produced the only two Nobel Prizes for Medicine in Africa, one to Laveran in 1907 for his work on malaria, and the other to Nicolle in 1928 for his work on typhus.

The creation of the Office de la Recherche Scientifique Coloniale in October 1943 marked the first attempt at research coordination in the French colonies. Thereafter, French colonial authorities operated mainly through ORSTOM (*Office de la Recherche Scientifique Technique Outre-Mer* – Office for Overseas Scientific and Technical Research) and through a group of applied research organisations, GERDAT (Groupement d'Etudes et de Recherches pour le Développement de l'Agronomie Tropicale) for agriculture in francophone Africa. These included the Institute for Research in Tropical Agriculture (IRAT), the Institute for Research on Oil and Oil-bearing Plants (IRHO), and the Institute for Research on Cotton and Textiles (IRCT). Generally, ORSTOM was responsible for basic research (hydrology, soil science, entomology and virology) and GERDAT for applied research carried out in the various areas of coffee, cocoa, tea, tropical forests, rubber, rice and other crops.[16]

Unlike the British case, "only modest effort was accorded by French colonial or metropolitan authorities to the development of research activities in African colonies" (Eisemon *et al.*, in Forje, 1989: 21).[17] Of course, this is a partial point of view, as in some areas that were of crucial political importance, such as the control of peasants and agriculture, public S&T utilities were set up and managed by a body of professionals, who were often ahead of scientific practices in France. However, it can be argued that there were fewer institutional linkages and collaborations among francophone colonies in the field of science and technology. According to Forje (1989: 21), there was no coordination of French colonial policy on S&T activities up until the Second World War. The S&T activities of each institute or territory were thus both explicitly and implicitly assimilated and undertaken by research institutions in metropolitan France with African branches.

According to Dahoun (1999), the British colonial legacy has certainly advantaged scientific production in anglophone African countries. He argues that the English-speaking countries benefit at the very basic level because of the anglophone bias of the Thomson Reuters Science Citation Index databases, noting that "... as Nigeria and Kenya are English-speaking countries their scientific institutions normally publish in English. Therefore, they have easy access to the reviews and scientific journals in the UK and in the US which are the best-known mainstream journals worldwide" (Dahoun 1999: 14). Dahoun, however, agrees that the more important reason for the relatively good performance of the former British colonies relates to the differences in research organisation between the French and British administrations, as discussed. Dahoun argues that "in the former British colonies, the British preferences disappeared relatively quickly and the emigrating researchers were replaced by local research personnel and the direction of research changed toward research of local interest". On this basis, Dahoun postulates that anglophone African countries should have developed an indigenous scientific capacity far more quickly than francophone African countries. However, recognising that this hypothesis does not hold across all countries, Dahoun points out that there are some anglophone African countries that do not produce significant research output. In these countries (Somalia, Sierra-Leone and Liberia), recent radical political turmoil has inhibited scientific production.

It is less clear how the continuing legacy of colonial scientific institutions in many African countries should be assessed. On the one hand, such institutions have had the negative effect of creating long-term dependence by the African country on the colonial power (long after independence), which led to neglect in establishing local institutions (*cf.* Gaillard's [2003] interesting thesis in this regard in his study of the Tanzanian science system). On the other hand, some of the institutes (such as the Pasteur Institutes in francophone countries) remain sites of significant capacity and provide stabilising continuity within the scientific landscape of these countries.

Previous studies (Narva´ez-Berthelemot *et al*., 1999; Boshoff, 2009, 2010) have found that the less productive a developing country, the greater the dependence on international co-authorship for mainstream publication. As with other studies on developing countries, increased presence in the ISI science citation indexes appears to be associated with increasing levels of international co-authorship Narva´ez-Berthelemote *et al.* (2002) have also commented on the fact that the colonial legacies of many African countries are apparent in the ties with France and the United Kingdom.

Three of the smallest francophone countries (Burkina Faso, Gabon and Mali) have been selected for discussion to illustrate how widespread and pervasive the French influence remains in these countries, especially in agricultural and health sciences. Table 5.11 lists the number of papers published by four prominent French research institutions with at least one author from these countries. The results show that collaborations with these institutes, as well as the worldwide network of Pasteur Institutes in other countries, constitute a significant proportion of the overall output of these small countries. It is likely that these collaborations also involve financial support from the French hosts, which contributes to the continued sustainability of some small centres and institutes in these countries.

The colonial legacy has had another more recent manifestation. It is increasingly clear that some of the colonial powers – whether because of a sense of guilt or political considerations, or simply because of the common linguistic and cultural linkages – have begun to support their former colonies in rebuilding their science systems. This is clearly evident in the lusophone countries of Angola and Mozambique, where Portugal and Brazil have become major 'guardians' in rejuvenating and funding scientific research.

Table 5.11: Co-authorships with French institutes: Burkina Faso, Gabon and Mali (1990–2009)

Country	CIRAD, Montpellier	IRD Centre for Development Studies, Montpellier	CNRS, France	Pasteur Institutes (worldwide)
Burkina Faso (1 497)	102	125	47	82
Gabon (1 051)	19	24	26	79
Mali (1 065)	56	16	37	25

Of the 814 papers (in Scopus, 1990–2005) produced by Mozambican scientists, 65 were co-authored with colleagues in Portugal. As other studies have shown, geographical proximity also matters, as 110 of these papers were co-authored with South African scientists. However, the experience of Angola, the other lusophone country in the study, was very different, in that almost a quarter (52) of their 220 papers were co-authored with Portuguese scientists and scholars and 18 with scientists from Brazil. South Africa has less influence in Angola, with only 13 papers co-authored with Angolan scholars.

The question arises whether the continuing colonial legacy also affects the nature of co-authorship, and specifically whether the African authors are properly recognised. This issue is related to the ethics of authorship as well as relations of power in interdisciplinary international research groups. Our aims were far more modest, namely, to establish: (1) how many papers in some of the small countries have a local scholar as first author, and (2) how many papers of these countries are single-authored as opposed to multi-authored papers. It is true that patterns of authorship vary greatly across scientific fields, with papers in the life sciences, chemistry and medicine generally involving large numbers of authors (especially in the case of clinical-trial studies), whereas papers in fields such as mathematics, the humanities and social sciences are often produced by a single author. Four countries with relatively small science systems (Angola, Burkina Faso, Gabon and Mali) were selected for a more detailed analysis of authorship patterns (Table 5.12).

Table 5.12: Comparing authorship patterns for Angola, Burkina Faso, Gabon and Mali (1990–2009)

Country	Total papers	Single-authored papers	2–5 authors	6–10 authors	More than 10 authors	% of papers where local author is the first author
Angola	220	15 (6.8%)	133 (60.5%)	68 (30.9%)	18 (8.2%)	41%
Burkina Faso	1 497	69 (4.6%)	598 (39.9%)	656 (43.8%)	174 (11.6%)	60%
Gabon	1 051	62 (5.9%)	462 (44.0%)	410 (39.0%)	118 (10.8%)	65%
Mali	1 065	42 (3.9%)	470 (44.1%)	395 (37.1%)	158 (14.8%)	45%

Note:
The numbers of total papers for the four countries are slightly different from those reported in Annex A because the figures reported here include only Scopus data, whereas those in Annex A include WoS data for 1990–1995 and Scopus data for 1996 onwards.

In very small systems, a small number of very productive scientists quite often dominate (and therefore also skew) scientific output. For example, of the 220 Angolan papers, 91 (41%) of these were produced by Angolan first authors. This is misleading, however, as one of the pre-eminent scientists in Angola, Prof. Anabela Leitão (Department of Chemical Engineering at Agostinho Neto University and holder of the UNESCO Chair in Chemical Engineering), produced 15 of these papers. If her production is excluded, only 76 (or 35%) of these papers were produced by an Angolan first author.

5.4.3 Destabilising influences on scientific production

The production of science in many countries in Africa (as elsewhere) is dependent on a stable political and economic environment. However, we have witnessed many regional and local political and military events that have led to the closing of scientific institutions and universities in many countries and effectively put science back many decades. Examples include the civil war in Rwanda/Burundi, the Mengistu regime in Ethiopia, Idi Amin's dictatorship in Uganda and the civil wars in Mozambique and Angola. Such events have had different negative impacts on institution-building in these countries, often leading to the suspension of overseas research funding (for example, the Swedish International Development Cooperation Agency's [Sida] Department for Research Cooperation suspended its support of Ethiopia in the late 1990s), the closing of institutions because of lack of government funding, and perhaps most notably, the large-scale flight of top academics and scientists to other parts of the world. A good example of the devastating impact on a single institution is that of Makerere University in Uganda. Once a major site for internationally recognised research in the 1950s and 1960s, it suffered because of civil war and lack of government funding in the 1980s and beyond. This forced the university in the 1990s to enrol many more students than it could support (in order to raise funding through student fees), with the result that by the beginning of this millennium, it had over 30 000 students on a campus built for fewer than 15 000. It is only in recent years that student growth has been capped and student numbers have dropped.

In their bibliometric study of African science, Arvanitis *et al.* (2000) argue that political stability or instability is one of the more plausible explanations for the differences in science production between countries on the continent. In general, Africa witnessed more instability and uncertainty in the 1980s and 1990s, caused by political crises and civil wars and subsequent loss of investment in science (including loss of investment by international funders) and huge brain drain. However, the effects of these events have varied across countries and fields of science.

Arvanitis *et al.* (2000) distinguish main groupings of countries, mostly on the basis of political stability:

- Group 1: Egypt and South Africa as the main producers of "complete science" (where all the main scientific fields are covered). These two countries produce 49% of all scientific papers from Africa.
- Group 2: Four countries that together produce 25% of output (Nigeria, Kenya, Tunisia and Morocco). Although in many respects these countries have well-developed science systems, they also suffered from major political changes and turmoil between 1991 and 1997.
- Group 3: Seven countries (Algeria, Côte d'Ivoire, Senegal, Cameroon, Tanzania, Zimbabwe and Ethiopia) that consistently produce between 70 and 200 papers per year. This output is produced by groups or networks of specialised researchers working in a few research fields or a handful of leading research institutes that are able to sustain stable, if small, science systems.
- Group 4: Fifteen countries (Sudan, Ghana, Burkina Faso, Uganda, Malawi, Zambia, Gabon, Mali, Benin, Togo, Gambia, Congo Republic, Democratic Republic of Congo, Madagascar and Niger) that consistently produce between 20 and 70 papers per year.
- Group 5: The rest of the continent, which comprises countries with minuscule scientific capacity. In these countries, scientific output is erratic, produced by very few authors (more often than not by visiting scientists on short-term visits related to some bilateral scientific agreement or cooperation scheme). This group includes countries (Angola, Mozambique) that in recent years have experienced fundamental changes, international isolation, civil wars and massive erosion and destruction of infrastructure.

Table 5.13 summarises the production of scientific output during the 1990s according to these five groupings.

In addition to political instability, various international forces associated with globalisation and internationalisation of trade in the 1980s and 1990s have had devastating effects on the economies of many African countries. The decline in export volumes as well as the relative decline in the price of primary products in world trade in the 1980s and 1990s, combined with the mishandling of exchange rates and external reserves and huge external debt, have together created major resource shortfalls for African countries. This has placed serious pressure on their import capacity and the availability of resources for essential economic and social investment. The results include increased dependence of the typical sub-Saharan Africa country on aid from developed countries.

Table 5.13: Scientific output (1991–1997)

Groups	1991	1992	1993	1994	1995	1996	1997	Total
1. Two main producers	3 583	3 346	3 215	2 655	2 392	2 840	2 652	20 683
2. Four changing countries	1 569	1 572	1 531	1 434	1 409	1 785	1 633	10 933
3. Stable production	760	771	817	749	674	898	929	5 598
4. Low production	455	498	492	489	505	602	698	3 739
5. Erratic production	214	185	203	159	154	183	176	1 274
TOTAL	**6 581**	**6 372**	**6 258**	**5 486**	**5 134**	**6 308**	**6 088**	**42 447**

Source: Arvanitis *et al.* (2000: 464)

Note:
The label "changing countries" was generated by Arvanitis *et al.* (2000) and is meant to describe countries that were characterised by significant political changes and turmoil during the period of study.

Sawyerr (2002) aptly summarises the situation:

> The reality of globalisation – deriving from movements in economy and production – erodes the capacity of the typically marginalised and dependent sub-Saharan African state to generate enough production, savings and investment to ensure sustainable development. For its part, the ideology of neo-liberalism and the institutional arrangements that promote it, limit the policy instrument available to the state for intervening in the market place to ensure the provision of the basic needs of its people, thereby restricting the state's capacity to fulfil its principal function.

He continues:

> The collapse of many national economies in Africa under these forces and the accompanying destabilisation of social structures threw all institutions, including those of higher education, into a prolonged crisis. A variety of structural adjustment programmes (SAPs) were introduced in the 1980s and 1990s to reverse the economic and social crises. The programmes were

> intended, first, to give freer reign to market forces by removing rigidities in the production, pricing, marketing and exchange rate regimes. They also sought to cut back the role of the state, downsizing it and reducing its reach. All this was to be combined with the rapid opening up of the economy to international competition. The results are yet new challenges to Africa's universities – the downgrading of university funding (in favour of basic education) and the pressure on them to adjust to the severe austerity regimen imposed by the various economic stabilisation policies, at the same time as they were pressured to increase enrolment and maintain quality levels, without commensurate increases in resources … A further factor was the policy of privileging expenditure on basic education at the expense of higher education, a posture reflecting the policy positions of the World Bank and leading donor agencies, and the argument that the social rate of return on investments in basic education was higher than in higher education.

To summarise, at the same time as university enrolments increased exponentially in many African countries, both government support and external donor aid to higher education were severely reduced. The result was quite predictable, with many universities thrown into financial crisis, laboratories and libraries not receiving any maintenance, overcrowded classrooms and large-scale flight of top academics from these institutions. It was only towards the end of the 1990s that these trends started to be reversed, and government and international aid was restored to universities in Africa (most notably through the Partnership Foundation in the USA). However, it is evident that research and scholarship were among the main losers during these years.

5.5 Concluding comments

The production of science is dependent on a wide range of systemic, institutional and individual forces. The impact of historical influences, especially colonial legacies, on science in many African countries has been discussed in some depth. However, there have been other influences from historical factors: those science systems with old and well-established universities (as in South Africa and Egypt, where universities have been in existence for more than a century) have clear advantages over those systems where universities were established only four or five decades ago.

The role and contribution of higher education to scientific production in many of these countries cannot be overestimated. Irrespective of the size of the country, it is evident that knowledge production in all 19 countries is dominated by the work of academics and scholars at the major universities. The size of the country – and therefore also the size of the higher education sector – only affects the number of universities involved in scientific output. The smallest science systems on the continent often rely heavily on the role and contribution of one (or a few) public universities as the main producers of knowledge. In countries such as Namibia, Botswana and Swaziland, there are no significant research institutes outside the national universities, and 80–90% of the small research output of these countries is generated by academic staff at these institutions. This is also true of countries where one university dominates the production of science, as in Angola (Agostinho Neto University), Lesotho (National University of Lesotho), Mali (University of Bamako) and Mozambique (Eduardo Mondlane University). This pattern is repeated even in medium-sized university systems; for example, scientific production in Ethiopia is dominated by Addis Ababa University and production in Uganda by Makerere University.

A few countries (Kenya, Ghana and Senegal) have a larger array of scientific institutions, including a number of public universities, government-funded laboratories and institutes, and internationally based agencies. In the two largest science systems on the continent (in South Africa and Egypt), the situation is quite different. Although the University of Cairo is the most productive university in Egypt (and in fact among the top 500 universities in the world in terms of the Shanghai ranking), significant contributions are made by other universities. In South Africa, five universities (the universities of Cape Town, Stellenbosch, Pretoria, KwaZulu-Natal and the Witwatersrand) consistently produce 50% of total country output, but a second tier of research niche universities (the universities of the North-West, Free State, Johannesburg, the Western Cape and Rhodes University) all make significant and growing contributions to national science. If one adds a vibrant science council sector (including the CSIR, Human Sciences Research Council [HSRC] and Mintek) and small but very productive national research facilities in the areas of astronomy, biodiversity and space science, it is not surprising that South Africa dominates scientific output on the continent.

The bibliometric analyses illustrate how science mirrors the economic and physical realities of a country. The scientific effort in most of the countries in the study reflects the physical and material realities and challenges of three major domains: food security, disease control and industrialisation.

Whereas agricultural research dominated research agendas in the 1990s (especially in anglophone African countries), research in medicine and related fields now dominates. In addition to the challenges faced by traditional tropical and other infectious diseases (including trypanosomiasis [sleeping sickness] and malaria), the HIV/AIDS pandemic together with the continuing effects of tuberculosis have led to renewed effort in R&D in these areas. Issues related to food security persist, and the situation is worsening. The continuous effects of drought, poor crops and the impact of internationalisation (and open trade) on certain markets exert renewed pressure in this area.

Three of the countries in the study (South Africa, Egypt and Algeria) can be described as semi-industrialised nations, and there are pockets of industrialisation in Nigeria, Kenya and Tanzania. These countries have developed local capacity in engineering sciences (especially metallurgical and mining engineering), chemistry and chemical engineering, and physics (including nuclear physics and astrophysics). Coupled with growing pockets of expertise in electronics, mathematics and computing sciences, it is not surprising that the shape of knowledge production in these countries differs markedly from the rest of the continent.

In the final instance, however, Africa's share of world science continues to decrease. The few African countries where scientific output is substantial and even growing are not as productive as other developing countries elsewhere in the world; these countries therefore do not have a significant affect on the overall findings in this regard. For Africa to become more competitive with respect to scientific output will require greater investment in human capital development, the strengthening of scientific institutions and equipment, as well as significantly higher funding for science.

[11] DARE is a computerised data retrieval system for documents in the social sciences and humanities.

[12] Thomson Reuters publishes the online Web of Knowledge, a premier research platform. The latter includes the Web of Science (WoS), which provides access to a number of leading citation databases, including the Science Citation Index Expanded, the Social Sciences Citation Index and the Arts and Humanities Citation Index. The three citation indexes originated with the Institute for Scientific Information (ISI), which is now part of Thomson Reuters. For that reason journals listed in the WoS are often also referred to as ISI journals. Any references to ISI data in this report should therefore be interpreted to mean all journal articles in the WoS database.

[13] This trend, incidentally, has been reversed in recent years. The number of South African journals in the ISI citation indexes in 2009 exceeded 40.

[14] Population estimate figures were sourced from the *CIA Factbook* (www.cia.gov/library/publications/the-world-factbook).

[15] Scopus classifies all journals into 27 fields. However, it is clear from a closer inspection of what is included in these fields that there is significant overlap in the allocation of journals to different fields. Three fields that are important for this analysis are specified below by listing some of the more common disciplines that they include. These disciplines were identified by inspecting journal titles: AGRICULTURAL AND BIOLOGICAL SCIENCES (horticulture, zoology, entomology, ecology, biotechnology, marine science, microbiology, water science, human biology, plant sciences, botany, geography, aquaculture, dairy science, crop science, bioscience, food science and technology); ENVIRONMENTAL SCIENCES (ecology, water science, geosciences, aquatic sciences, biodiversity, marine and coastal research) and EARTH AND PLANETARY SCIENCES (geosciences, astronomy, marine and coastal research, water science, biosciences).

[16] For a more detailed discussion of this early history, see Gaillard and Bush (1993).

[17] For a well-documented perspective, see Bonneuil (1998, 1999).

[18] Tables 5A.1 and 5A.2 deviate from the earlier decision to use Scopus data only from 1996 onwards and WoS data for the period 1990–1995. The reason for the deviation is because CREST had already standardised the names and spelling variants of South African universities in the WoS database (as part of other research activities) and could therefore easily extract the relevant information for presentation here.

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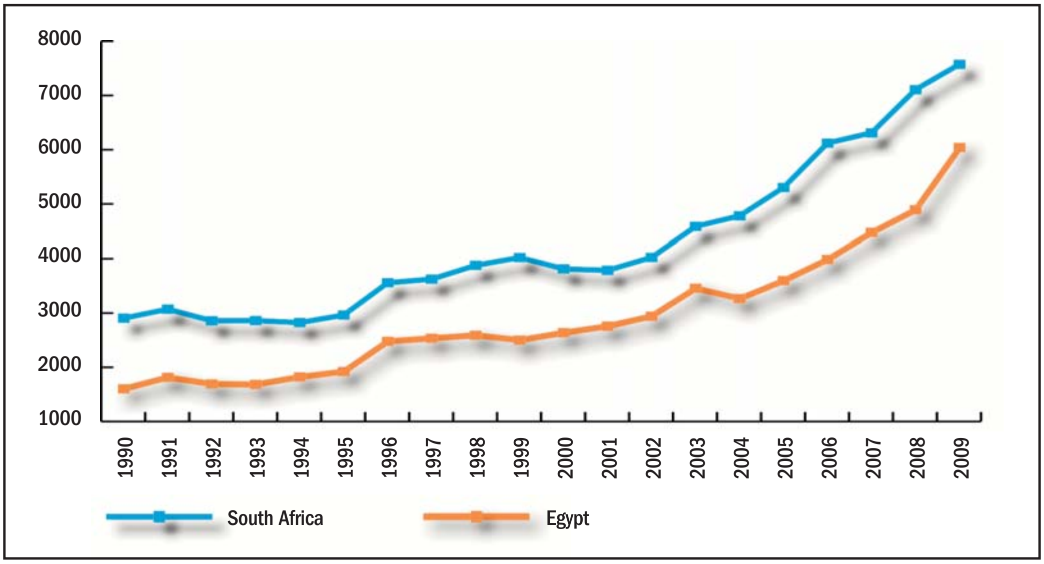
Annex A: Country analyses

For the purposes of the country analyses, the 19 countries in the study have been classified into the following groups:

- Group 1: Powerhouses of science in Africa (more than 50 000 papers during 1990–2009)
- Group 2: Medium-sized science systems (between 10 000 and 30 000 papers during 1990–2009)
- Group 3: Neither medium-sized nor small science systems (between 2 000 and 6 000 papers during 1990–2009)
- Group 4: Small science systems (between 800 and 2 000 papers during 1990–2009)
- Group 5: Scientific minions (fewer than 300 papers during 1990–2009).

Group 1: Powerhouses of science in Africa (more than 50 000 papers during 1990–2009) – South Africa and Egypt

Figure 5A.1: Scientific papers by South Africa and Egypt (two countries in Group 1) (1990–2009)



South Africa (ranked 1st; n = 86 649 papers)

The national system of public science (excluding private sector R&D) in South Africa comprises three main sectors: the higher education sector (23 universities), the science council sector (including national research facilities) and a small sector made up of government research institutes and units.

The higher education sector in South Africa accounts for the bulk of the country's research output. This is mainly due to a long history of strong research universities (the first South African university was established in 1829) as well as the concerted research effort of the top eight to ten universities since the 1960s. Four South African universities (the universities of Cape Town, Pretoria, the Witwatersrand and KwaZulu-Natal) regularly feature among the top 500 world universities according to the Shanghai rankings, while Stellenbosch University also features in the University of Leiden's ranking of the top 400 world universities (together with the other four).

Table 5A.1 shows South Africa's total output of papers from journals in the WoS and Scopus databases for the period 1995–2007. The figures show a steady increase in output since 1995, and total output almost doubled. The table also shows how the share of output by academics at universities increased over the same period, from 80% in 1995 to 86% in 2007.

Table 5A.1: South Africa's research output (comparing papers in the WoS[18] and Scopus databases, with the focus on higher education) (1995–2007)

YEAR	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
WoS papers	3 711	4 114	4 197	4 395	4 535	4 338	4 460	4 791	4 684	4 854	5 712	6 168	6 245
Scopus papers	2 406	3 551	3 617	3 871	4 015	3 805	3 779	4 017	4 579	4 773	5 295	6 270	6 437
Higher education papers (in WoS)	2 987	3 317	3 402	3 555	3 691	3 560	3 701	3 977	3 974	4 140	4 899	5 342	5 346
Higher education share	80%	81%	81%	81%	81%	82%	83%	83%	85%	85%	86%	87%	86%

In a recent study, Mouton and Gevers (2009) analysed the specific contribution of the major universities to overall output in the higher education sector. It was found that 11 of the 23 universities each produced more than 1 000 papers in ISI journals over the period 1995–2007. The combined output of these 11 universities constitutes 92.5% of total output by the sector. The individual shares of the 11 universities are summarised in descending order in Table 5A.2.

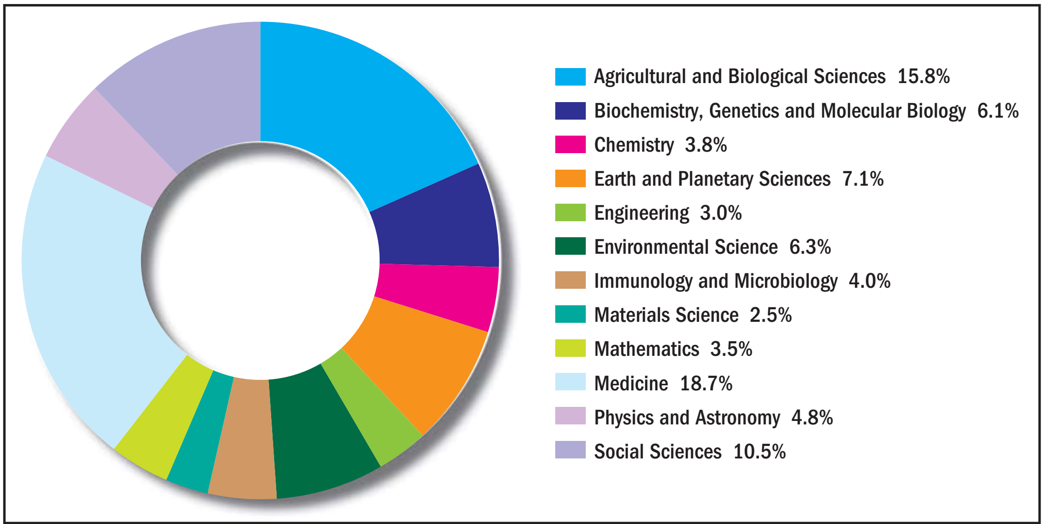
Table 5A.2: University shares of South African research output in ISI journals (1995–2007)

	Total (1995–2007)	Share (%)
University of Cape Town	10 219	19.7
University of the Witwatersrand	8 523	16.4
University of Pretoria	6 998	13.5
University of KwaZulu-Natal	6 670	12.9
Stellenbosch University	6 150	11.9
University of the Free State	2 181	4.2
Rhodes University	1 963	3.8
University of Johannesburg	1 562	3.0
North-West University	1 456	2.8
University of the Western Cape	1 212	2.3
Nelson Mandela Metropolitan University	1 047	2.0

In addition to the universities, the other main contributors to South Africa's research output are staff at the science councils (most notably the Council for Scientific and Industrial Research [CSIR], Human Sciences Research Council [HSRC] and Agricultural Research Council [ARC]), the national research facilities (for example, the South African Astronomical Observatory and the Hartebeesthoek Radio Astronomy Observatory) and some government research institutes (such as the National Health Laboratory Service and South African National Biodiversity Institute). However the diminishing share of the non-university sector could be an indication of the increasing commercialisation of the research portfolio at the science councils, which have been increasingly forced to earn additional revenue through contract research. Closer inspection of the contributions of the individual science councils also shows that the ARC recorded no growth in its output over the period 1995–2007, reflecting perhaps the impact of organisational difficulties at the council.

A breakdown by main scientific field (Figure 5A.2) shows that South Africa's research output in Scopus journals is quite evenly spread, with six fields recording more than 5% of total output. Output in medicine, and agricultural and biological sciences predominates, and there were substantial contributions by the social sciences and earth sciences (reflecting the country's traditional strengths in geology and mining). Equally noteworthy is the strong output in physics and astronomy and the more recent growth in research on infectious diseases (tuberculosis, malaria and HIV/AIDS) as reflected by the output in immunology and microbiology.

Figure 5A.2: Shape of scientific output: South Africa (top 12 fields account for 86% of total output) (2005–2009)



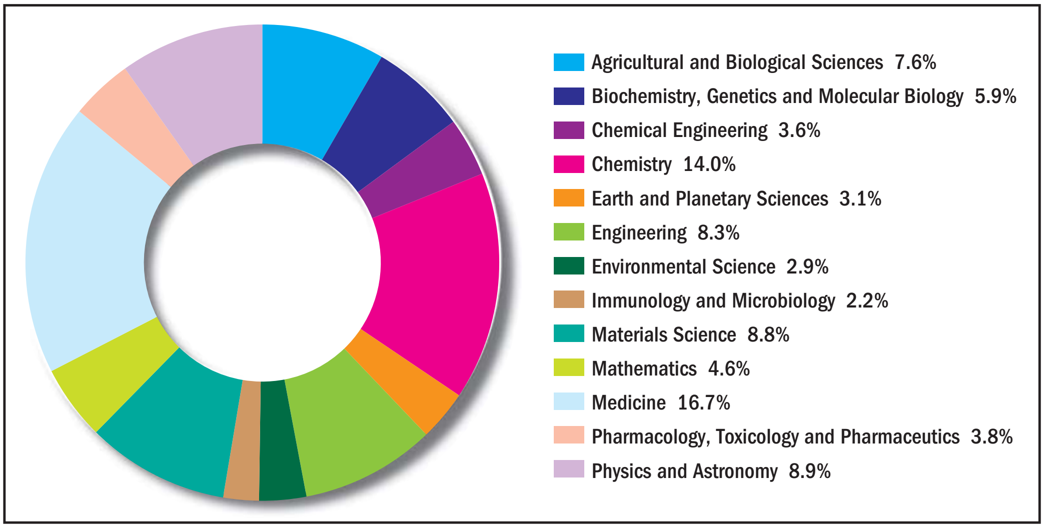
Egypt (ranked 2nd; n = 59 412 papers)

Egypt's research output has been steadily growing over the past 20 years (at an average rate of 4.5%), but its average growth rate of 13.3% in recent years has solidified its position as the second largest producer of science on the continent.

Egypt shares with South Africa a similar shape in knowledge production, with seven fields recording an output of more than 5%, but there are significant differences. Apart from the substantial output in medicine, the next four fields (chemistry, physics, materials sciences and engineering) demonstrate Egypt's strengths in the exact sciences and engineering fields. Output in the agricultural and biological sciences constitutes 7.6% of total output, while the social sciences and humanities do not feature at all.

The major producers of scientific research in Egypt are the active research universities in the country and the National Research Centre (which consistently produces about 10% of total annual output). Cairo University (ranked in the top 500 in the Shanghai rankings) is the most productive university, followed closely by Ain Shams University, Assiut University, Alexandria University, Al-Azhar University, Mansoura University and Suez Canal University. A research centre outside the university sector that consistently contributes to national output is the Atomic Energy Authority of Egypt.

Figure 5A.3: Egypt: Shape of scientific output (top 13 fields account for 90% of total output) (2005–2009)

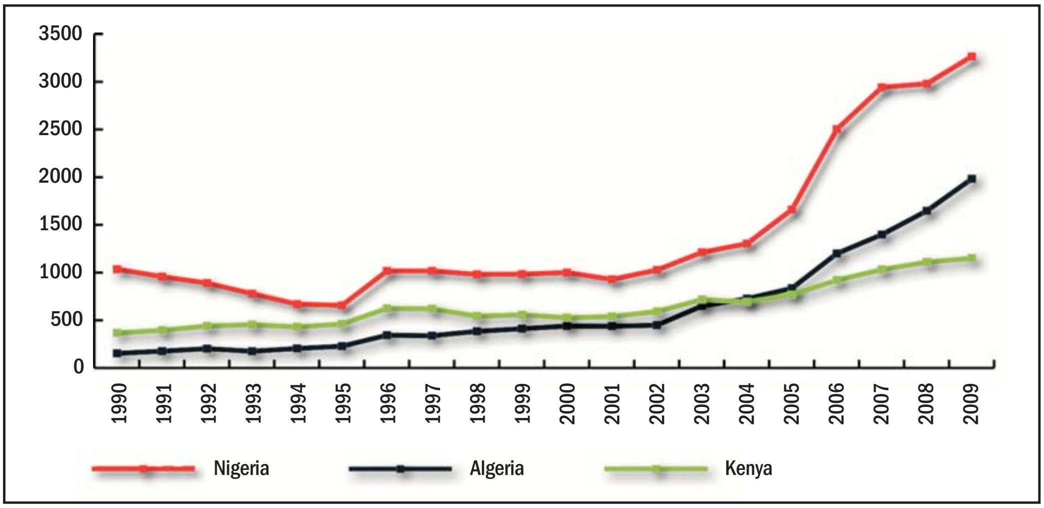


Group 2: Medium-sized science systems (between 10 000 and 30 000 papers during 1990–2009) – Nigeria, Kenya and Algeria

Nigeria (ranked 3rd; n = 27 743 papers)

Nigeria is the third-largest producer of science (behind South Africa and Egypt) among the 19 countries in the study, with total output of more than 27 700 papers. As previous research has shown (*cf.* Arvantis *et al.*, 2000), Nigerian scientific output saw a particularly dramatic collapse during the decade of the 1990s. Scientific output dropped to a mere 650 papers in 1995. Over the next ten years, research in Nigeria started to recover very slowly. The recovery has become a massive renewal of science, as the past four years have witnessed the production of almost 3 000 papers per year.

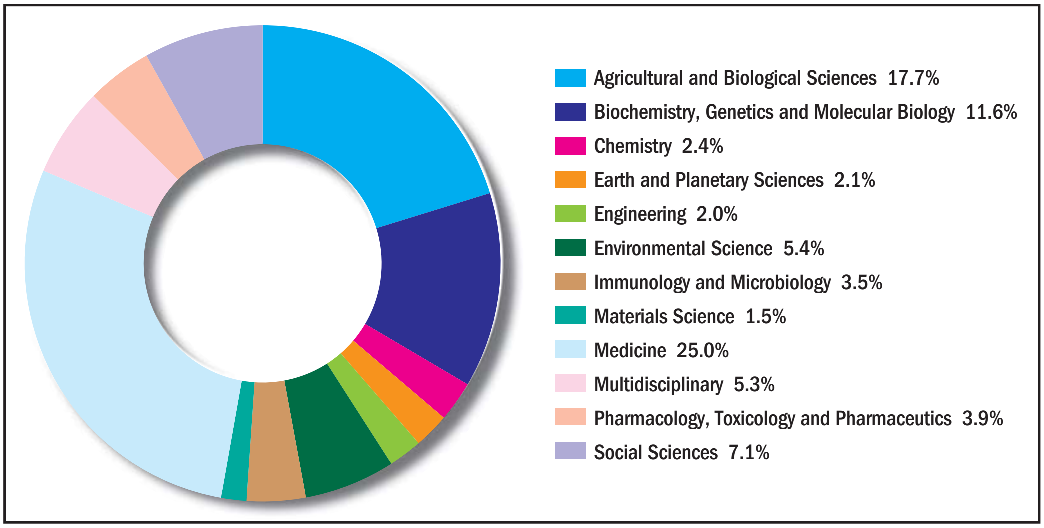
Figure 5A.4: Scientific papers of Nigeria, Algeria and Kenya (three countries in Group 2) (1990–2009)



Research output in Nigeria is dominated by the university sector, with the major contributors being the universities of Ibadan, Obafemi Awolowo, Benin, Nigeria, Ahmadu Bello, Ilorin, Lagos and the Federal Universities of Technology.

The only government research institute that regularly contributes to the country's research output is the International Institute of Tropical Agriculture (IITA), which has its headquarters in Ibadan, Nigeria and

Figure 5A.5: Nigeria: Shape of scientific output (top 12 fields account for 88% of total output) (2005–2009)



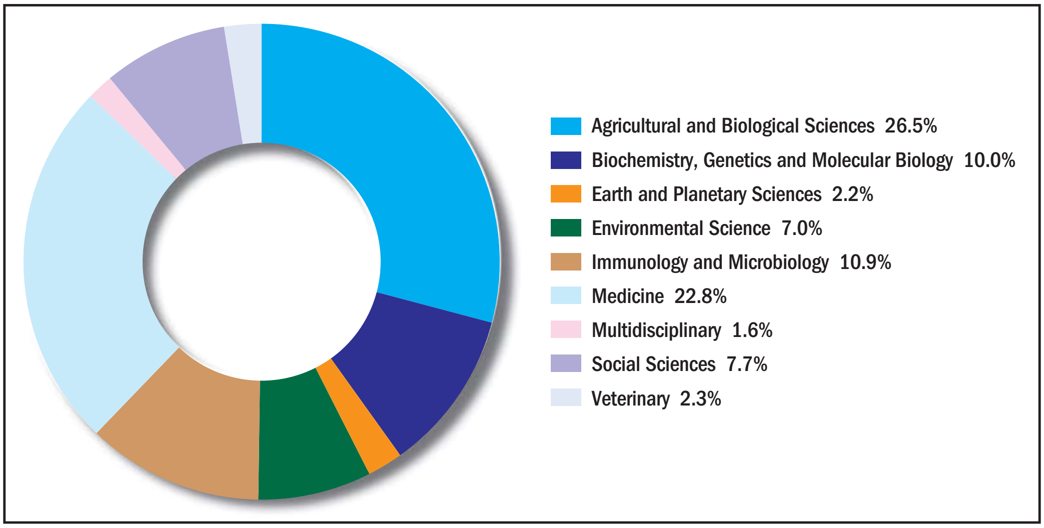
several research stations across Africa. IITA employs over 100 international scientists supported by more than 1 000 nationally recruited staff. IITA is one of the largest of the 15 centres principally supported by the Consultative Group on International Agricultural Research (CGIAR).

Nigerian science is dominated by the three fields of medicine, agricultural and biological sciences, and biochemistry and molecular biology, and there are significant contributions from the social sciences, environmental sciences and various multidisciplinary sciences.

Kenya (ranked 4th; n = 12 784 papers)

Kenya's relative political and economic stability is reflected in the positive and steady growth in scientific output over the past 20 years. The past three years have seen the country exceeding annual output of 1 000 papers.

Figure 5A.6: Kenya: Shape of scientific output (top 9 fields account for 91% of total output) (2005–2009)



Although the major universities (University of Nairobi, Kenyatta University, Egerton University and Moi University) are significant contributors to the country's overall output, it is the maze of international and government-based research institutes in the fields of health and agriculture that characterise Kenya's output. In health sciences, these are the Kenya Medical Research Institute, Wellcome Trust Research Laboratories in Nairobi and Ministry of Health. In agriculture, there are the International Livestock Research Institute (ILRI), International Centre for Insect Physiology and Ecology (ICIPE), World Agroforestry Centre, Kenya Agricultural Research Institute and National Museum of Kenya.

The shape of Kenyan science is dominated by knowledge production in agriculture (26.5%) and three related life sciences fields: medicine (22.8%), immunology and microbiology (10.9%) and biochemistry and molecular biology (10.0%). The social sciences are in fifth place with a contribution of 7.7%.

Algeria (ranked 5th; n = 12 334 papers)

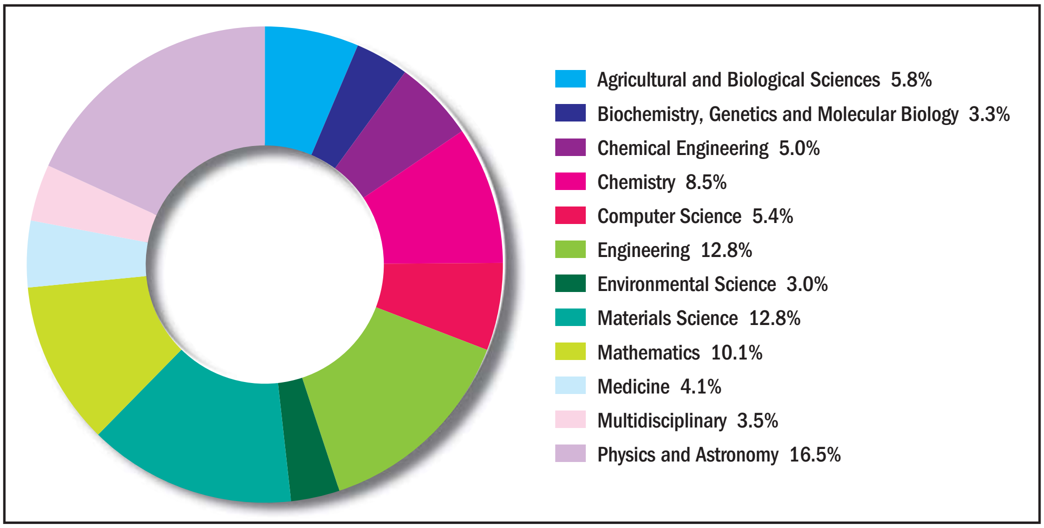
Science in Algeria has been a story of success. Algeria's average annual growth rate of 14% is the second highest among all 19 countries in the study, while the average growth of 23% over the most recent five-year period is by far the highest. If the current rate of growth continues, Algeria will soon overtake Kenya as the fourth largest producer of science on the continent.

The higher education sector produces the bulk of scientific output in the country. The most productive universities are the Houari Boumediene University of Sciences and Technology, Mentouri-Constantine University, Badji Mokhtar University, University of Sidi-Bel-Abbes, University of Oran, Mohamed Boudiaf University of Sciences and Technology of Oran, Abou Bakr Belkaid University of Tlemcen and Ferhat Abbas University.

The significant strides made in industrialisation, the dominance of the petroleum industry and investments in chemical engineering in Algeria are reflected in the shape of its research output, which is dominated by physics, engineering, materials sciences, mathematics and chemistry (which together contribute 60.7% of total output). Unlike many other African countries, agricultural research (5.8%) and medicine (4.1%) make far more modest contributions to overall research production. It is also interesting that Algeria is the only country where computer science (5.4%) features in the top 10 fields.

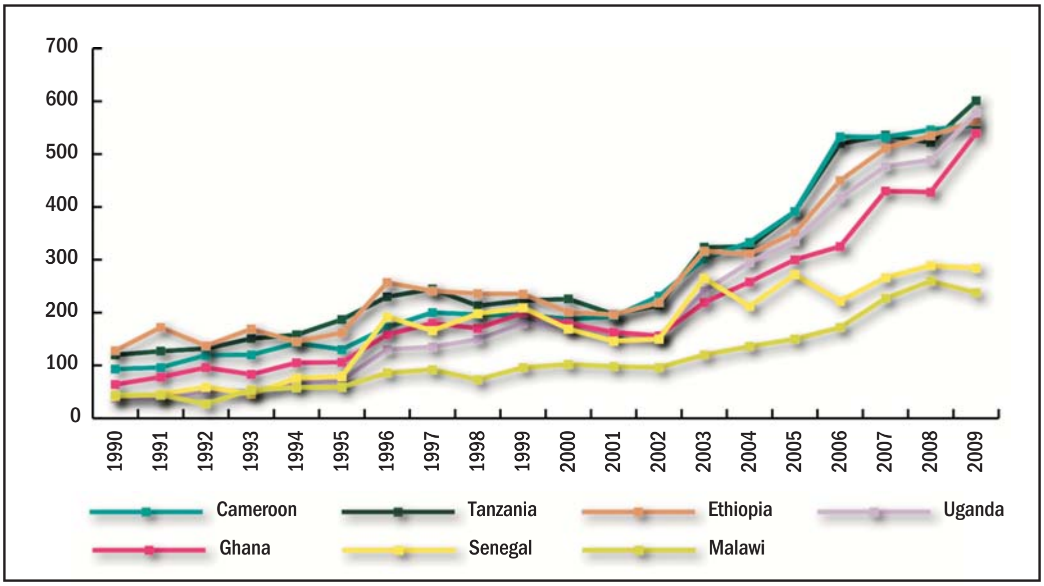
Although Algeria is ranked fifth among the 19 countries in the study, it does not compete well with the other countries in North Africa. The number of publications by Morocco and Tunisia, for instance, markedly exceeded those by Algeria during 2000–2004 (Pouris & Pouris, 2009). This discrepancy appeared only in the last decade and is most plausibly explained by the substantial loss of high-level human capital. Previously productive fields have completely collapsed (for example, biology), but new ones have emerged on the strength of young researchers assisted by international cooperation. This is the case especially in engineering sciences, physics and chemistry.

Figure 5A.7: Algeria: Shape of scientific output (top 12 fields account for 91% of total output) (2005–2009)



Group 3: Neither medium-sized nor small science systems (between 2 000 and 6 000 papers during 1990–2009) – Tanzania, Cameroon, Ethiopia, Uganda, Ghana, Senegal and Malawi

Figure 5A.8: Scientific papers of Tanzania, Cameroon, Ethiopia, Uganda, Ghana, Senegal and Malawi (seven countries in Group 3) (1990–2009)



Tanzania (ranked 6th; n = 5 642 papers)

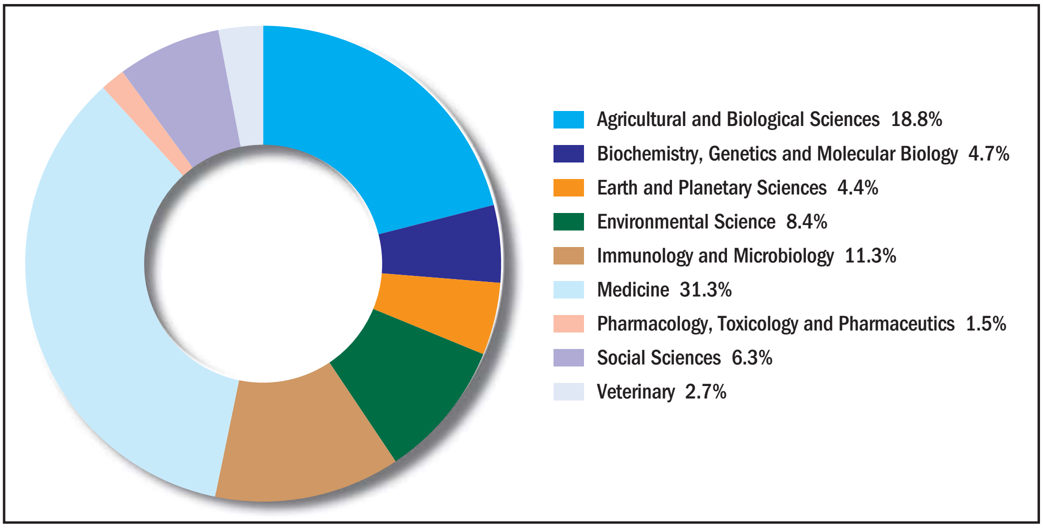
Tanzania's scientific output has seen a steady and fairly consist increase over the past 20 years. The country has produced more than 500 papers annually over the past four years and reached the 600 mark in 2009. Production is dominated by a small number of public universities (University of Dar es Salaam, Muhimbili University of Health and Allied Services and Sokoine University of Agriculture).

Tanzanian science is dominated by medical and related research (with the fields of medicine and immunology contributing 42.6% of total output). Research in agriculture is the second most productive field (18.8), whilst the environmental sciences (8.4%) and social sciences (6.3%) also make a significant contribution.

In the field of health research, government-based research institutes (such as the National Institute for Medical Research in Tanga and the Ifakara Health and Research Development Centre) regularly produce more than 50 papers per year. Another small, but interesting producer of science is the Kilimanjaro Christian Medical Centre, which is funded by the Good Samaritan Foundation.

In the environmental and agricultural fields, the Tanzania Wildlife Research Institute, Tanzania Food and Nutrition Centre and National Resource Institute make smaller contributions to the national output.

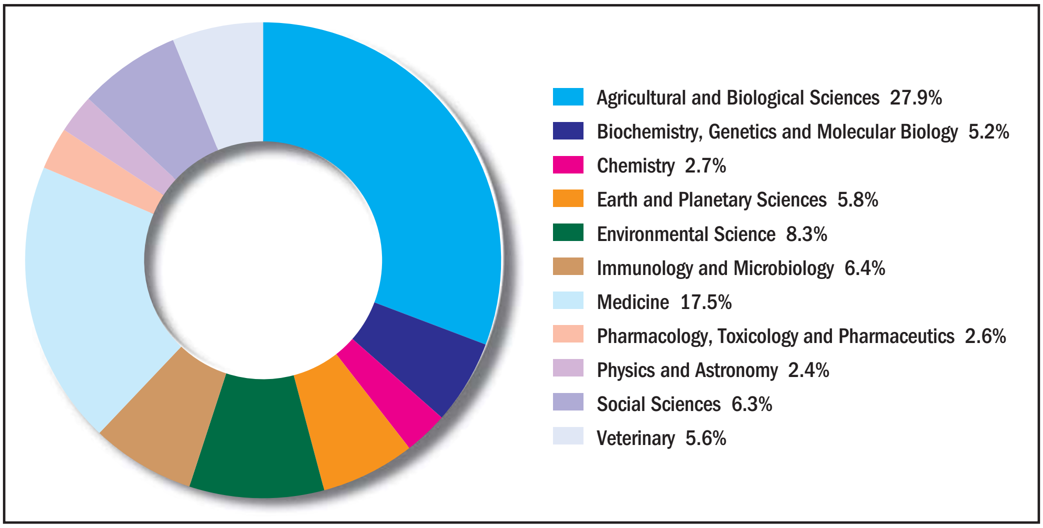
Figure 5A.9: Tanzania: Shape of scientific output (top 9 fields account for 89% of total output) (2005–2009)



Ethiopia (ranked 7th; n = 5 534 papers)

With a total output of more than 5 500 scientific papers over the past two decades, Ethiopia is the seventh ranked country among the 19 countries in the study. With the exception of a three-year period around the turn of the century – which coincided with the civil war with Eritrea and subsequent loss of

Figure 5A.10: Ethiopia: Shape of scientific output (top 11 fields account for 91% of total output) (2005–2009)



international donor funding – Ethiopia has seen a steady increase in its scientific output. The average output of the past three years has been more than 500 papers per year.

The bulk of the research output in Ethiopia is produced by academics at the major universities – first and foremost Addis Ababa University, but with significant contributions by academics at Haramaya University (an agricultural university), Jimma University and Mekelle University. Other major contributors to overall scientific production are the International Livestock Research Institute and Debre Zeit Agricultural Research Centre in the field of agriculture, and the Armauer Hansen Research Institute and Ethiopian Health and Nutrition Research Institute in the field of medical and health research.

The influence of international science funding on a relatively small system is well illustrated in the case of Ethiopia. Since 1975, Sweden – through the Swedish International Development Cooperation Agency (Sida) Department for Research Cooperation (SAREC) – has supported scientific research in Ethiopia with general funding (estimated at more than $100 million since 1975) (Mouton *et al.*, 2007). Part of this funding involved strengthening exchange relations between Ethiopia and Sweden and supporting doctoral students from Ethiopia in sandwich programmes to enrol at Swedish universities. It is therefore not surprising that Ethiopian academics and scientists collaborate to a large degree (and almost exclusively) with Swedish scientists. Closer inspection of the scientific output shows significant collaboration with Swedish institutions, such as the Swedish Agricultural University, the Karolinska Institute, the University of Lund and many others.

Ethiopia's traditional strengths in livestock research and studies in fauna and flora are reflected in the substantial contribution made by the agricultural and biological sciences (27.9%). Studies in medicine, immunology and microbiology make up 23.9%, and there are significant contributions by the environmental sciences (8.3%), social sciences (6.3%) and earth and planetary sciences (5.8%).

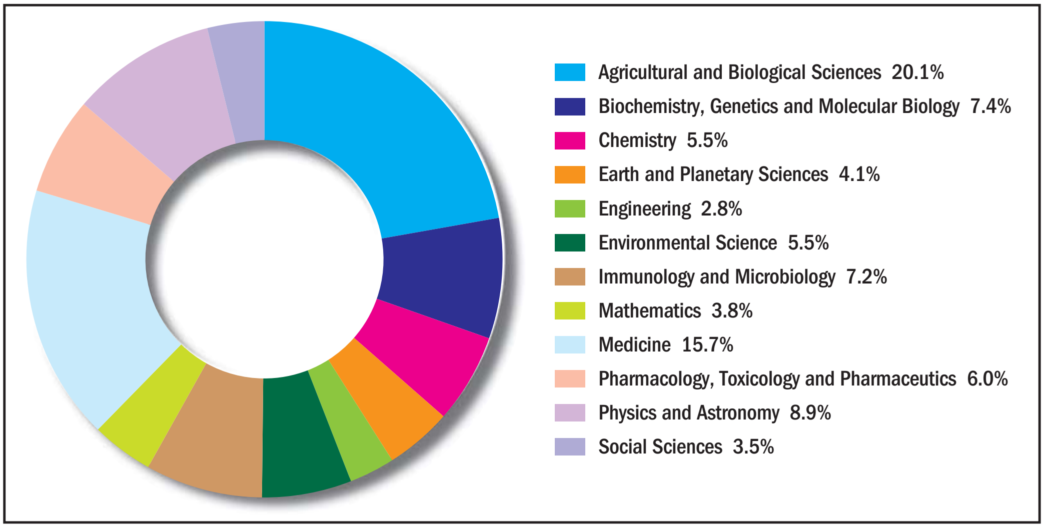
There is limited scientific collaboration, mostly in the field of agriculture, as evidenced by co-authorships with universities in Belgium and the Netherlands (Catholic University of Leuven and Wageningen University), as well as co-authorship with the London School of Hygiene and Tropical Medicine in the field of health research.

Cameroon (ranked 8th; n = 5 265 papers)

With a total output of almost 5 300 scientific papers over the past 20 years, Cameroon is ranked 8th among the 19 countries in the study. Since 2005, there has been consistent production of more than 500 papers per year. The vast majority of these papers are produced by academics at the major universities in Cameroon, namely (in descending order): the University of Yaoundé, University of Dschang and University of Douala. Other noticeable contributions are by the Pasteur Centre of Cameroon, Yaoundé General Hospital, Institute for Development Research, and Agricultural and Forestry Centre and Agronomy Centre, which falls under the Ministry of Scientific Research and Innovation.

Although Cameroon is a medium-sized country in terms of research productivity, scientific production is quite well balanced, with eight fields contributing more than 5% of total output. Although research in agricultural and biological sciences is the single biggest field (20.1%), the overall output of medicine and related fields (28.9%) predominates. The relatively large outputs in the exact sciences are of interest: physics and astronomy (8.9%), chemistry (5.5%) and mathematics (3.8%).

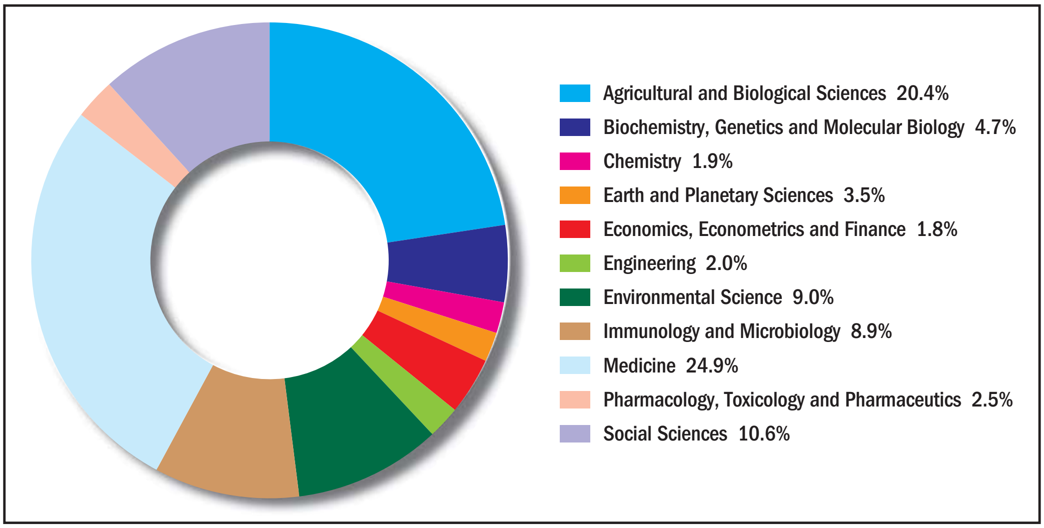
Figure 5A.11: Cameroon: Shape of scientific output (top 12 fields account for 91% of total output) (2005–2009)



Ghana (ranked 9th; n = 4 236 papers)

From a very small base of fewer than 100 papers per year in the early 1990s, Ghana's research output increased slowly, declining again around the turn of the century, before experiencing a higher growth rate (of almost 16%) over the period since 2005 and exceeding 500 papers per annum in 2009 for the first time.

Figure 5A.12: Ghana: Shape of scientific output (top 11 fields account for 90% of total output) (2005–2009)



Two universities (the University of Ghana and Kwame Nkrumah University of Science and Technology) dominate the output of the higher education sector. These two institutions consistently produce about 50% of total country output. Two smaller universities (the University of Cape Coast and University for Development Studies) produce between 80 and 100 papers per year.

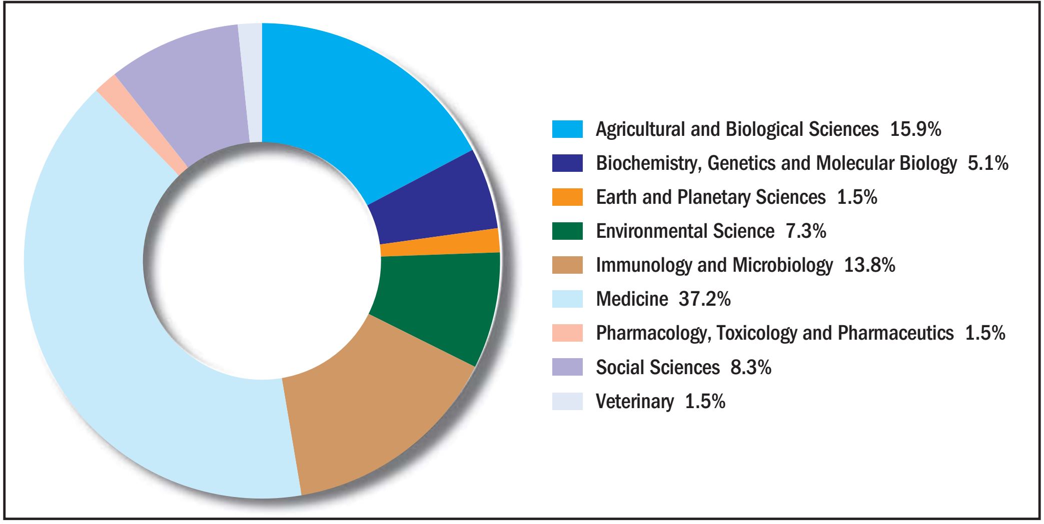
Ghana has a well-developed sector of internationally supported and government-based research institutes in agriculture and health. As far as agriculture is concerned, the major contributors to scientific production are the Food Research Institute, Crops Research Institute, Cocoa Research Institute, International Water Management Institute (Ghana) and Savanna Agricultural Research Institute. In the field of medicine and health research, the major centres are the Ministry of Health centres, University of Ghana Medical School, Komfo Anokye Teaching Hospital, Noguchi Memorial Institute for Medical Research and Navrongo Health Research Centre. In recent years, the Ghana Atomic Energy Commission has also published a small number of papers (50 over the past five years).

A quarter of Ghana's output is in medicine (24.9%), and there are further contributions in the related fields of immunology and microbiology (8.9%), and pharmacology and toxicology (2.5%). The relative strength in the social sciences (10.6%) is noteworthy.

Uganda (ranked 10th; n = 4 231 papers)

The impact of the brain drain and cuts in funding during the 1980s and 1990s in Uganda is evident in the rather poor scientific production during the early 1990s. From 1997 onwards, there has been a gradual increase in scientific output. More substantial and consistent annual output is evident since 2003. Since 2005, the country has produced more than 400 papers annually and achieved its highest output in 2009 with 578 papers.

Figure 5A.13: Uganda: Shape of scientific output (top 9 fields account for 92% of total output) (2005–2009)



Academics at Makerere University produce between 35% and 50% of the total scientific output of the country. A significant proportion of this output is produced by the Makerere University School of Public Health.

The biggest producers of agricultural research in the country are the National Crops Resources Research Institute (NACRRI) (previously the Namulonge Agricultural and Animal Production Research Institute) and the International Institute of Tropical Agriculture.

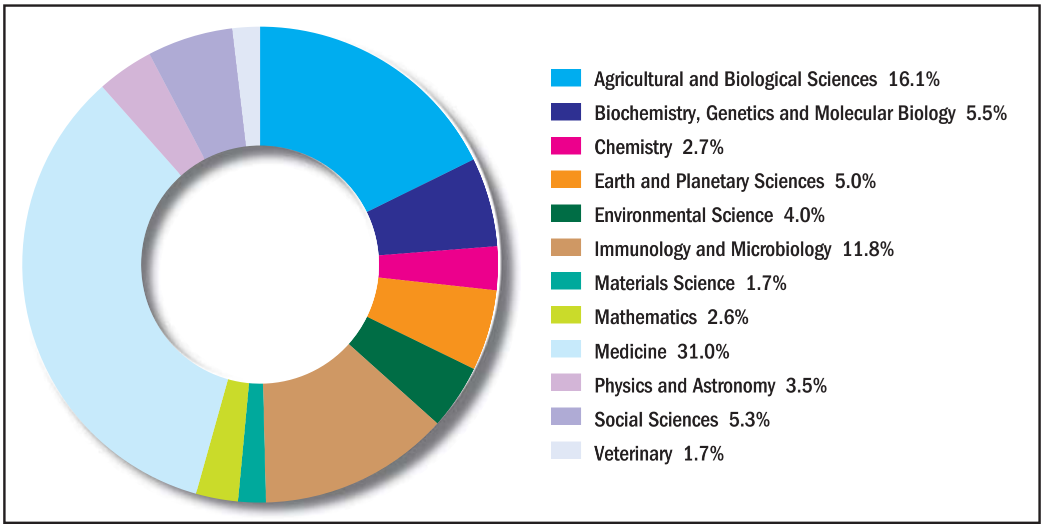
The shape of scientific production is very much concentrated in a small number of fields: the top six fields produced 87.6% of all output over the past five years. The concentration on medical and health issues (with medicine and immunology together producing over half of all output [51.0%]) reflects the realities of the pervasiveness of tropical and endemic diseases in the country.

Senegal (ranked 11th; n = 3 387 papers)

Senegal's total output has been steady at over 200 papers per year since 2002. Research output is dominated by the Cheikh Anta Diop University, which regularly produces about a third of the country's output.

Two factors determine the shape of scientific production in Senegal: the very significant contribution of medicine and related fields (42.8%), as well as a very well-balanced distribution of a further seven to nine fields. In addition to the contribution of the agricultural, biological and environmental sciences, there are nascent strengths in the exact sciences of physics, chemistry and mathematics.

Figure 5A.14: Senegal: Shape of scientific output (top 12 fields account for 91% of total output) (2005–2009)

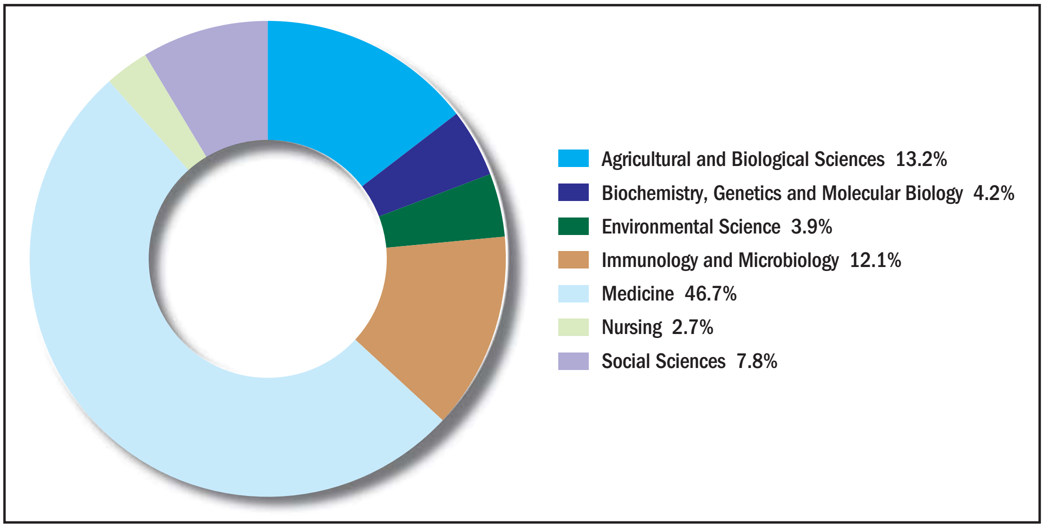


A number of research institutes make significant and regular contributions to the country's research output, including the Institut de Recherche pour le Développement Dakar, the Pasteur Institute of Dakar and two hospitals, the Centre Hospitalier Universitaire de Dakar (a psychiatric hospital established in 1956) and the Hôpital Principal de Dakar (established as a military hospital in 1880). In the field of agriculture, the Institut Sénégalais de Recherches Agricoles and the École Inter-États des Sciences et Médecine Vétérinaires (both of which are situated in Dakar) also produce significant numbers of papers.

Malawi (ranked 12th; n = 2 232 papers)

The total research output of Malawi over the period 1990–2009 was just over 2 200 papers. Scientific production was very variable until 2000, after which there was a steady increase, with production exceeding 200 papers per year over the past three years. The pre-eminent producer of scientific papers in Malawi is the College of Medicine at the University of Malawi. Other significant producers of scientific papers in the field of medicine are the Ministry of Health and the Malawi-Liverpool-Wellcome Trust Clinical Research Programme.

Figure 5A.15: Malawi: Shape of scientific output (top 7 fields account for 91% of total output) (2005–2009)

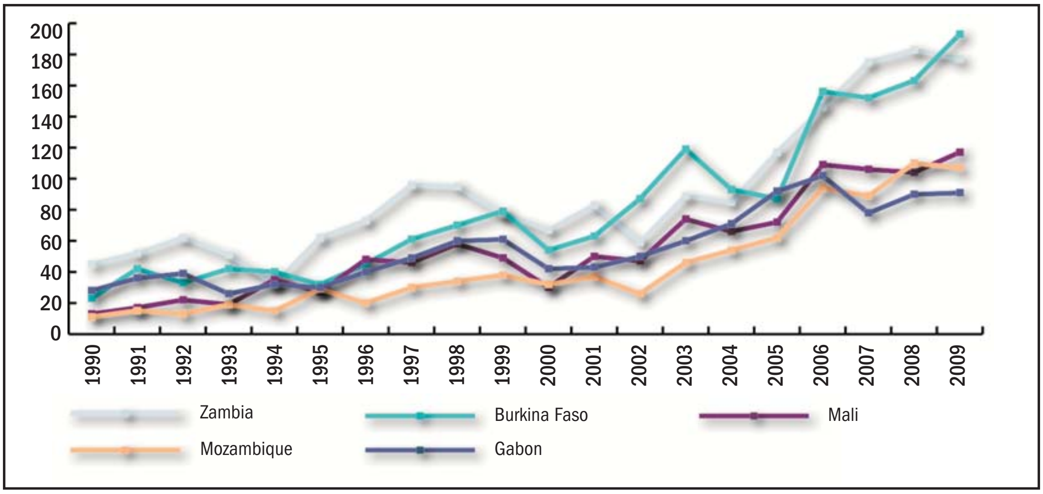


In the field of agriculture, the Chitedze Agricultural Research Station is the main producer of scientific papers. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, non-political organisation that conducts innovative agricultural research and capacity building for sustainable development with a wide array of partners across the globe. Its research unit in Malawi is based at the Chitedze Research Station in Lilongwe.

The shape of knowledge distribution in Malawi is not unlike that of its neighbour, Uganda, with a mere five fields producing 84% of total output. If one adds research in the fields of immunology and microbiology, the medical and health sciences produce 58.8% of all science in Malawi. Other significant contributions are in agriculture, the social sciences, biochemistry and molecular biology, and environmental sciences.

Group 4: Small science systems (between 800 and 2 000 papers during 1990–2009) – Zambia, Burkina Faso, Mali, Mozambique and Gabon

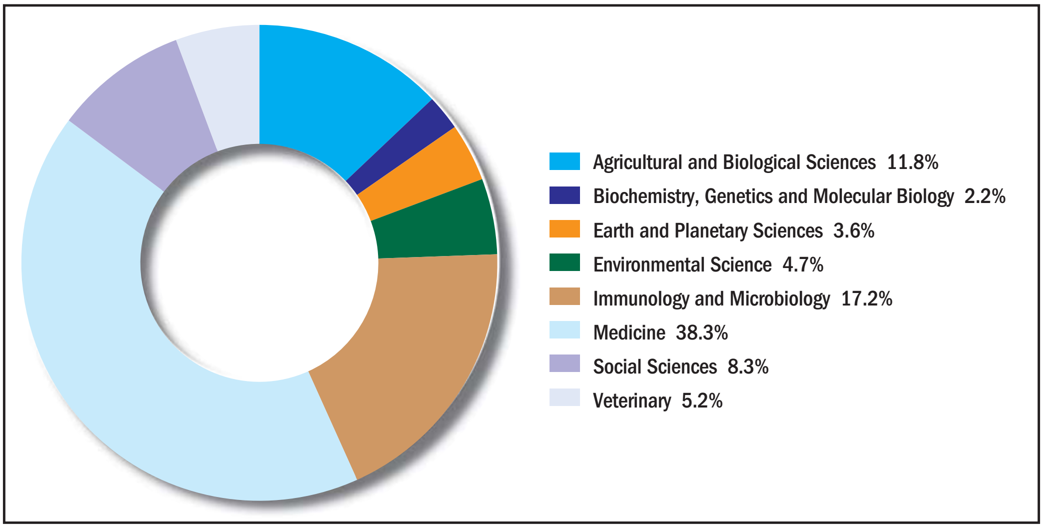
Figure 5A.16: Scientific papers of Zambia, Burkina Faso, Mali, Mozambique and Gabon (five countries in Group 4) (1990–2009)



Zambia (ranked 13th; n = 1 826 papers)

Zambia produced close to 2 000 papers over the past 20 years and since 2007 the country has consistently produced at least 150 papers a year. The University of Zambia dominates scientific production in the country, accounting for more than 40% of papers during 2005–2009.

Figure 5A.17: Zambia: Shape of scientific output (top 8 fields account for 91% of total output) (2005–2009)



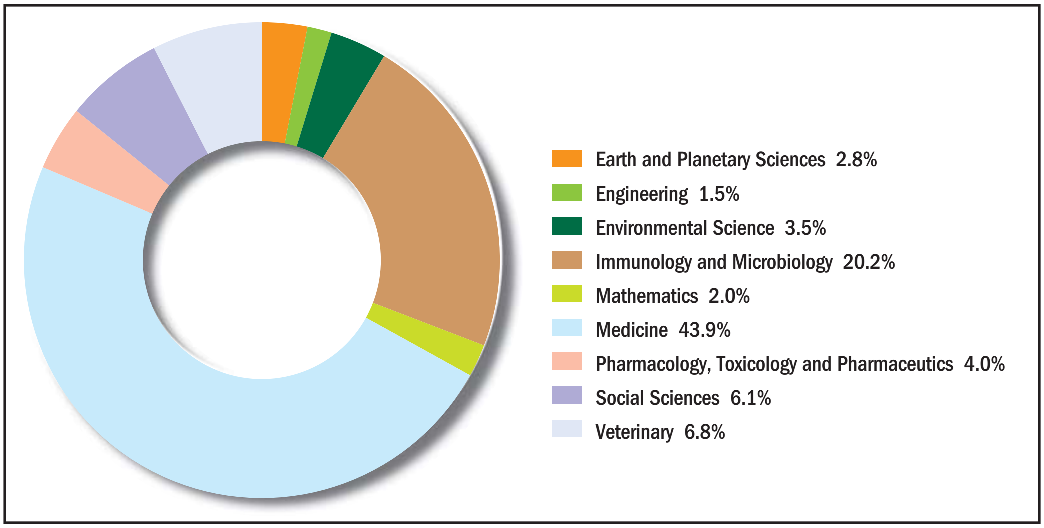
Zambia's scientific output is very typical of a small science system, with seven fields dominating output. Once again, the production of knowledge in medicine and related fields is predominant (55.5%), followed by a very significant contribution by the social sciences (8.3%). The very high position of veterinary science (ranked fifth with 5.2%) is noteworthy.

Burkina Faso (ranked 14th; n = 1 715)

Over the past 20 years, Burkina Faso has produced approximately 1 700 scientific papers. Average annual output hovered around 100 from the late 1990s onwards and has consistently been above 150 since 2005. Research output in Burkina Faso is dominated by three institutions: the University of Ouagadougou, the Muraz Centre and the Institut de l'Environnement et de Recherches Agricoles (INERA). Of the 1 057 scientific papers produced over the most recent five-year period, the University of Ouagadougou produced 305, the Muraz Centre 133 and INERA 83. Foreign collaboration (measured in terms of co-authored papers) is strongest with the IRD Centre in Montpellier and the London School of Hygiene and Tropical Medicine.

The dominance of medicine and related research (68.1%) in the Burkina Faso science system is the strongest of any of the countries in the study. Two other niche areas are veterinary sciences (6.8%) and social sciences (6.1%).

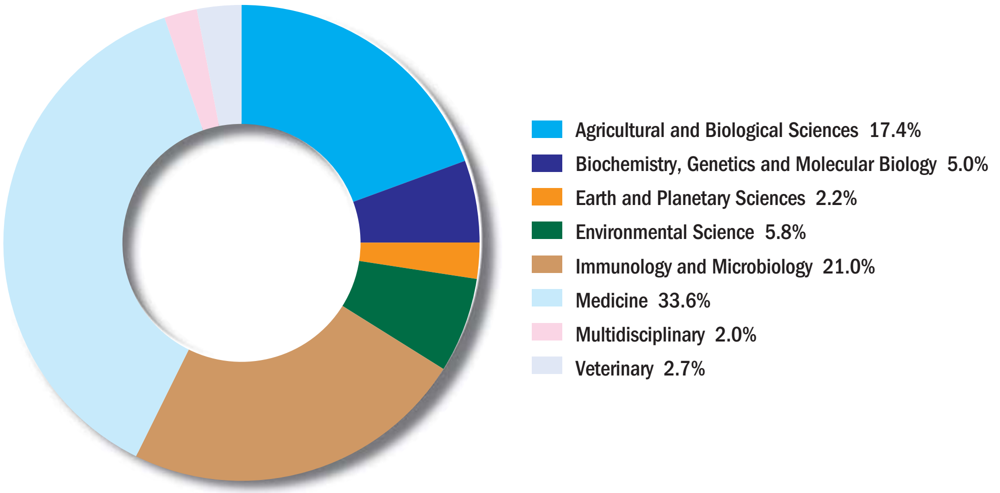
Figure 5A.18: Burkina Faso: Shape of scientific output (top 9 fields account for 91% of total output) (2005–2009)



Gabon (ranked 15th; n = 1 120 papers)

The total research output for Gabon over the past 20 years is just over 1 100 papers. Although there has been an increase in output since the 1990s, there is no evidence of much increase in recent years. After peaking in 2006 at 102 papers, output since then has been fewer than 100 papers per year.

Figure 5A.19: Gabon: Shape of scientific output (top 8 fields account for 90% of total output) (2005–2009)



Gabon's scientific production is focused on medical research topics, with a strong focus on primate research and especially on the ebola virus (given the regular occurrence of outbreaks in Gabon), but also on factors associated with the decline in the numbers of the great apes (due to hunting and the ebola virus). This research is carried out at the International Centre for Medical Research in Franceville.

Gabon demonstrates the typical shape of science in small countries with five fields producing 82.9% of total output. More than half of this output is in the fields of medicine and related disciplines (54.9%), and a further 23.2% in the agricultural, biological and environmental sciences.

A focus of research in Gabon is infectious diseases (especially malaria). Research in this area is conducted at the world-famous Albert Schweitzer Hospital (Medical Research Unit). The Research Unit receives no annual budget, and is funded solely through project grants. Current or recent funding agencies include the US National Institutes of Health, European Union, Ministry of Education and Research, Germany, World Health Organisation/TDR (for research on diseases of poverty), Bill and Melinda Gates Foundation and Fortüne Programme (Forschungsförderung der Tübingen Medizinischen Fakultät) of the Medical Faculty of the University of Tübingen. The impact of the latter funding is clearly reflected in the fact that a considerable proportion of papers produced by Gabon is done through co-authorship with scientists at Tübingen.

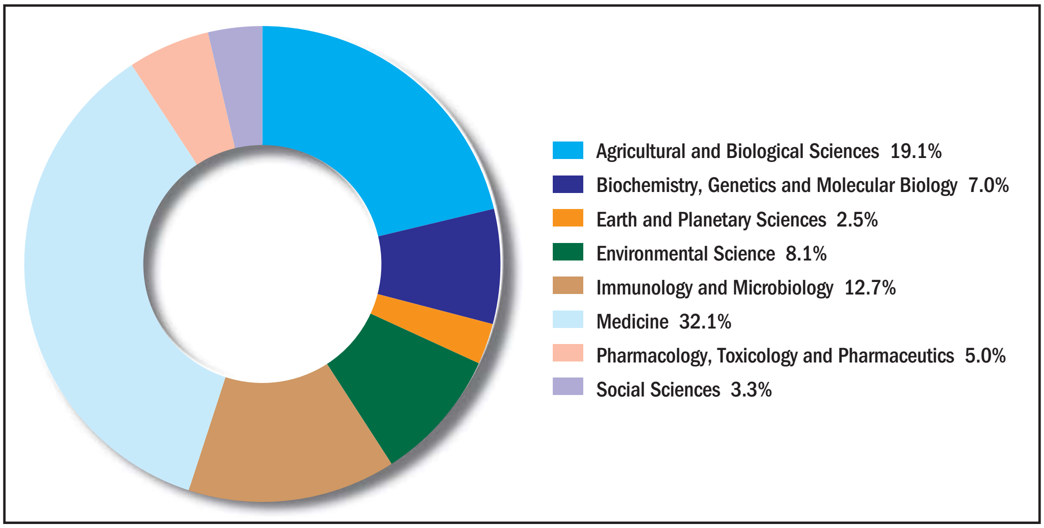
Mali (ranked 16th; n = 1 109 papers)

Mali has produced just over 1 100 papers over the past 20 years and has only managed more than 100 per year since 2005. The bulk of the papers are produced by the University of Bamako (which was only established in 1996), especially by the Faculty of Medicine, Pharmacy and Odonto-Stomatology. In the field of health research, other major players are the Institut National de Recherche en Santé

Publique and the National Institute of Allergy and Infectious Diseases. In the field of agriculture, the major players are the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the Central Veterinary Laboratory.

The distribution between medicine and related sciences (44.8%) and agricultural and environmental sciences (27.2%) is more even in Mali's science system that in several of the other countries in the study. There were smaller contributions by biochemistry and molecular biology (7.0%), a small but significant contribution by pharmacology and toxicology (5.0%) and a contribution of 3.3% by the social sciences.

Figure 5A.20: Mali: Shape of scientific output (top 8 fields account for 90% of total output) (2005–2009)

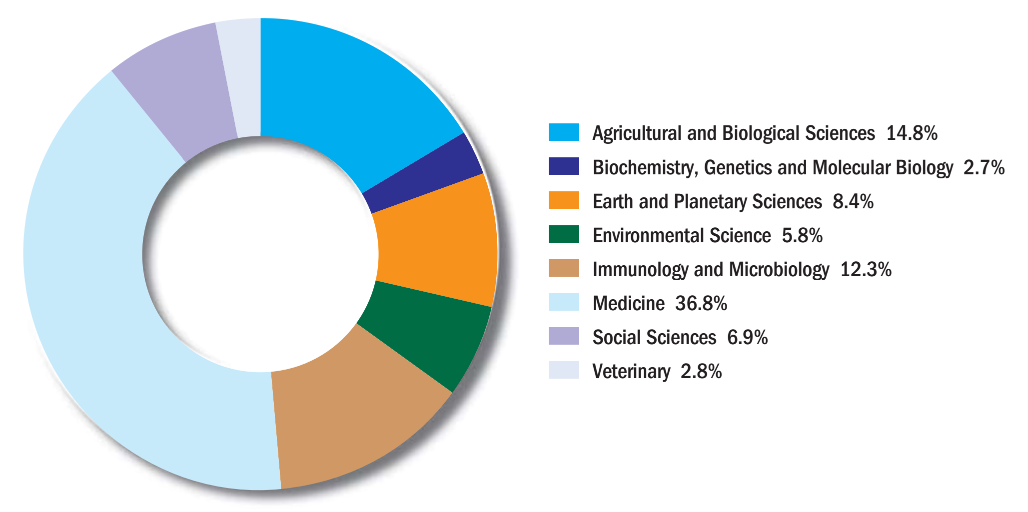


Mozambique (ranked 17th; n = 881 papers)

The total research output by Mozambique over the period 1990–2009 is slightly less than 900 papers. From an almost non-existent base in 1990 (undoubtedly because of the political instability and civil war), output has grown steadily and only managed to exceed 100 papers per year for the past two years. Three institutions dominate the small production: the Eduardo Mondlane University, National Institute for Health (Instituto Nacional de Saúde) and Centro de Investigação em Saúde at Manhiça (CISM).

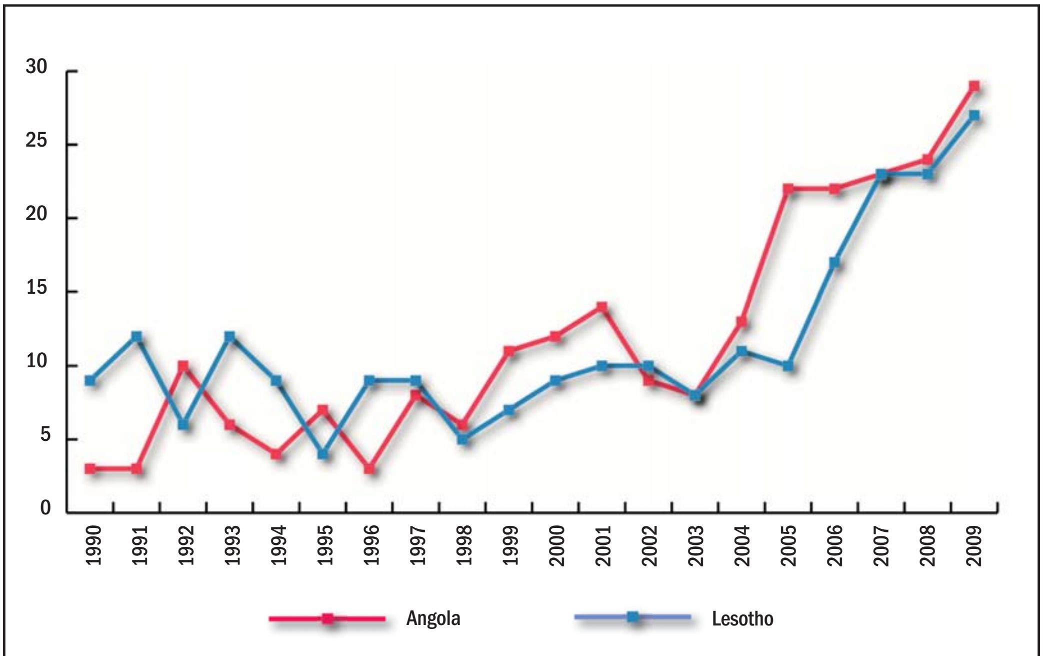
Almost half the scientific research in Mozambique is in the fields of medicine and immunology (49.1%), and a further quarter in agriculture, biological sciences and earth and planetary sciences (22.8%). The social sciences produce a small but noteworthy 6.9% of all output.

Figure 5A.21: Mozambique: Shape of scientific output (top 8 fields account for 91% of total output) (2005–2009)



Group 5: Scientific minions (fewer than 300 papers during 1990–2009) – Angola and Lesotho

Figure 5A.22: Scientific papers of Angola and Lesotho (two countries in Group 5) (1990–2009)

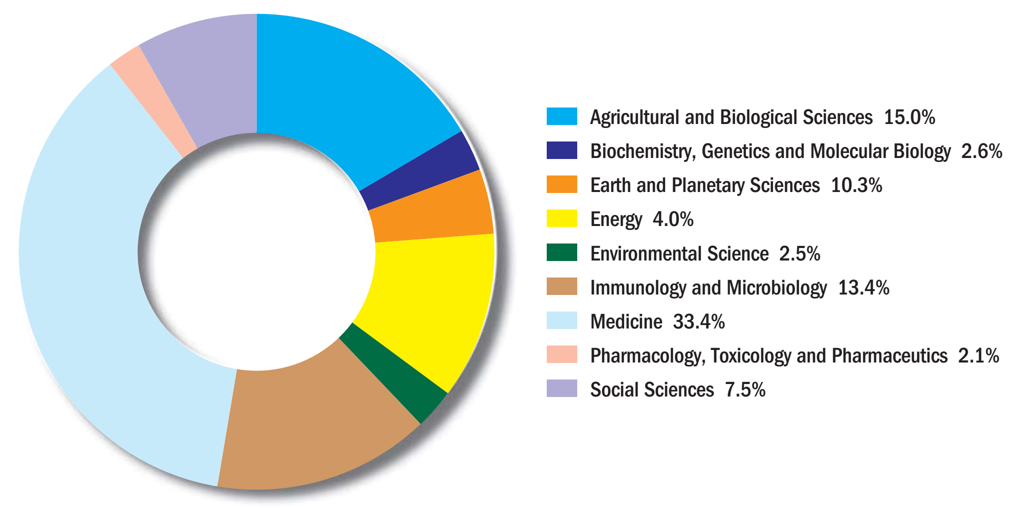


Angola (ranked 18th, n = 237 papers)

Angola is slowly rebuilding its country after the end of a 27-year civil war in 2002. The total output of papers for the country over the period 1990–2009 is a meagre 237. The only positive feature is the slight growth over the past five years to an average of more than 20 papers per year. Most of the papers are consistently produced by the Agostinho Neto University (varying between 15% and 50% of annual output) and the Institute to Combat Trypanosomiasis (ICCT) (Instituto de Combate e Controle das Tripanossomíases), which forms part of the Ministry of Health. Other smaller and more irregular producers of scientific papers in this small research system are the Institute for Tropical Science Research (Instituto de Investigação Científica Tropical), National Programme for Malaria Control, National Institute for Fisheries Research (which collaborates with the Institute for Marine Research at the University of Cape Town, South Africa) and the Veterinary Research Services.

The very small output by the Angolan science system is concentrated in five fields. Medicine and immunology contribute almost half (46.8%) of the total output and agriculture, biology and earth sciences a further quarter (25.3%).

Figure 5A.23: Angola: Shape of scientific output (top 9 fields account for 91% of total output) (2005–2009)

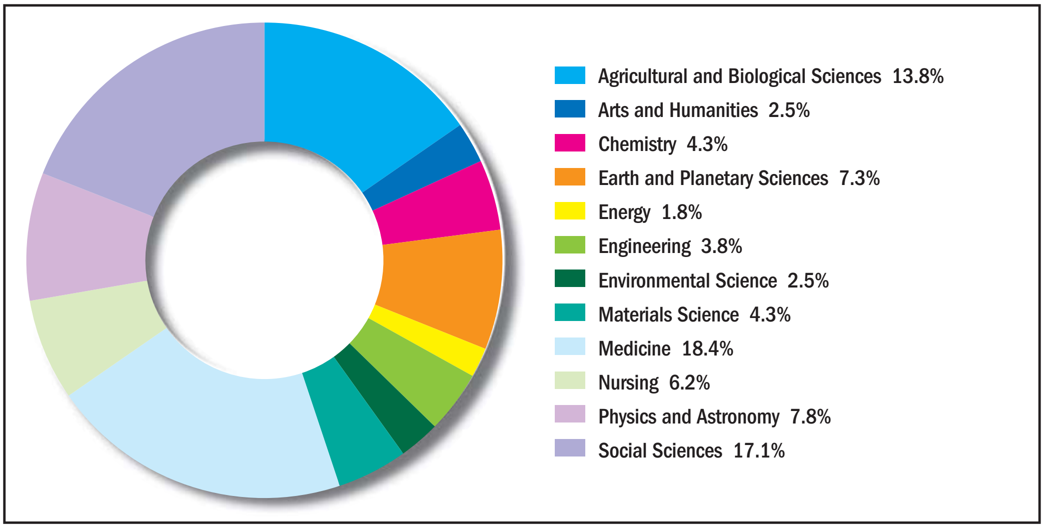


Lesotho (ranked 19th; n = 230)

Lesotho is the least productive country among the 19 countries in the study. It has produced only 230 papers over the past 20 years. The past three years have seen a slight increase, with an average of more than 20 papers being produced per year. For all practical purposes, a single institution, the National University of Lesotho in Maseru, produces all the scientific output of the country.

Lesotho's very small output is concentrated in three fields: medicine (18.4%), social sciences (17.1%) and agricultural and biological sciences (13.8%), with smaller contributions by physics and astronomy (7.8%), earth sciences (7.3%) and nursing (6.2%).

Figure 5A.24: Lesotho: Shape of scientific output (top 12 fields account for 90% of total output) (2005–2009)



Annex B: Breakdown of scientific papers by field for each country

Table 5B.1: Broad and sub-field breakdown (percentage) of scientific papers of countries in Groups 1 and 2 (2005–2009)

Field	Group 1 (%)		Group 2 (%)		
	South Africa	Egypt	Nigeria	Algeria	Kenya
Agricultural and Biological Sciences	15.8	7.6	17.7	5.8	26.5
Arts and Humanities	2.0	0.2	0.6	0.1	0.5
Biochemistry, Genetics and Molecular Biology	6.1	5.9	11.6	3.3	10.0
Business, Management and Accounting	0.9	0.5	0.9	0.2	0.7
Chemical Engineering	1.5	3.6	1.2	5.0	0.3
Chemistry	3.8	14.0	2.4	8.5	1.2
Computer Science	1.1	1.8	0.6	5.4	0.2
Decision Sciences*	0.3	0.2	0.1	0.4	0.0
Dentistry	0.3	0.5	0.5	0.0	0.1
Earth and Planetary Sciences	7.1	3.1	2.1	2.7	2.2
Economics, Econometrics and Finance	1.3	0.2	0.5	0.1	1.0
Energy	0.7	1.6	0.9	2.0	0.2
Engineering	3.0	8.3	2.0	12.8	0.9
Environmental Science	6.3	2.9	5.4	3.0	7.0
Health Professions	0.6	0.2	0.4	0.2	0.3
Immunology and Microbiology	4.0	2.2	3.5	1.0	10.9
Materials Science	2.5	8.8	1.5	12.8	0.4
Mathematics	3.5	4.6	1.4	10.1	0.2
Medicine	18.7	16.7	25.0	4.1	22.8
Multidisciplinary	0.6	1.6	5.3	3.5	1.6
Neuroscience	0.7	0.5	0.5	0.3	0.6
Nursing	0.7	0.3	1.4	0.1	0.6
Pharmacology, Toxicology and Pharmaceutics	1.6	3.8	3.9	0.8	1.5
Physics and Astronomy	4.8	8.9	1.3	16.5	0.3
Psychology	2.2	0.1	0.5	0.1	0.6
Social Sciences	8.3	0.9	6.6	0.7	7.1
Veterinary	1.5	1.0	1.9	0.4	2.3
Total	**(N=32 372)**	**(N=22 955)**	**(N=13 333)**	**(N=7 050)**	**(N=4 936)**

Note:
* Decision science, or operational research as it is more commonly referred to, involves the application of quantitative techniques to decision-making (www.businessdictionary.com/definition/operations-research-OR.html). In Scopus the category includes journals such as *Applied Stochastic Models in Business and Industry*, the *European Journal of Operational Research* and the *Journal of Scheduling*.

Table 5B.2: Broad and sub-field breakdown (percentage) of scientific papers of countries in Group 3 (2005–2009)

Field	Group 3 (%)						
	Tanzania	Cameroon	Ethiopia	Uganda	Ghana	Senegal	Malawi
Agricultural and Biological Sciences	18.8	20.1	27.9	15.9	20.4	16.1	13.2
Arts and Humanities	0.3	0.0	0.3	0.1	0.7	0.3	0.1
Biochemistry, Genetics and Molecular Biology	4.7	7.4	5.2	5.1	4.7	5.5	4.2
Business, Management and Accounting	0.4	0.1	0.6	0.4	1.7	0.1	0.3
Chemical Engineering	0.4	0.8	0.5	0.2	0.4	0.8	0.1
Chemistry	0.9	5.5	2.7	0.6	1.9	2.7	0.3
Computer Science	0.1	0.7	0.3	0.2	0.3	0.8	0.3
Decision Sciences	0.0	0.2	0.1	0.1	0.0	0.2	0.1
Dentistry	0.9	0.0	0.1	0.5	0.1	0.8	0.0
Earth and Planetary Sciences	4.4	4.1	5.8	1.5	3.5	5.0	2.2
Economics, Econometrics and Finance	0.8	0.9	2.0	0.6	1.8	0.6	0.9
Energy	0.6	0.6	0.3	0.2	0.6	0.4	0.4
Engineering	1.4	2.8	1.2	0.7	2.0	1.3	0.6
Environmental Science	8.4	5.5	8.3	7.3	9.0	4.0	3.9
Health Professions	0.6	0.2	0.2	0.6	0.4	0.5	0.5
Immunology and Microbiology	11.3	7.2	6.4	13.8	8.9	11.8	12.1
Materials Science	0.2	2.3	0.9	0.4	1.0	1.7	0.6
Mathematics	0.5	3.8	1.2	0.5	0.5	2.6	0.2
Medicine	31.3	15.7	17.5	37.2	24.9	31.0	46.7
Multidisciplinary	1.3	1.3	0.7	0.7	1.2	0.5	0.5
Neuroscience	0.4	0.4	0.6	0.9	0.2	1.0	0.3
Nursing	1.2	0.6	0.4	1.3	1.0	0.6	2.7
Pharmacology, Toxicology and Pharmaceutics	1.5	6.0	2.6	1.3	2.5	1.3	1.0
Physics and Astronomy	0.4	8.9	2.4	0.2	1.4	3.5	0.4
Psychology	0.5	0.3	0.3	1.2	0.6	0.1	1.2
Social Sciences	5.8	3.5	6.0	7.1	10.0	5.2	6.6
Veterinary	2.7	1.1	5.6	1.5	0.4	1.7	0.5
Total	**(N=2 570)**	**(N=2 557)**	**(N=2 408)**	**(N=2 296)**	**(N=2 022)**	**(N=1 333)**	**(N=1 047)**

Table 5B.3: Broad and sub-field breakdown (percentage) of scientific papers of countries in Groups 4 and 5 (2005–2009)

Field	Group 4 (%)					Group 5 (%)	
	Zambia	Burkina Faso	Mali	Mozambique	Gabon	Angola	Lesotho
Agricultural and Biological Sciences	11.8	0.0	19.1	14.8	17.4	15.0	13.8
Arts and Humanities	0.1	0.0	0.5	0.0	0.9	0.0	2.5
Biochemistry, Genetics and Molecular Biology	2.2	0.0	7.0	2.7	5.0	2.6	1.8
Business, Management and Accounting	0.6	0.2	0.0	0.1	0.0	0.0	0.0
Chemical Engineering	0.1	0.0	0.0	0.7	0.1	1.5	1.5
Chemistry	0.4	0.0	1.4	0.6	1.3	1.9	4.3
Computer Science	0.2	0.7	0.1	0.4	0.1	0.3	0.0
Decision Sciences	0.0	0.2	0.0	0.2	0.2	0.0	0.0
Dentistry	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Earth and Planetary Sciences	3.6	2.8	2.5	8.4	2.2	10.3	7.3
Economics, Econometrics and Finance	0.6	0.9	0.2	1.4	0.0	0.0	0.3
Energy	0.8	0.6	0.1	0.5	0.2	4.0	1.8
Engineering	0.7	1.5	1.0	0.8	0.4	0.9	3.8
Environmental Science	4.7	3.5	8.1	5.8	5.8	2.5	2.5
Health Professions	0.7	0.5	0.3	0.6	0.1	1.1	0.3
Immunology and Microbiology	17.2	20.2	12.7	12.3	21.0	13.4	1.5
Materials Science	0.5	1.2	0.2	0.3	0.1	0.0	4.3
Mathematics	0.2	2.0	0.2	0.6	1.4	0.8	1.3
Medicine	38.3	43.9	32.1	36.8	33.6	33.4	18.4
Multidisciplinary	0.1	1.3	2.2	0.2	2.0	0.8	1.0
Neuroscience	0.6	0.6	0.9	0.1	1.1	0.0	0.7
Nursing	1.7	0.9	0.7	0.6	0.8	0.8	6.2
Pharmacology, Toxicology and Pharmaceutics	1.0	4.0	5.0	1.7	1.2	2.1	0.3
Physics and Astronomy	0.4	1.9	0.2	0.3	0.9	0.2	7.8
Psychology	1.7	0.6	0.2	0.4	0.4	0.0	0.3
Social Sciences	6.6	5.5	3.1	6.9	1.9	7.5	16.8
Veterinary	5.2	6.8	2.2	2.8	1.8	0.8	1.3
Total	**(N=798)**	**(N=751)**	**(N=508)**	**(N=462)**	**(N=453)**	**(N=120)**	**(N=100)**

Chapter 6. Recommendations

The production of this first *African Innovation Outlook* has proved to be more challenging than expected, but also quite exciting. In starting to provide information on the state of science, technology and innovation (STI) in the 19 selected African countries, the *Outlook* also identifies a number of information gaps that need to be addressed in the subsequent phases of the ASTII programme.

Over the period of implementation, between 2007 and 2010, members of the Focal Points spearheaded the implementation of the ASTII activities at national levels and strove to embrace supplementary responsibilities in addition to their normal duties. In accessing and disseminating STI information, they faced the challenges of limited information technology infrastructure and the high cost of bandwidth. In most participating countries, the absence of a related budget line in the national budget and the lack of alternative financial support at national level delayed procurement of services, including transport, telecommunication services and local training. The biggest challenges, however, was the fact that most of the countries were undertaking the R&D and innovation surveys for the first time without any institutional memory to fall back on. The survey units had to deal with unfamiliar concepts and methodologies. Respondents were also uninformed about what was required of them and the relevance of the exercise to their businesses and operations. Where more significant engagement was sustained, good quality data were collected and relevant indicators produced.

Discussions on the R&D and innovation surveys at national levels raise debate on the role of STI in social and economic development. The Focal Points, having become acquainted with new knowledge acquired through the ASTII training, are now in a position to demonstrate the role of indicators in policy processes. A case in point was better articulation of the inputs needed in computing R&D intensity, an indicator that measures the resources that a country dedicates to R&D as a percentage of its gross domestic product (GDP). The estimation of this indicator informs the 1% target set by the African Union in the Khartoum Decision EX.CL/Dec.254 (VIII) on Science and Technology in 2006.

The experience gained in implementing the first phase of ASTII has motivated additional countries to join the programme and stimulated areas that need further research.

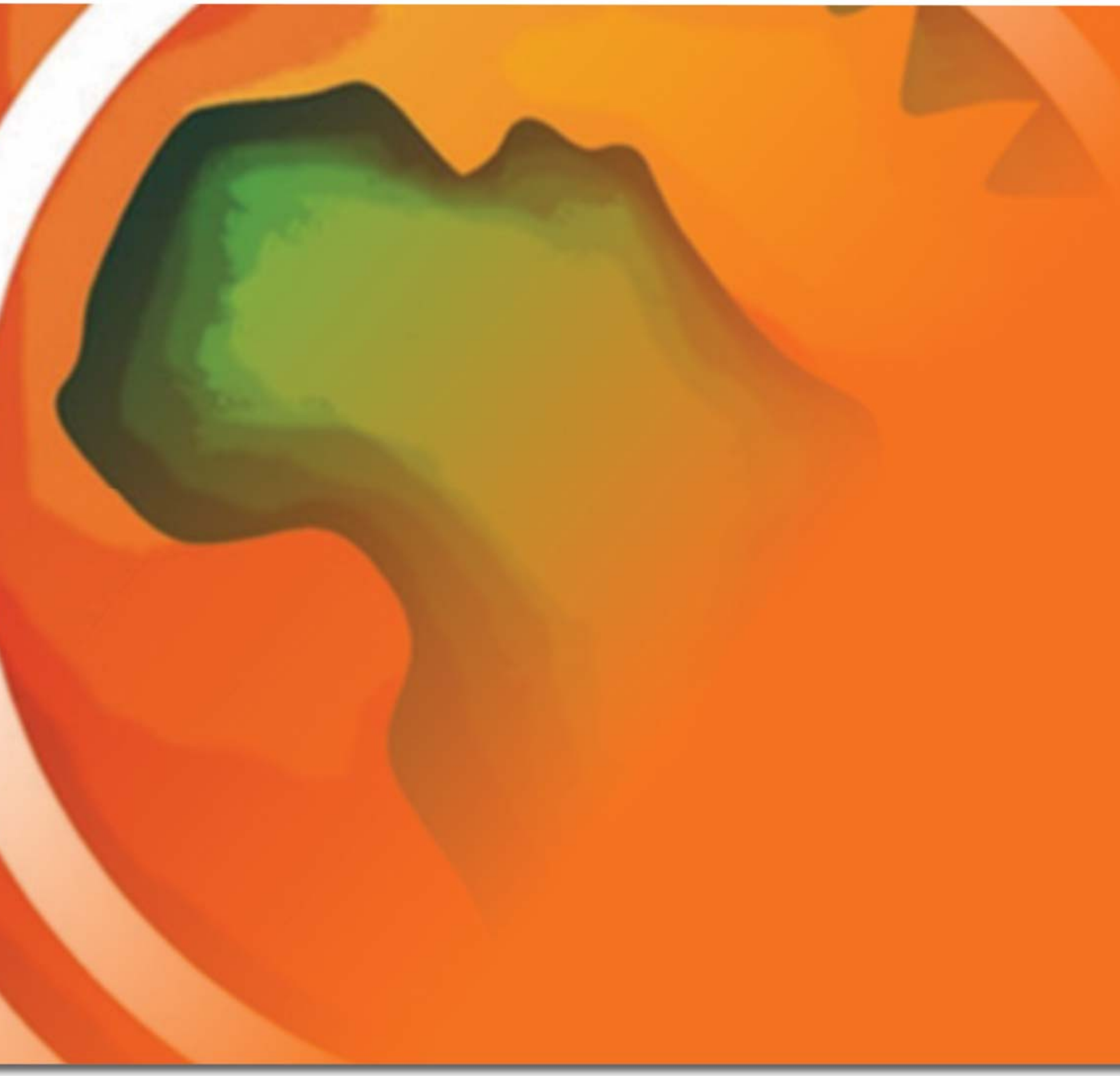
In order to overcome the challenges experienced, consolidate the experience and face future challenges, the ASTII programme needs to strengthen its multisectoral and cross-cutting approach. To this end, the programme will call for increased involvement of the statistics community to address measurement issues; researchers, academics and practitioners to address the knowledge gaps; policy-makers and businesses to support and enrich the debate on the relevance of, and demand for, the indicators produced; and international partners to share their experience and provide resources where necessary.

The following actions are recommended to take the programme to the next levels of implementation:

- Mobilise political support and create ownership of the ASTII programme, building on the experience gained during the implementation phase in collecting and analysing STI data
- Provide the African Union system and governments with the opportunity to compare and monitor the development of STI in member states
- Enable African countries to utilise reliable and accurate information on STI for policy-formulation and tracking commitments
- Support researchers in addressing the information and knowledge gaps.

The ASTII initiative has been supported by the Swedish International Development Cooperation Agency (Sida)

Sida



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