National Experiences in the Transfer of Publicly Funded Technologies in Africa: Ghana, Kenya and Zambia

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Note

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The term "publicly funded" refers to the source of funding and not the R&D performing institutions. Public sources of funding may include government agencies, donors, foundations and other not-for-profit organizations.

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

The terms "number", "proportion" and "percentage" refers only to the totals of centres or entities that chose to complete the survey and not of the country. Therefore, statements such as "ten per cent of the researchers have PhDs" do not refer to the national average of researchers but of the centres involved in the survey.

The terms "technology transfer" and "technology commercialization" refer to the identification and transfer of research outputs of potential economic and social value to a wider range of users in the public and private sector and may be used interchangeably in this paper. For instance, a "technology transfer office" is the same as a "technology commercialization office".

Preface

The Economic Commission for Africa (ECA) series on technology transfer for Africa's development is designed to highlight the importance of technology transfer in economic development. The main objectives of the studies in this series are to explore trends in technology transfer, the preferred modes and channels of technology transfer, the impact of technology transfer on industrial productivity and efficiency, and the mechanisms and measures countries may use to facilitate technology transfer.

All countries depend on technology transfer to some extent in their efforts to meet national aspirations and challenges. However, it is generally difficult for any countries, to specialize in all fields of technology; this explains why worldwide, technologies are sourced from different origins..

The technology transfer for Africa's development series seeks to understand the interplay between technology transfer and development. In particular, it unravels and highlights the contribution of technology transfer to innovation, entrepreneurship, investment, efficiency, productivity and the export performance of African countries. Technology transfer is a means of helping African countries to meet their health, nutritional, sanitation, energy and communication needs, among others. This is only possible, however, if the appropriate support mechanisms that encourage technology transfer and diffusion are in place.

This study highlights the broad challenges that Africa's research and development (R&D) institutions face in diffusing knowledge to the productive sector. African countries and their development partners invest a modest but substantial proportion of their resources in R&D institutions in the hope that the knowledge developed will improve the competitiveness of domestic firms, diversify their exports and stimulate the development of new firms and the expansion of existing ones, thereby creating jobs and wealth. A better understanding of the issues that hinder the market from accessing that knowledge, which is created at considerable expense, would help policymakers to design policies that encourage the commercialization of publicly funded technology. The study also sets out various ways in which countries can encourage firms and institutions to acquire new and emerging technology.

Acknowledgements

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

The study was prepared and organized by Victor Konde. The survey in Ghana was undertaken by Godfred Frempong and Emmanuel Tetteh, the survey in Kenya was carried out by Richard M. Liahona and the survey in Zambia was conducted by Roy Mwenechanya and Buchisa Mwalongo. The case of the Institute for Industrial Research of the Council for Scientific and Industrial Research was prepared by Herbert A Obiri, Acting Director; the case of the Production Department of the Kenya Medical Research Institute was submitted by James Kimotho, Head of the Production Department; and the case of the National Institute for Scientific and Industrial Research was prepared by Francis Tembo, its Executive Director. In addition, the three cases were presented by the authors at a workshop on industrial research in manufacturing held in Pretoria, South Africa, on 21 and 22 November 2012; Victor Konde visited and toured the facilities of the centres in 2013.

The initial draft report of the results of the surveys benefited greatly from the inputs of participants at the two-day workshop held in Pretoria. The present version of the study also reflects valuable comments provided by Jonathan Tambatamba, Patrick Nkanza, Yee Kwan Tang, Hopestone Chavula and Matti Sinko. However, any errors and omissions are the responsibility of the principal author.

Our gratitude also goes to the heads of institutions and senior policymakers in Ghana, Kenya and Zambia who took time off from their heavy schedules to complete the surveys and provide valuable information on examples and initiatives, which have formed the core of this publication. The work was supported by funds from the United Nations and the Government of Finland.

Abstract

The study uncovers some of the major hurdles impeding the transfer of publicly funded technologies from R&D institutions to the African market, and proposes a number of policy options that Governments could implement to facilitate technology transfer. A pilot survey of 28 carefully selected R&D institutions in Ghana, Kenya and Zambia was undertaken to understand the mechanisms, policies and resources that are currently in place to transfer research outputs to market and the key obstacles to technology transfer. In addition, a detailed case study of one centre in each of the countries was conducted to provide further insights into the key institutional arrangements that facilitate or hinder technology transfer.

Key findings

The three main hurdles to the transfer of R&D outputs to market were a lack of clear guidelines and policies at the institutional level; a lack of funding for technology transfer; and the low prioritization of technology transfer as a core activity of R&D institutions. The lack of clear guidelines and policies setting out the standards, procedures and support needed to take research outputs to market and the low prioritization of technology commercialization as a core mission of R&D institutions were found to be particularly problematic, which could explain why institutions allocated insufficient resources to technology transfer activities.

It was found that the most commonly used mechanisms to transfer R&D outputs to market were training and the provision of products and services. Almost all centres had undertaken training for other parties and about half of the centres surveyed had successfully commercialized products, with a quarter having earned revenue from those activities. However, other means of technology transfer, such as licensing technology to third parties and developing start-ups and joint ventures, were not commonly used. Likewise, intellectual property right claims were rare except in Kenya, where six of the eight centres surveyed had applied for a total of seven patents, two of which had been secured. Similarly, the main outputs of formal collaborations were publications and staff training.

In terms of R&D capacity, some of the R&D centres had limited and, in some cases, declining capacity. Specifically, a decline in absolute numbers of researchers and in the proportion of funding dedicated to research activities and capital investment was recorded, in particular at national industrial research centres. Such trends may explain why few centres filed or secured patents, registered products and formed firms.

Policy interventions

There are a number of basic steps that countries could take to promote technology transfer. Those include the provision of clear national technology transfer policies and guidelines that enable minimal standards on technology protection, ownership and sharing of benefits resulting from publicly funded R&D to be set; reserving a portion of R&D funding specifically for technology transfer activities; offering funding and incentives (such as tax rebates and awards of recognition) for cases of successful technology transfers; and requiring institutions to introduce mechanisms that facilitate technology transfer. The above actions may help to provide the necessary incentives to encourage researchers and institutions to protect and transfer publicly funded research outputs, promote partnerships between R&D centres and the private sector, and ensure that R&D centres prioritize technology transfer as one of their core activities.

Overall, the surveys demonstrated that some of the elements that facilitate technology development and transfer were present, but support for their improvement and strengthening was critically needed. In addition to the measures for supporting technology transfer outlined above, Governments will need to arrest the current decline in R&D capacity, in particular the decline in the numbers and qualifications of researchers and financial resources for research and capital investment. That will ensure that R&D centres develop relevant and, where necessary, novel technologies that can be protected and transferred to end-users.

1. Introduction

Investment in the generation, acquisition and diffusion of technology is seen as necessary in meeting development aspirations. An estimated 1.7 per cent of the world's gross domestic product (GDP) is invested annually by the private and public sector in "basic and applied research and experimental development" (henceforth referred to as R&D) to develop knowledge, skills and technologies to meet various economic and social development aspirations. France, Germany, Japan, the United States of America and the United Kingdom of Great Britain and Northern Ireland were estimated to account for 59 per cent of global spending on R&D in 2009 (Royal Society, 2011). In those five countries, as in most of the advanced economies, the private sector generally accounts for over half of R&D expenditure.

Africa is estimated to have invested 0.4 per cent of its GDP in R&D in 2007 (UNESCO, 2010). According to the African Union's New Partnership for Africa's Development (NEPAD), over 60 per cent of total expenditure on R&D in most African countries comes from Governments, donors and public institutions, and more than 70 per cent of activities related to R&D are performed in government laboratories, public R&D institutions and higher education establishments. In the European Union, the business sector accounts for 1.2 per cent of gross expenditure on R&D as a percentage of GDP, while the government and higher education sectors account for 0.3 per cent and 0.5 per cent. The main business sectors in Africa (e.g., oil, mineral and timber extraction) are not R&D-intensive, while sectors such as agriculture traditionally rely on public R&D investment, even in developed countries

That difference in the sources of funding for R&D has a number of implications for technology development and transfer. Governments and other public institutions invest resources in R&D in the hope of achieving cultural, economic, environmental and social benefits for society as a whole (Organization for Economic Cooperation and Development, 1997). It is for those reasons that African leaders have committed themselves to increasing gross expenditure on R&D to at least 1 per cent of GDP (African Union, 2007). Such benefits can quickly be realized if public R&D institutions are supported and empowered with the necessary tools and resources to develop and transfer knowledge to the market. This can also help R&D institutions to become viable partners in the economic transformation of Africa from a continent dependant on natural resources to one that is innovation-based.

As a first step, there is a need to evaluate the ability, practices and interests of R&D institutions to transfer and diffuse publicly funded research outputs to the target private and public sector users (referred to here as the market). The term "ability" is used to describe the R&D capacity to generate and diffuse relevant knowledge to the market; "interest" refers to whether R&D institutions perceive technology transfer as a core activity; and "practices" refers to the modes and channels[11] that R&D institutions prefer or are permitted to use to transfer technology to market. Such an evaluation could identify critical challenges, inefficiencies, opportunities, practices and hurdles that may exist in the transfer of R&D outputs developed at great public expense to the market.

This paper seeks to investigate and reveal:

a. Whether publicly funded research outputs in Africa are reaching the target market;

b. Whether current practices and strategies used to take research outputs to market are optimal;

1 Modes refers to internal and external technology transfer while channels refers to the route by which the transfer took place, be it internal or to a third party (e.g., licensed, sold, donated, start-up, spin-off, investment, training). For details, see: ECA (2010). *A technological resurgence? Africa in the global flow of technology*.

c. Whether research outputs are relevant to the needs of the business sector;

d. The key hurdles that limit the transfer of technology from R&D institutions to market.

It is now propitious to address the above issues as African economies and science and technology institutions are performing well. For instance, 10 of the 20 top performing countries in the world are in Africa (International Monetary Fund, 2012), while poverty levels in Africa have declined by around 17 per cent in the last decade alone (World Bank, 2013). Additionally, foreign and domestic investment and trade on the continent are expanding rapidly. From a science and technology perspective, Africa's formal higher education enrolment is growing at 16 per cent a year (World Bank, 2010), while the scientific production of African Union members grew 25 per cent faster than the world average between 2005 and 2010 (African Union-NEPAD, 2013). In addition, evidence of the contribution of science and technology to Africa's economic prosperity and wellbeing is also starting to emerge. The remarkable uptake and growth in the application of information and communication technologies in Africa is perhaps the most visible sign (Word Bank and African Development Bank, 2012).

There is no doubt that Africa is making significant progress. However, there are doubts over whether public R&D institutions are playing a significant role in driving the current economic growth, or whether the expanding business sector is helping to fuel the emergence of indigenous innovation capacity. ECA (2010) noted that Africa's acquisition of capital goods and technical and professional services from abroad was growing faster than the world average, while payment of royalties and licensing fees – associated with the use of the intellectual assets of others- remained low. Similarly, the number of scientific publications was growing rapidly, while the number of patents granted to Africa by the United States Patent and Trademark Office (regarded as a global repository of patents of global value) had declined over the last two decades (Economic Commission for Africa, 2010). That may suggest that a gap in the innovation system exists where R&D activities in public institutions may not be linked to industrial technology needs.

Such a gap might suggest differences in the needs of users and in the interests of R&D institutions, as well as the relevance of R&D outputs in meeting the needs of users, even if they were in the same field of interest. It may also indicate a lack of conducive legal and regulatory frameworks for technology transfer and an absence of key science, technology and innovation platforms or infrastructure that facilitate partnerships between academia, industry and Governments.

Like private sector R&D, public institutions are funded to meet the goals set by the funding agencies rather than solely those of users. For instance, most health funding is targeted towards HIV/AIDS, malaria and tuberculosis, largely for policymaking (e.g., surveillance of infection and drug resistance) and for clinical trials of drugs and vaccines developed elsewhere. Very little funding goes into the discovery and development of new treatments and diagnosis. African pharmaceutical firms are mostly engaged in repackaging imported medical preparations rather than manufacturing drugs, vaccines and medical devices. The gaps that exist in terms of experimental development and production and manufacturing need to be closed in order to build an innovative pharmaceutical industry. That can be achieved by encouraging pharmaceutical firms to build in-house capacity to become innovators and increasing funding for the discovery and experimental development of novel products. R&D institutions could be encouraged to put in place institutional arrangements to further develop the technology to a level that local firms could adapt and manufacture. Governments could provide incentives for pharmaceutical firms to become innovators by targeting more funding towards the discovery and development of novel products or technologies, stimulating the formation of innovative firms and boosting the R&D capacity of existing pharmaceutical firms (see the case of the Kenya Medical Research Institute in section 4.1).

Such arrangements depend on conducive legal and regulatory regimes and a business environment that encourages technology transfer from R&D institutions to firms. In particular, the rules governing procurement and the use of public property, national science, technology and innovation infrastructure (e.g., incubators, parks and industrial zones) and intellectual property rights, among others, need to be examined. Those regulations may limit the number of avenues that public institutions can use to take R&D products to market. For example, the successful commercialization of a University of Zambia network into Zambia's first Internet service provider – Zamnet Communication Systems Ltd – was both a major milestone and a challenge. On the positive side, Zambia became the fifth country in Africa to get onto the Internet, in 1994, demonstrating that Internet services were profitable even in poor countries (Konde, 2004). On the negative side, the rules on ownership, management and disposal of a public firm were only settled after a three-year court case (1997-2000) that eventually awarded all private shares back to the University of Zambia. The absence of national and institutional guidelines on the transfer of publicly funded property was the source of the problem, rather than the technology itself.

The choice of a channel for transferring a technology may depend on the existence of private or public sector users with the necessary skills, resources and knowledge to effectively implement the technology (Schacht, 2012; Todorova and Durisin, 2007). For instance, Zamnet was developed owing to the lack of an existing Internet service provider and the unwillingness of the Government and donors to fund an Internet connection because it was seen as irrelevant. The University of Zambia had the basic skills, facilities and partnerships needed to successfully implement the technology. Understanding the demands that technology transfer may place on the acquiring party is crucial to the successful application of the technology in the "manufacture of a product, application of a process or rendering of a service" (United Nations Conference on Trade and Development, 1985; Charles and Howells, 1992). The choice of a channel for the transfer of technology may also be influenced by the relationship between the transferor (technology generator, property-rights owner or seller) and the acquiring party, and the level of technology sophistication and complexity[2] (Abrahm et al, 1998).

Nevertheless, Africa presents many opportunities to improve its indigenous R&D capacity and performance to meet its development needs. Africa has a small but growing number of good universities and R&D institutions. Africa has also an emerging dynamic private sector. According to Ernst and Young (2012), the proportion of new intra-African investment projects as percentage of total investment projects has grown from 8 per cent in 2003 to 17 per cent in 2011. Domestic investment in Africa was about 18 per cent of total investment recorded in 2008 (Munemo, 2012). While small, it provides a basis for building and maintaining closer relations between academia, industry and Governments, which is central to the successful transfer of technology (Etzkowitz and De Mello, 2000).

2 If the technology is easy to copy, the technology owner may prefer channels where it retains control (e.g., licence to affiliates). If the technology is too sophisticated to bring to market alone, licensing to other players or forming joint ventures with others may be preferred.

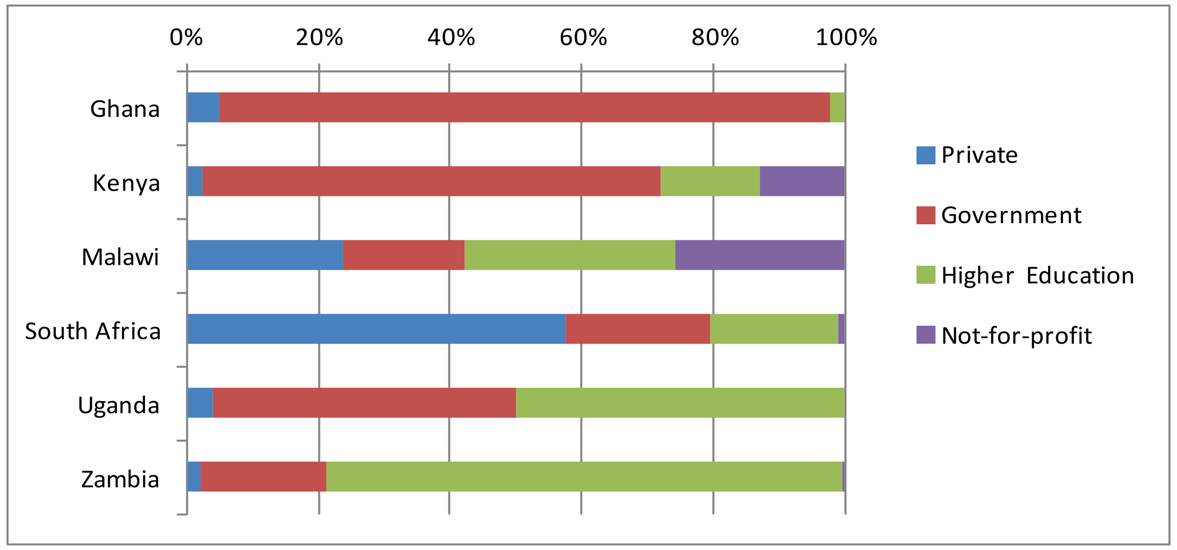
2. Setting the scene

Section two provides a general picture of the scientific and industrial performance of the continent and the target countries (Ghana, Kenya and Zambia). The main aim is to provide an overview of the national environment within which African R&D institutions produce, acquire and transfer technology. In that regard, the section provides an overview of the key human, financial and technological resources, legal and regulatory instruments and supporting hard and soft infrastructure needed to produce, acquire, adapt and transfer technology efficiently and effectively to the market. The human, financial and technological resources are assessed using standard and internationally agreed innovation and R&D indicators (Organization for Economic Cooperation and Development, 2002) to ensure the comparability of data between countries and between institutions and the comparability of findings. Cases and examples are used to highlight some of the challenges observed at the national level in terms of technology transfer.

2.1 Performance of research and development institutions in Africa: selected trends

In brief, the capacity of R&D institutions to generate knowledge can be indirectly assessed through the amount of funding received for R&D, and the number of R&D personnel, scientific publications and intellectual property rights claimed or registered. In terms of funding, the main sources of R&D funding in the majority of African countries are Governments, donors and public institutions, except in South Africa, where private sector investment exceeds 50 per cent (African Union-NEPAD, 2010). In Ghana, Kenya and Zambia, the private sector accounts for less than 5 per cent of gross expenditure on R&D. There are some major differences in terms of gross expenditure on R&D by sector of performance (see figure I). The government sector (i.e., government laboratories and R&D institutions) accounts for a large share of gross expenditure on R&D in Ghana and Kenya, while in Zambia it is the higher education system. The public sector dominates R&D funding and performance in all three countries.

Figure I: Gross expenditure on research and development by sector of performance



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

In terms of R&D personnel, data suggest that the number of researchers in Africa remains very low in all countries. As shown in table 1, the number of researchers per million inhabitants ranged from 24 in Mozambique to 815 in South Africa, which is far below innovative economies such as the Republic of Korea (4,627 researchers per million inhabitants). With regard to the three countries surveyed, Ghana and Zambia have approximately five times fewer researchers than Kenya.

Table 1: Number of researchers involved in research and development

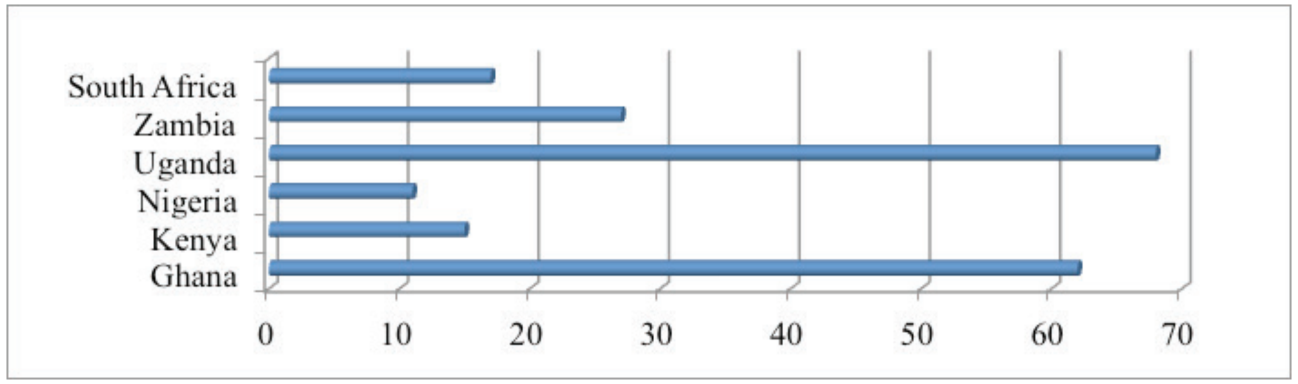
Country	Total researchers	Researchers per million inhabitants
Mozambique	522	24
Gabon	527	371
Zambia	612	50
Ghana	636	28
Malawi	733	49
Uganda	785	26
Mali	877	71
United Republic of Tanzania	2 755	67
Kenya	3 794	100
Cameroon	4 562	244
Senegal	7 859	661
Nigeria	17 624	119
South Africa	40 084	815

Source: African Union-NEPAD (2010), African Innovation Outlook 2010.

Limitations in human and financial resources invested in R&D have an impact on the quantity, quality and relevance of research outputs. Measured in terms of research papers, the number of papers published by African researchers has grown from 21,200 in 2005 to 39,400 in 2010. While this growth is substantial, Africa as a whole publishes fewer papers in peer-reviewed journals than Italy (71,000 in 2010). What is more, South Africa accounts for a quarter of the papers published by African researchers. With regard to the three countries surveyed in this study, Kenya has a higher number of scientific publications than Ghana and Zambia: in 2009, there were approximately 1,149 scientific publications in Kenya, versus 472 and 189 in Ghana and Kenya[33]. However, Ghana has a higher number of papers published per researcher than Kenya or Zambia (see figure II).

3 ECA estimate based on Thompson Reuters Web of Science database.

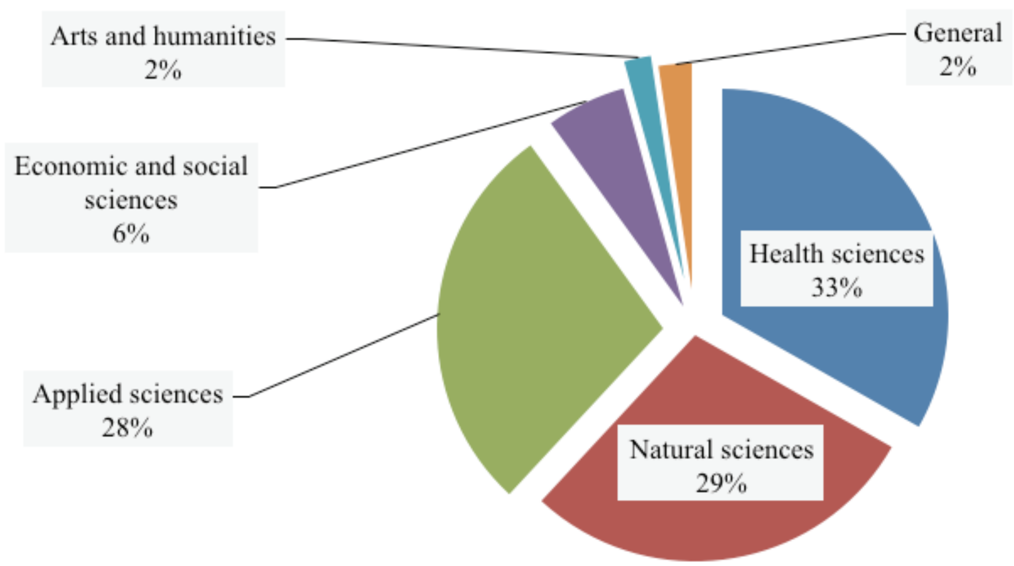
Figure II: Scientific publications per 100 researchers (2007-2008)



Source: AU-NEPAD, 2010 and ISI data, ECA analysis.

African publications are concentrated in the fields of health and natural and applied sciences (see figure III), which suggests that most of the R&D performed in Africa is in those three sectors. That is not unexpected given the number of organizations providing generous financial resources that have supplemented national R&D investment in health (e.g., the Bill and Melinda Gates Foundation, The Global Fund to Fight AIDS, Tuberculosis and Malaria, Wellcome Trust, European and Developing Countries Clinical Trials Partnership, GAVI Alliance and the African Malaria Network Trust). Such arrangements have also emerged in agriculture, involving organizations such as Alliance for a Green Revolution in Africa, the Forum for Agricultural Research in Africa and the African Agricultural Technology Foundation and in biosciences, with participation from Bio-Innovate, Biosciences eastern and central Africa (BecA) Hub, Association for strengthening agricultural research in eastern and central Africa, among others. However, such partnerships and international support for industrial R&D appears to be much less.

Figure III: Africa's publications by main fields of study (sum of 2008-2010)



Source: African Observatory for Science, Technology and Innovation (2013). Assessment of the state of science and technology in the African Union 2005-2010.

2.2 Absorptive capacity of African firms

The ability of R&D institutions to transfer technology may also depend on the absorptive capacity of firms and communities to utilize the knowledge produced. An assessment of the African industrial base or the absorptive capacity of African society is beyond the scope of this paper. Nevertheless, insights can be drawn from studying some indirect proxies such as industrial and manufacturing value added as a proportion of GDP, technology imports and exports in trade.

Africa's proportion of medium and high technology exports in total exports has slowly declined from 10.4 to 7.5 per cent between 1995 and 2012 (see table 2). This is much lower than the world average of 34 per cent of technology exports in total merchandise exports. Among the target countries, Kenya's medium and high technology exports in total merchandise exports have increased from 10.7 to 15.2 per cent between 1995 and 2011, while Ghana has recorded increases from 1.8 to 4.3 per cent, with Zambia showing increases of 1.9 to 6.4 per cent over the same period. Overall, Africa is not a major exporter of medium and high technology products and its firms are likely to have a limited absorptive capacity for new and emerging technologies.

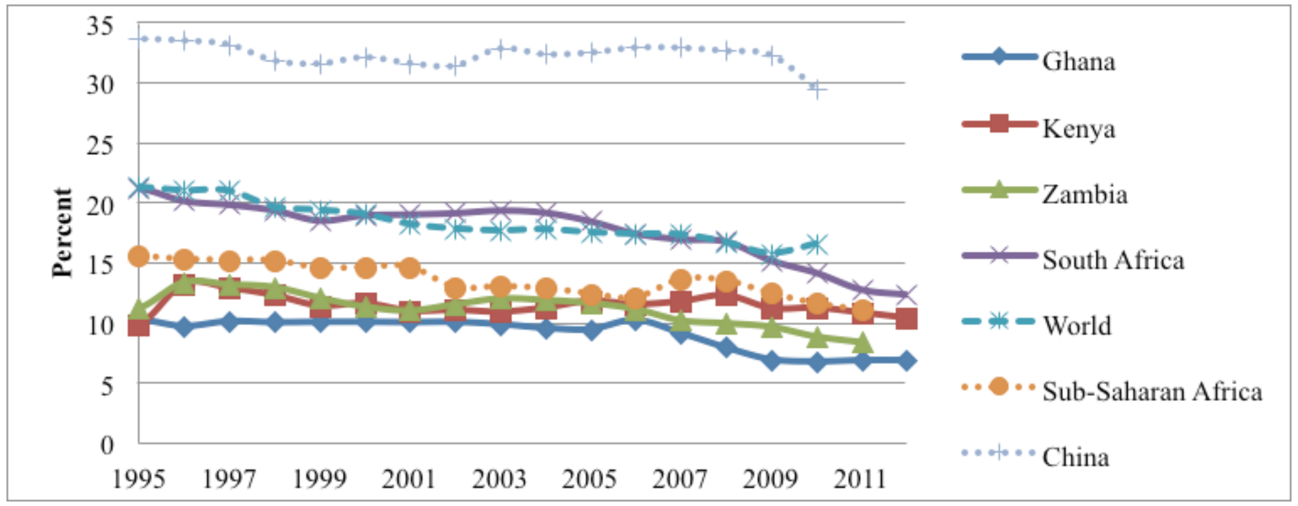
Table 2: Proportion of medium and high technology-intensive manufacturing in total exports, as a percentage of total merchandise exports

	Tech level	1995	2000	2005	2010	2012
Africa	Medium	5.0	4.1	3.9	4.2	3.8
	High	5.4	4.1	3.8	3.8	3.7
World	*Medium*	22.6	22.2	21.5	19.3	19.1
	High	13.5	13.7	14.8	15.0	14.6
Ghana	*Medium*	1.0	1.6	1.2	2.3	2.4
	High	0.8	1.2	1.0	3.3	1.9
Kenya	*Medium*	3.5	2.8	3.6	5.0	5.6
	High	7.2	6.2	7.4	8.7	9.7
Zambia	*Medium*	1.4	2.2	1.7	2.5	2.8
	High	0.5	0.7	0.8	2.1	3.6
South Africa	*Medium*	15.1	13.9	15.9	15.1	14.8
	High	8.2	8.3	8.8	7.2	7.4

Source: ECA analysis based on UNCTAD Handbook of Statistics Online (June 2013).

When measured as manufacturing value added (see figure IV), Africa's 10 per cent of manufacturing value added as percentage of GDP is below the world average of 16 per cent and far below that of China (30 per cent). In our target countries, manufacturing value added contributes about 10 per cent to the GDP of Kenya and Zambia. More importantly, manufacturing value added has kept up with the rapid growth in African GDP. In short, there is a small but substantial manufacturing base in the selected countries, which is in line with the observation that the continent is acquiring technology at a very fast pace (Economic Commission for Africa, 2010).

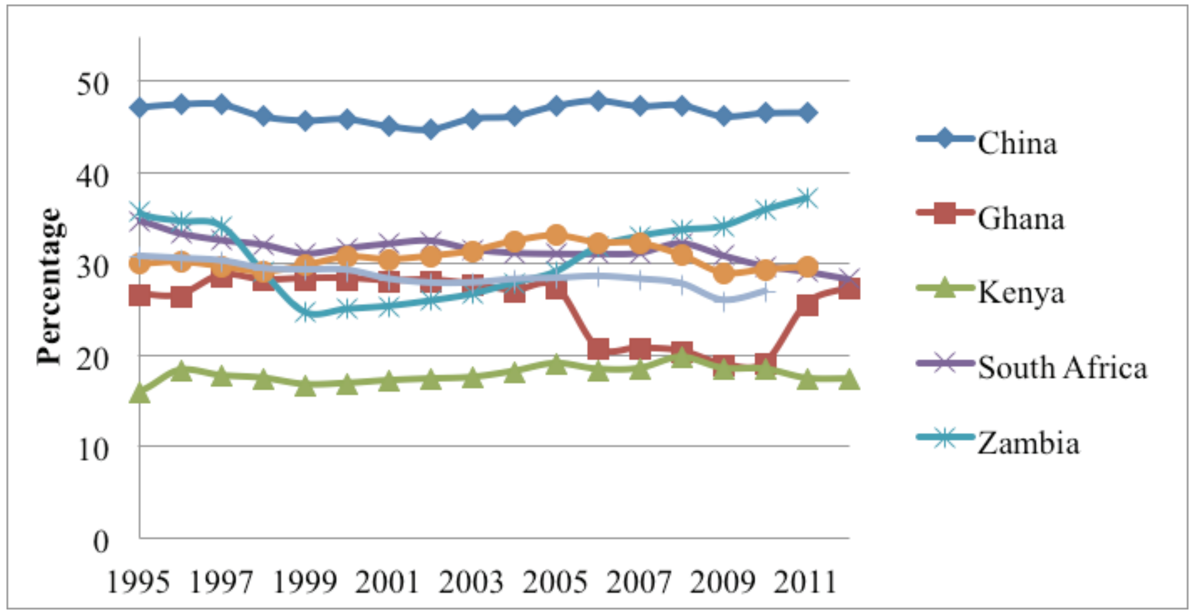
Figure IV: Manufacturing value added as percentage of gross domestic product



Source: World Development Indicators, 2013.

In terms of industrial performance, assessed as industrial value added,[44] Africa has started to reverse some of the decline registered in the 1990s (see figure V) (Sandrey and Edinger, 2011). Zambia has seen industrial value added jump to 37 per cent of GDP – up from 25 per cent in 1999 – driven largely by the expansion of the mining sector. Despite Kenya being an agricultural country, its industrial base contributed between 15 and 20 per cent between 1995 and 2011. With the discovery of petroleum, the contribution of industry to the GDP of Ghana jumped from 19 per cent in 2009 to 26 per cent in 2011.

Figure V: Industrial value added as percentage of GDP



Source: World Development Indicators 2013.

4 Comprises value added in mining, manufacturing, construction, electricity, water and gas.

Taken together, Africa seems to have a growing scientific, technological and industrial base that has not been outpaced by the rapid growth in raw material exports. The data appear to suggest that there is an emerging manufacturing base that may need the support of industrial research institutions and whose development must be taken into account to inform industrial research agenda. It is feasible that a group of industrial partners could engage and collaborate with African R&D institutions and actively absorb and utilize R&D outputs.

3. Objectives and methodology

3.1 Objectives

Despite the progress made over the last few years, the extent to which technology transfer has been integrated into the core business of R&D institutions in Africa is poorly understood. For this reason, this study primarily explores the current practices of leading R&D institutions in transferring technology to the market. More specifically, it focuses on:

a. The capabilities and performances of R&D institutions in terms of technology development and transfer;

b. The existence or absence of technology transfer policies and guidelines of institutions;

c. Formal partnerships, collaboration and services provided to public and private sector; and

d. The perceptions of senior staff members with regard to technology transfer challenges.

This is based on the observation that the successful transfer of technology depends on, first, the capacity of R&D institutions to generate knowledge that is relevant and accessible to private and public sector users and, second, the existence of willing private and public sector users to exploit the capabilities, skills and knowledge base of R&D institutions (Schacht, 2012). Some of these can be tracked as formal agreements, collaborative arrangements, services contracts and consultancy services offered to the market, while others may be monitored in terms of funds generated from such activities and products and firms commercialized.

3.2 Research design and methodology

The survey was conducted using a tested and modified survey tool based on a R&D survey used by New Zealand. It involves collecting data on R&D expenditure, publications, intellectual property rights, networking, support rendered to industry and perception of R&D managers with regard to technology transfer. National data on R&D were available from the NEPAD African Science, Technology and Innovation Indicators Initiative; the data largely focused on the institutional environment within which most R&D currently takes place. While the Initiative's work is focused on national level R&D investment and performance, this survey looks at R&D institutions more broadly.

The first three pilot surveys were carried out in Ghana, Kenya and Zambia. The three countries were chosen for the following reasons:

a. They have the same level of economic development, as monitored in terms of human development indicators, and are classified as either low- or medium-income countries by the World Bank.

b. They are from three different regions of Africa.

c. The economic structure and population of the three countries are different: Kenya (40 million inhabitants) depends on agriculture and services, Ghana (23 million inhabitants) on agriculture and mining and Zambia (13 million inhabitants) on mining.

d. They were participating in the NEPAD African Science, Technology and Innovation Indicators Initiative, which enabled ready access to additional data.

e. They have the same colonial history (former British colonies) and therefore have similar R&D institutions, laws and traditions

The survey components in Ghana and Zambia did not include entire university faculties, but focused more on their non-teaching and R&D intensive departments. For example, the Technology Development and Advisory Unit at the University of Zambia, which was included in the survey, does not participate in teaching. Some of its members of staff are recruited from the private sector and its manpower structure resembles that of private R&D organizations. It is headed by a manager, has a marketing, production and service section, and meets its operational costs and half of staff costs from contract R&D and product sales. In Ghana, individual research centres of the Council for Scientific and Industrial Research, which are all non-teaching units and account for almost half of the country's R&D expenditure, formed the core target respondents of this survey. With a mandate and, in some cases, a do-or-die requirement to take their outputs to market, these centres are likely to understand the challenges faced and the measures needed to facilitate technology transfer.

The terms "technology transfer" and "technology commercialization" refer to the identification and transfer of technologies of potential economic and social value to a wider rage of users in the public and private sector. For the purposes of clarity, some sections of the survey will primarily use "technology commercialization", especially in referring to the practices used and challenges faced in taking potentially economically viable research outputs to market. This is particularly useful in ensuring that the respondents have a clear and common understanding of assessment of inventions, protection of inventions, licensing and transformation of inventions or discoveries into products and firms (Jolly, 1997).

4. Key findings

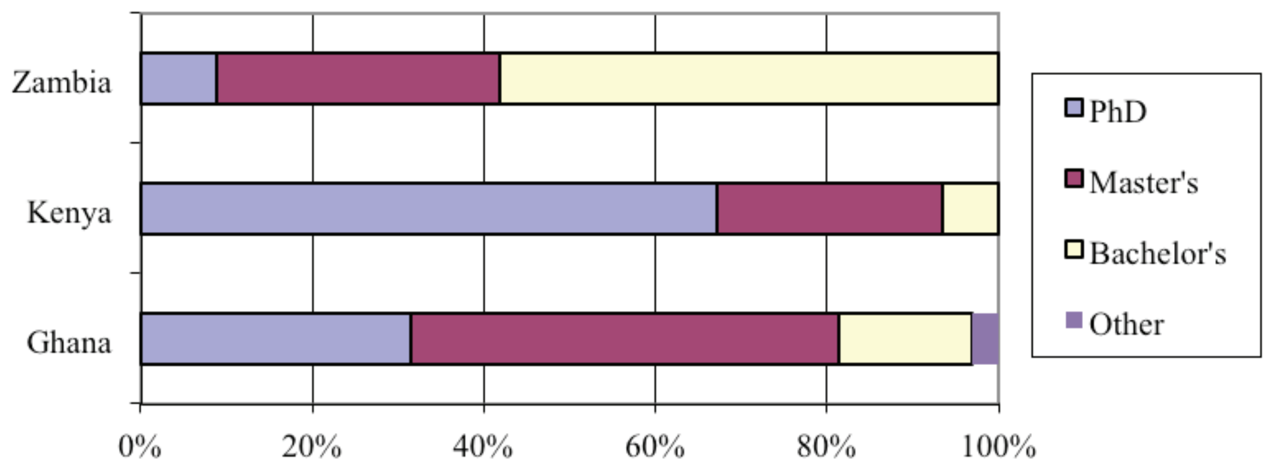
This section highlights the major findings in selected areas that affect innovation in general, and technology development and transfer in particular. The areas highlighted here include human capital, partnerships and strategic alliances, funding, provision of services to the private sector and technology commercialization. These are intended to reveal the quality of R&D institutions in terms of their ability to produce technology and their relationships with partners and clients. Lastly, it presents the results of the perceptions of R&D managers in terms of the importance of resources allocated and the importance attached to technology transfer as a key activity of their institutions.

Unless stated otherwise, the data in the report is based on case studies of a total of 28 R&D institutions that completed and returned the questionnaire: 7 in Zambia, 8 in Kenya and 11 in Ghana. The 28 responses came from a carefully selected 48 R&D institutions: 14 in Zambia, 14 in Ghana and 28 in Kenya. This represents a successful return rate of 58 per cent, with the highest return rate being in Ghana (78 per cent) and the lowest in Kenya (40 per cent). The centres and units were selected based on their mandates and reputation for R&D performance at the national level. Entire universities were eliminated from the survey in Ghana and Zambia but three universities were included in the case of Kenya.

4.1 Staffing of research and development centres

The presence of highly skilled researchers is one of the major elements that underpin the scientific, technical and entrepreneurial competitiveness of locations, with a view to making them birthplaces of technology and technology-intensive firms (Zucker and others 1999; Zucker and Darby, 2001). As such, the qualifications of researchers and their managers are important in ensuring that high-quality knowledge is generated and translated into products, processes and firms. In the case of Africa, qualified staff are needed to successfully compete for funding from international institutions. Such funding is important in keeping up with peers, improving the quality of research facilities and expanding the research agenda.

Figure VI: Qualifications of research and development researchers at surveyed institutions



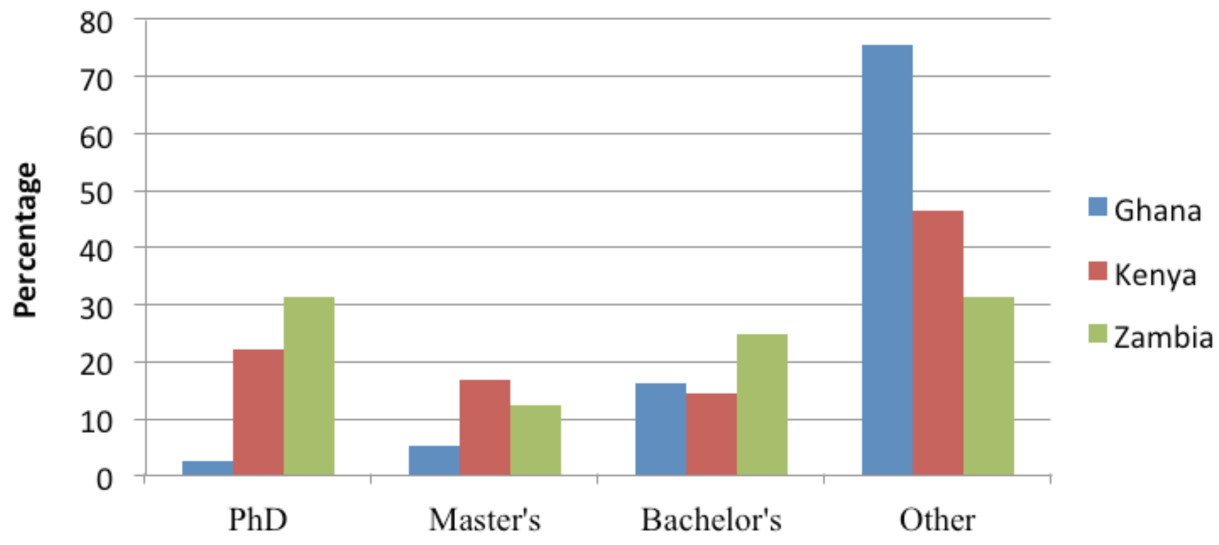
Source: ECA survey

Figure VI above shows that Kenya has a higher proportion of researchers with doctoral degrees (69 per cent), while Ghana has a high proportion of researchers with master's degrees (49 per cent). A large proportion of researchers in Zambia have only a bachelor's degree (58 per cent) and the country also reported the lowest proportion of researchers with doctoral degrees (9 per cent). Overall, Kenya has a relatively larger research community (3,800) than Ghana and Zambia (between 600 and 700).

As expected, all the technicians at centres surveyed in Zambia had other qualifications (including diplomas and certificates), while Kenyan centres were the only ones that reported technicians with master's degrees. Ghanaian centres reported about 8 per cent of technicians with bachelor's degrees and 83 per cent with other qualifications. In general, researchers and technicians in Kenyan centres have more advanced qualifications than those in Ghanaian and Zambian centres.

In terms of R&D managers, 31 per cent of those in Zambian centres and 22 per cent in the Kenyan centres have a doctoral degree, while only 3 per cent of R&D managers in Ghanaian centres surveyed had such a qualification (see figure VII). About 75 per cent of R&D managers in Ghanaian centres have other qualifications, while in Kenya and Zambia 46 per cent and 31 per cent of R&D managers have other qualifications.

Figure VII: Qualifications of research and development managers



Source: ECA survey

That implies that there is a shortage in R&D human capital in all three countries surveyed and that the problem may be more significant in Africa than in other developing countries. For example, Cuba's biotechnology sector alone employed some 12,000 scientists in 2000 (Konde, 2009), far above the total number of researchers reported in the three countries surveyed (the total headcount of R&D personnel is 6,799 in Kenya, 2,115 in Ghana and 2,219 in Zambia) (African Union-NEPAD, 2010).

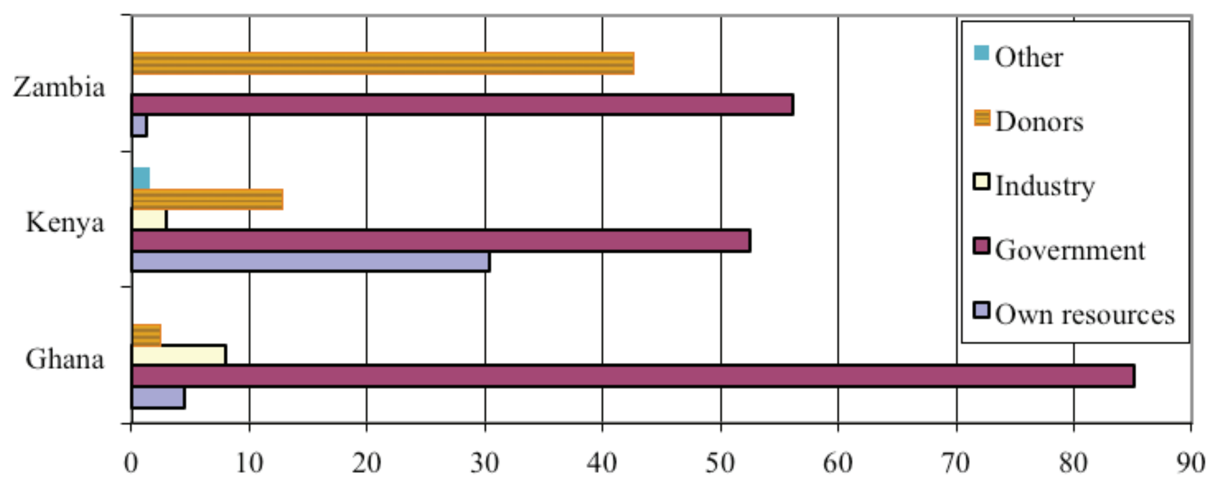
The greatest numbers of highly trained and senior researchers are employed in universities and are the major contributors to knowledge- and skills-generation. For example, it was noted that the University of Zambia contributes about 40 per cent of Zambia's total publications in peer-reviewed journals (African Union-NEPAD, 2010). It may be that the relatively larger number of researchers with higher qualifications at the university compared with other R&D institutions contributes to its higher output of publications.

4.2 Sources of research and development funding

A centre of excellence is expected to have a diversified funding base to ensure its sustainability. Heavy dependency on one source of funding makes the centre susceptible to changes in prosperity or the changing goals of the funding body. Furthermore, the source of funding could also provide some indication of relationships and interactions between the centres' staff and other key stakeholders. Financial relationships have a major influence on R&D activities, especially in the case of institutions with insufficient financial resources. The providers of R&D funding often have their own expectations and agendas for which they may seek solutions, support or ownership.

It was observed that over 85, 66 and 52 per cent, respectively, of R&D funding in Ghana, Zambia and Kenya comes from the Government. Only Kenyan centres reported over 30 per cent of R&D funding originating from the institutions' own resources. Zambian centres reported over 42 per cent of R&D funding as originating from donors, while Ghana was the only country whose centres reported over 5 per cent of R&D funding coming from industry (see figure VIII). Actual funding per centre is rather low. For example, in Zambia, R&D expenditure per R&D employee ranged from $12,000 to $80,000 in 2009. This is in line with the finding that Zambia's R&D expenditure per R&D personnel is about $22,000 (African Union-NEPAD, 2010).

Figure VIII: Sources of research and development funding, as a percentage of total value



Source: ECA survey

A major area of concern is the low level of R&D funding from the private sector. This may be due to the lack of incentives and initiatives to encourage the private sector to collaborate with universities and R&D institutions. A second concern is the dependence on foreign funding agencies (collectively referred to here as donors), especially by research centres in Zambia. In terms of funding from Governments, it was not possible to discern central government direct funding through the relevant ministry or agency from government contracts. For instance, a university may get its core funding through the ministry of education and contract grants from other ministries (e.g., health, defence, technology, etc.) or municipality (e.g., extension services) based on work it is expected to perform. Such contract funding may suggest that government agencies value the quality of R&D services offered, as well as the existence of good working relationships between R&D institutions and government agencies and a government policy to use R&D institutions to undertaken some of their activities.

In terms of expenditure, there is evidence that most of the R&D expenditure of the centres that provided information went towards staff salaries. For example, data indicate that Kenyan institutions spent 76.5 per cent of their total expenditure on personnel, followed by 13.9 per cent on services and 7.6 per cent on consumables; only about 2 per cent was spent on R&D infrastructure development. Taken together with the data in figure VIII, it appears that government funding goes towards salaries while donor funding is used to support research activities.

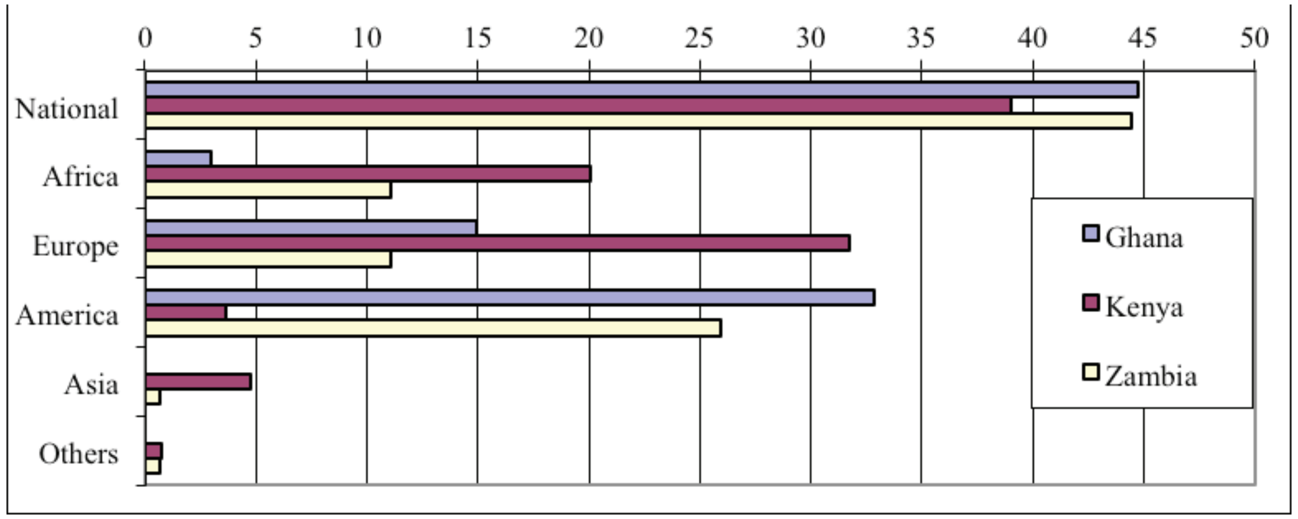
The research also revealed that the funding source had an impact on technology development and transfer. One head of a R&D institution recalled a case: "We won a contract from an agency to develop a manual production system to be used in the construction of low-cost housing in rural areas. We designed, produced and tested the system and demonstrated that our system was better than those on the market. Although the agency's interests later shifted, finding private partners to buy the machine failed for two reasons. First, private partners wanted the machine to be automated. However, such a modification was not allowed according to the terms of the original contract. Second, the private partners wanted to use the machine in the booming urban construction industry and not in rural areas. After prolonged negotiations, the private operators eventually lost interest and settled for an imported system". This illustrates how R&D conducted under the influence of few funding agencies can affect R&D mandates and ultimately the commercialization of outputs. Similar sentiments were also identified in R&D centres working on energy-efficient, food, health and information technologies, which even if successful will not be able to be taken to market (see section 5 for some examples).

4.3 Formal research and development collaborations: partners and outputs

Collaborations are critical, given the increasing complexity of R&D and the need for multidisciplinary teams in bringing R&D outputs to market in sophisticated fields such as biotechnology and information technology. They are also crucial in lowering the risks associated with technology development and application, leveraging external resources, and facilitating and improving chances of success in R&D, production, distribution and marketing. This section looks at the types of partnerships and outputs resulting from such collaborations.

The results of the survey pinpoint one major observation: all the centres surveyed reported that most of the formal collaborations are with national partners; in some cases, all formal collaborations were with national partners (see figure IX and table 3). This is in contrast to a popular belief that African centres largely collaborate with partners abroad (Adams and others 2010; Nwaka and others, 2010). This difference is based on the fact that collaborations have routinely been mapped based on international co-authored publications in peer-reviewed journals. In this case, national co-authorship by researchers from the same country, but not necessarily from the same institution, is not captured. Furthermore, there are other types of collaborations that do not lead to publications (e.g., training, installation of systems, advisory services), which are not captured if measured through journal entries. Another key observation was that collaborations with Asian partners, including China and India, remain low despite the fast growing influence of those countries in science and engineering.

Figure IX: Composition of research and development alliances (percentage of total)



Source: ECA survey.

In terms of outputs, most of the collaborations in the centres surveyed were focused on staff training and the main outputs were publications. Very few centres reported collaborations in product development and firm formation. This trend was observed in almost all the collaborations, whether national or international. Table 3 provides an example of the research outputs of collaboration arrangements for eight Ghanaian centres.

Table 3: Outputs of research and development collaborations at eight Ghanaian institutions

	National	Africa	Europe	America	Asia	Others
Number of partner institutions	24	11	16	3	6	
Outputs						
Papers	26	18	11	3	5	0
Patents	0	0	0	0	0	0
Products	3	2	3	1	0	0
Firms	0	0	1	1	0	0
Staff trained	21	11	6	2	1	0

Source: *ECA survey*

In terms of the financial value of the collaborations, the eight Ghanaian R&D centres reported 29 formal agreements worth approximately $1.24 million in 2009, an average of $42,835 per agreement (see table 4). The public sector accounted for about two-thirds of formal agreements and slightly over half of the value reported. However, one R&D agreement with a donor was worth twice more than the value of an agreement with the public or private sector institution. In a nutshell, a few agreements with donors may be more highly pursued or prized than agreements with non-governmental organizations (NGOs), industry and other domestic public actors due to their significantly higher value.

Table 4: Types of research and development agreements of eight Ghanaian institutions

	Number	Value	US$ per agreement
Public	18	683,798	37988.78
Industry	4	149,229	37307.25
NGOs	3	50,110	16703.33
Donors	4	359,065	89766.25

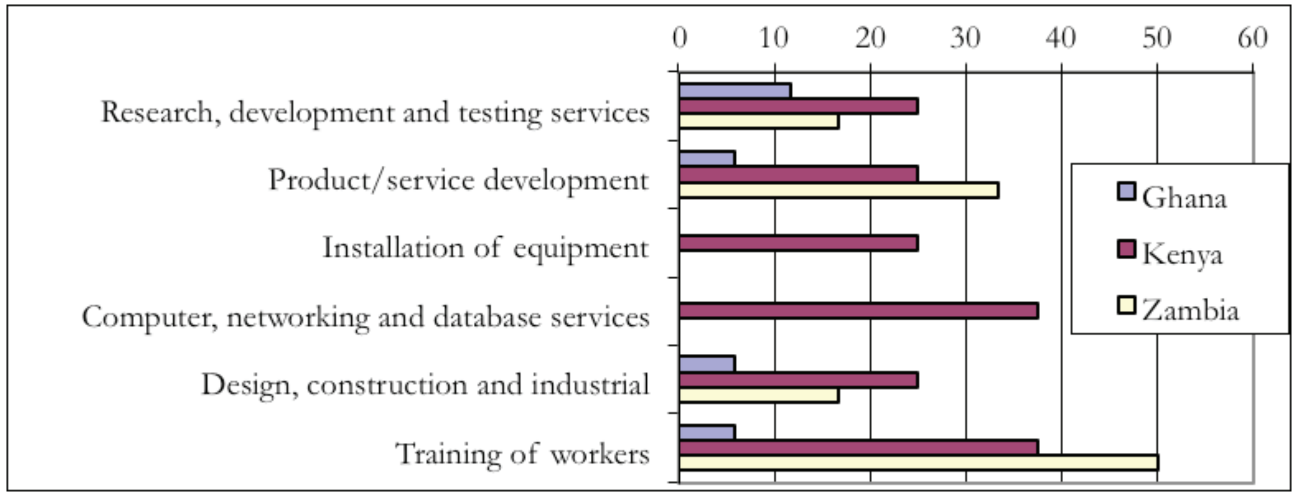
Source: *ECA survey*

4.4 Services offered by research and development institutions to industry

The interactions and relationships of R&D centres can be measured by the type of business, professional and technical services provided to the private sector. Some of the key services that R&D institutions would normally provide to the private sector include architectural, engineering, consulting, installation, research, development, management and analytical testing services. Africa spends its modest resources importing basic business, professional and technical services that could easily be sourced at home. It would also be possible to develop such capacity through collaborations between knowledge centres and industry.

As shown in figure X, the most common services offered by R&D institutions to the private sector are training of workers, and research, development and testing services. The differences observed were largely due to the composition of the research institutions surveyed in the countries and incomplete data. Although some centres indicated that services were provided, they did not give relevant data regarding the actual number of such services or their value. For example, the seven R&D centres in Zambia offered 20 research, development and testing services, 2 product/service developments, 1 installation of equipment, 1 design, construction and industrial engineering, and 5 staff training services. However the value of all these activities and services was, in most cases, not indicated, even though some of the R&D institutions surveyed had to generate their own operational funds from private activities.

Figure X: Services offered to industry by research and development institutions (as a percentage of total services)



Source: ECA survey

4.5 Commercialization of research and development outputs

This subsection focuses on technology commercialization[5], the challenges R&D institutions face and the practices they use to take their products to market. Technology commercialization takes many forms and involves various steps, including assessment of the invention or knowledge, protection of intellectual property, licensing, business incubation and firm formation, among others. Such technology may be new to the world, continent, country, institution and end-user or to an application (e.g., mobile banking), and thus it may not be protected or protectable by existing intellectual property regimes. The novelty of the technology may be captured in terms of intellectual property applications made and registered by the rightful owner while value may be indirectly assessed by financial payments for use of the technology.

In Kenya, six centres filed seven patent applications; two were granted patents at home but none secured any patent abroad. One institution registered an industrial design, four institutions claimed copyrights and two copyrights were awarded. Four institutions commercialized their R&D outputs, only two indicated that they had generated income from commercial activities, and one institution applied for 11 trademarks.

In Zambia, two centres secured patents at home, one centre claimed three copyrights, three centres commercialized six products, two centres did not claim any intellectual property rights or commercialize any products, and no centres secured patents abroad or registered industrial designs. Two centres claimed to have generated income from the commercialization of their R&D outputs.

In Ghana, none of the centres applied for or were granted patents, industrial designs and copyrights at home or abroad. However, eight centres had commercialized their research outputs and four centres reported that they had generated income from the ventures.

The findings may indicate that most of the R&D outputs with high potential for commercial success are not new to the world and hence may not be protectable through patents or industrial designs. The limited use of intellectual property rights by the centres may also suggest the absence of mechanisms that encourage the use of intellectual property rights, the lack of novel products worth protecting given the costs of intellectual property protection, and the lack of skills and financial resources to apply and secure intellectual property protection, among others. The fact that most of the funding comes from donors and Governments may also have an impact on the type of research undertaken (e.g., surveys and surveillance) and the dominant focus on products for micro and small firms, both of which may have limited potential for commercialization and intellectual property protection.

In order to identify the main hurdles to technology transfer, the study first looked at the mandates of the centres and then took a detailed look at their perception of resource availability, the relevance of their research outputs, private sector interest and the clarity of guidelines, among others. In general, the mandates of the centres are clearly declared in their institutional statutes and reflected in their documents and on their websites. The mission of most of the centres surveyed emphasized technology transfer.

5 The term technology "commercialization" is preferred in this section to technology "transfer" for two reasons. First, it makes it explicit that it refers to the process of taking the outputs to market. Second, the questionnaire used the term "commercialization".

This is illustrated in the following examples taken from centres' mission statements:

"…ensure high and sustainable crop productivity and food security through development and dissemination of environmentally sound technologies" (Crop Research Institute, Ghana).

"…generate and disseminate sustainable technologies and knowledge through innovative research for improved productivity, processing, value addition and marketing" (Tea Research Foundation, Kenya).

"…promote sustainable human development through the development, acquisition and dissemination of technology, production processes and management know-how appropriate to society" (Technology Development and Advisory Unit, Zambia).

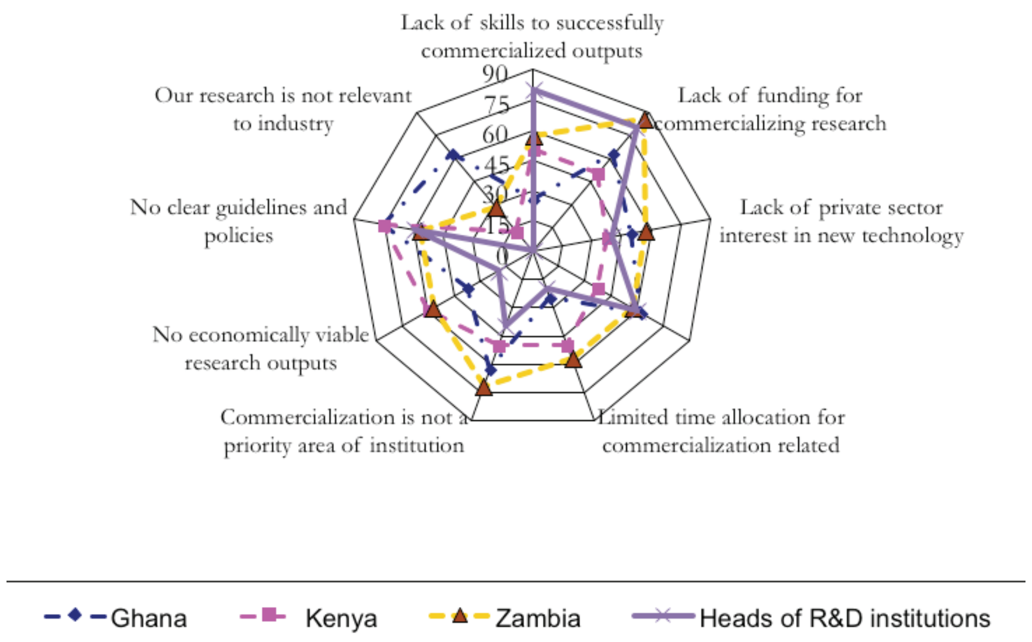
Given that their mandates require R&D institutions to transfer technology to the market, this part of the research focused on the key hurdles and institutional arrangements that may hinder the successful commercialization of R&D outputs. To achieve this goal, senior managers and heads of R&D institutions were asked to score the statements in figure XI on the extent to which they hinder technology commercialization at their respective institutions (not at the national level)[6]. To get further insights, we asked the 10 heads of the R&D institutions from Egypt, Ethiopia, Ghana, Kenya, Malawi, South Africa, Zambia and Zimbabwe that attended the expert group meeting on the role of R&D centres in manufacturing in Africa, which took place in December 2012, to complete this section.[7]

For simplicity, a higher level of stringency was applied that assumes that responses of "no effect", "limited effect" and "moderate effect" represent minor hurdles while responses of "great effect" and "major effect" represent major hurdles that need immediate attention to facilitate technology transfer. At this level of stringency, more than 50 per cent of all senior managers of centres interviewed in the three countries rated "no clear guidelines and policies", "lack of funding for technology commercialization" and "commercialization is not a priority of our institution" as the major hurdles to taking R&D outputs to market (see figure XI).

6 1 = no effect, 2 = limited effect, 3 = moderate effect, 4 = great effect, 5 = major effect.

7 Care needed to be taken as almost all the centres were carefully selected and invited based on depth of R&D, good technology transfer practices and a long history of working with industry.

Figure XI: Major hurdles to technology commercialization



Source: ECA survey.

The lack of clear guidelines and policies is vividly illustrated by the case of Ghana, where centres belonging to the same parent organization have adopted different practices. For example, the share of consultancy fees retained by the institutions range between 30 and 90 per cent. Similarly, the proportion of proceeds from successful technology transfers paid to the research team ranged from 7 to 50 per cent. A similar trend was noted in Kenya, where the share of consultancy fees retained by the institutions ranged from 25 to 60 per cent. There was also a divide between universities and dedicated R&D institutions: universities retained 50 per cent or less of consultancy fees than dedicated R&D centres.

On the other hand, most centres in Kenya and Zambia seem to believe that their research outputs are relevant to industry. Only 20 per cent of Zambian and 12 per cent of Kenyan heads of R&D institutions thought that their products were not relevant to industry. This is important, as heads of institutions that believe that their R&D outputs are not relevant are unlikely to dedicate resources to commercializing such outputs. It is also worth noting that Ghanaian and Zambian centres, as well as the 10 heads of R&D centres, suggest that personal benefits for undertaking technology commercialization ventures are too low. This may seem contradictory, but could be due to the lack of clear guidelines on technology commercialization (also rated a problem by this same group) and the lack of incentives for entrepreneurial individuals.

This is backed up by the fact that many centres answered "no" to the question: "Does your institution put equal emphasis on commercialization in assessing staff performance as other core activities (e.g., teaching)? Where 'equal emphasis' is 100 per cent and 'not considered' is 0 per cent". In Ghana, about half of the managers answered "no", and only a quarter of institutions considered technology commercialization in appraisal of staff. Similarly, only one centre in Kenya and one centre in Zambia attached 100 per cent emphasis to technology commercialization. In Kenya, about a third of the centres did not attach any importance, while one third placed between 20–50 per cent emphasis on commercialization as a core activity.

This is particularly important because in most centres, the transfer of research outputs to market requires participation from researchers who understand the technology and the legal and regulatory requirements (safety, registration process, etc.). An issue for concern is that these centres attach more value to the publication of research findings than to technology transfer. As such, researchers are likely to invest more time in the areas that are considered in their performance appraisal than in those that the institution does not value as much.

One surprising finding is the observation that R&D institutions whose mandates include technology transfer think that technology transfer is not a priority. That may be due to the fact that the Governments and donors that fund most of the research in Africa have favoured some specific areas of concerns (e.g., health) and policy-oriented issues (e.g., prevalence of diseases or surveys on poverty levels, as opposed to discovery of treatments and firm formation) over others. The research outputs of such surveys (e.g., levels of drug-resistance pathogens to a treatment) are important to policymakers and drug manufacturers, but such research outputs are not commercializable. As such, the centres do not see themselves as developers of technologies that they can take to market, but rather as policy research institutes.

There are some national differences in aspects that impede commercialization. It was observed that Zambian centres rated more items assessed as major challenges, with the exception of "relevance of their research to industry". It is possible that the rapid privatization that made some R&D institutions semi-autonomous in terms of management, operation and resource mobilization have created new demands that have increased the risks: they now have to generate their own resources to perform R&D and commercialize products. For instance, the Technology Development and Advisory Unit at the University of Zambia is required to refund half the salaries it draws in the year back to the University, and it is also required to generate its own operational and infrastructure development costs. Similarly, the Golden Valley Agricultural Research Trust is an autonomous and self-sustaining public-private partnership between the Government of Zambia and the Zambia National Farmers Union that has been in place since 1993. The Golden Valley Agricultural Research Trust generates about 40 per cent of its budget from commercial farming and contract research[8] while the Government contributes less than 5 per cent;[9] the rest comes from donors and international partners. It is possible that such high requirements magnify the challenges of developing and taking products to market.

For policymaking purposes, particular attention should be placed on those items that were ranked as a challenge by more than 50 per cent of the respondents. In the case of Kenyan R&D centres, five items need attention: funding, guidelines, skills, time allocation and prioritization and technology commercialization. In the case of Ghana, five areas need attention: funding, prioritization, personal benefits, relevance of research and the lack of private sector interest. In Zambia, all the areas need attention except for the relevancy of research outputs.

8 See: http://www.gartzambia.org/files/Download/Profile%20of%20GART.pdf.

9 See: http://portal.unesco.org/education/es/files/55628/11999798175ZAMBIA.pdf/ZAMBIA.pdf.

5. Case studies on technology transfer at top centres in Ghana, Kenya and Zambia

This section examines details of specific technology transfer performance, the nature of the technologies developed, adapted and diffused, as well as the technology transfer challenges and opportunities. While the general findings of each target country presented in section 3 provide a broad picture, detailed analysis of specific case studies will offer practical information of the key institutional competencies and arrangements that may be affecting systemic technology development and transfer.

The detailed descriptions of the cases were authored and provided almost in full by the heads of the centres. The cases were presented at the meeting of heads of R&D institutions, in South Africa in 2012. As such, the details in the tables and figures in this section are based on institutional data and archives.

This section looks at one top R&D centre in each of the target countries. The first part looks at a technology development unit of the Kenya Medical Research Institute, the second part focuses on the National Institute for Scientific and Industrial Research of Zambia, and the third case presents the Institute of Industrial Research of the Council for Scientific and Industrial Research of in Ghana. All the centres are dedicated R&D institutes that have a training component in their work programmes.

5.1 Kenya Medical Research Institute production department

5.1.1 Brief overview

The Kenya Medical Research Institute is a state corporation established in 1979 to undertake health-care research to improve human health and quality of life. It is also one of the best performing research institutions in Africa, with about half of research involving collaborative arrangements. By 2012, the Kenya Medical Research Institute had over 4,000 employees, 1,250 of whom were employed by the Government of Kenya with the remainder employed by various collaborative partners. Of those employed by the Government, 74 had PhDs and a further 126 had MScs.

In 2004, the Kenya Medical Research Institute commenced the construction of a production facility with a view to transforming innovative, technically and commercially viable research outputs into commercial products. More specifically, the facility was intended to manufacture simple, sustainable and cost-effective diagnostic kits and other products. The facility was constructed through a partnership between the Japan International Cooperation Agency and the Government of Kenya, with three Japanese firms – Nihon Sekkei, Sumitomo Mitsui Banking Corporation and Mitsubishi –serving as the lead consultants.

The facility has a staff of 18, of which 12 have technical roles while the rest are business development and support staff. A total of 7 technical staff members have been trained in Japan in various relevant product development technologies such as immunochromatographic and enzyme-linked immunosorbent assay testing. The facility is managed by a head of department who reports to the director of the Kenya Medical Research Institute. Under the head of the department are the heads of the production, quality control, warehouse, maintenance and procurement sections.

The production facility has met some of the highest quality standards and has been recognized as a manufacturing centre of excellence. The facility is compliant with the current Good Manufacturing Practice and ISO 9001:2008, and is currently pursuing ISO 13485:2003 (quality assurance for medical devices and related services) and ISO 17024:2003 (conformity assessment: general requirements for proficiency testing). The facility's ultimate goal is to attain the prequalification of key products by the World Health Organization under its prequalification programme and to eventually pass the technologies on to local industries. The facility is also an African Network for Drug and Diagnostics Innovations centre of excellence in development and production of diagnostics.

5.1.2 Products manufactured

Since its establishment in 2006, the facility has progressively made substantial contributions to the health research and health-care needs of Kenya. The hemaglutination-based test kit for screening blood for hepatitis B virus (Hepcellâ® RPHA[1010] kit) was the first product to be commercialized. The kit was developed following collaboration between the Kenya Medical Research Institute and the Japan International Cooperation Agency and is in use in Kenya. The facility has so far manufactured Hepcellâ® kits for testing 800,000 hepatitis B cases, earning the facility $470,000. The plant also manufactures rapid detection kits for HIV-1 and HIV-2 (Kemcom Rapid®), the hepatitis B virus (Hepcell Rapid®) and the hepatitis C virus (Kempac Rapid®), although the marketing of those products has been hampered because they have not been given prequalification status by the World Health Organization. Other products include disinfectants such as a chlorine-based disinfectant (Tbcide®), an alcohol-based antiseptic (KEMrub®), and a Taq polymerase enzyme (Kemtaq®), commonly used in research.

The facility is also working with the Centre for Traditional Medicine and Drug Research, which has identified a number of products such as a herbal ointment for the treatment of human papillomavirus. In the area of field trials, the facility also works with some of the Institute's other units such as the Centre for Clinical Research, which has the capacity to undertake clinical trials and bioequivalence activities.

5.1.3 Current partnerships

The Kenya Medical Research Institute has a wide range of partners. For instance, the Program for Appropriate Technology in Health (PATH) is working with the Institute on DNA/RNA extraction kits and the upgrading of the rapid detection kit for HIV to fourth generation. The Japan International Cooperation Agency is helping with infrastructure development, staff training, the commercialization of sequencing services, real-time polymerase chain reaction, as well as the development of rapid test kits for yellow fever and Rift Valley fever. The United States Centers for Disease Control and Prevention are supporting the Institute in the establishment of facilities for the production of culture media, haematological controls and buffers, distilled water and molecular grade water, as well as the upgrading of rapid HIV detection kits from third to fourth generation. The Centers are also helping the Institute to acquire ISO 17043, ISO 13484 and the World Health Organization's prequalification. At the national level, the National Commission for Science, Technology and Innovation is funding product development.

10 RPHA stands for Reversed Passive Hemagglutination.

5.1.4 Commercialization challenges

Despite the significant progress registered, the Institute faces a number of challenges:

- Lack of critical mass of multidisciplinary scientists to support product development and commercialization activities (most scientists are trained to carry out basic research and not business development);
- Non-commercial working environment in the institute in which critical components like procurement and response to customers' needs are slow;
- Lack of a comprehensive policy for sharing revenues generated from the research outputs; and
- Disregard of apparefntly simple products that could be commercialized in the country to solve an existing problem (e.g., molecular grade water) by the Institute's scientists.

5.1.5 Current efforts to commercialize technologies

To help address some of these key challenges, the Kenya Medical Research Institute is currently designing a public-private partnership model with the Kenyan pharmaceutical industry. This will build on its current collaboration experience with local firms, some of which are already producing the Institute's products (e.g. disinfectants). In addition, the Institute is in the process of forming a business enterprise company that will be responsible for the commercialization of its products and services. As a first step, the Kenya Medical Research Institute has developed a draft revenue-sharing policy which will ensure that the income generated from product and service commercialization is ploughed into product development activities. Currently, the department is supporting three PhD and five MSc researchers with their projects, which are designed to develop more products. The Institute is also recruiting multidisciplinary scientists to support product development and commercialization.

5.2. National Institute for Scientific and Industrial Research, Zambia

5.2.1 Overview

The National Institute for Scientific and Industrial Research was established in 1967 as a centre of excellence in scientific, technological and industrial research. The Institute undertakes R&D activities to support industrial development and export growth, offers scientific and technological services to industries, rural communities and government agencies, promotes transfer technology to small and medium-sized enterprises, training of researchers and technologists and provides advisory and consulting services to the Government and industry.

The Institute has seven research centres that undertake research in animal, food, water, plant, mineral, materials and energy sciences located at its headquarters and other parts of the country. It also runs a number of technical support services such as the centralized analytical laboratory, information and communication services, and engineering and technical services.

5.2.2 Examples of successful technology transfers

Some of its main successes are in the food and nutrition fields. For instance, the Institute research developed the Maheu drink technology that was transferred successfully to Trade Kings Limited, which was then a small and medium-sized enterprises. This technology transfer directly contributed to the expansion of Trade Kings: its labour force increased from 25 to 120, it promoted the export of the non-alcoholic maize beverage to seven countries, and it also benefited suppliers of packaging materials. Trade Kings Limited later sold the Maheu drink technology to SABMiller of South Africa for $19.25 million in 2009.

The Institute's research helped Zambia to become the first country in sub-Saharan Africa to successfully fortify sugar. The Institute worked with Zambia Sugar to develop the technology, which is now used by all the companies in Zambia. Its success has seen other countries (such as Malawi) learn from the Zambian experience of fighting vitamin A deficiency.

More recently, with the support of NEPAD and the Council for Scientific and Industrial Research, the Institute helped to develop the first effective herbal medicine for the management of HIV/AIDS, which has been transformed from a concoction to a standardized capsule. In partnership with the Council for Scientific and Industrial Research of South Africa, the components with the active ingredients were isolated. The capsule formula has now entered its first phase clinical trials, popularly known as SF2000.

5.2.3 Examples of technology transfer failures

There are a number of technologies that have not been taken up by industry. For instance, the technology for producing baby-weaning foods from locally grown food crops with a view to combating malnourishment in hospitals, schools, clinics and refugee camps has not been taken up by commercial entities. This may be partly due to improved nutrition and a reduction in donor support for the target market segments (for example, as a result of the fall in the refugee population and the introduction of public school feeding programmes). Competition is also high in the food processing industry and well-established brands make it harder for new products to penetrate.

Gamma sterilized biological tissue grafts from pig skin have not been commercialized owing to the high cost of the equipment needed. There are at least 25 countries globally that produce such grafts for the treatment of burns. While the technology is well established, the cost of the equipment and the standard of the facilities needed are too high for small domestic firms.

5.2.4 Opportunities

However, the Institute is intending to exploit opportunities in other economic sectors, such as the development of agro-technologies suitable for the small-scale farming community, the development of local drugs for livestock and human diseases, R&D product development for local industry, and technical support for income-generation activities aimed at young people. The field of renewable energy research and technology, adaptive research in new materials and adaptation of new technology and innovations to local conditions and environment monitoring research offer some of the best opportunities to build on existing expertise and experience. Similarly, water resources, sanitation and building materials research for the construction industry all present areas of growth for the country.

5.2.5 Challenges

Nevertheless, the R&D capabilities of the Institute have been unsteady and eroded over the years. The two main challenges that the Institute faces are staffing and funding. As shown in table 5, the number of staff members has declined to a level lower than that of the 1970s. The number of scientists rose from 44 in 1970 to 78 in the 1980s, but has since fallen to 26.. Similarly, the number of technical staff increased from 91 in 1970 to 118 in 1980, but has since steadily declined to 21.

Table 5: Changes in staffing levels between 1970 and 2013

	1970	1980	1990	2000	2010	2013
Management	8	3	4	4	4	5
Scientists	44	78	68	42	30	26
Technical	91	118	104	49	22	21
Lab assistants			51	6	7	6
Support staff	97	19	203	163	110	116
Total	240	218	430	264	173	174

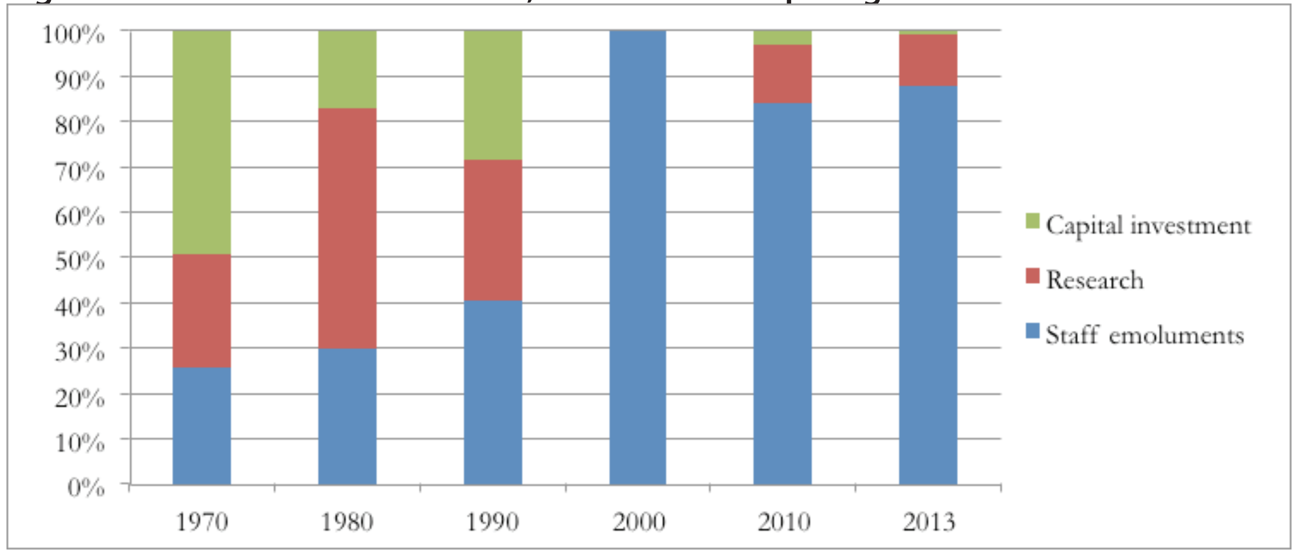
Source: National Institute for Scientific and Industrial Research.

A detailed analysis of staffing levels in 2012 reveals that only 2 researchers out of a total of 28 had doctoral degrees. The rest had master's degrees or bachelor's degrees, while all of the technical staff had other qualifications. In other words, since 2000, the Institute has steadily retired or retrenched senior scientists, with some moving on in search of better-paying jobs either locally or abroad, to the extent that the Institute has lost almost all its scientists.

Another challenge that the Institute faces is reduced support from the Government. Of the total budget of approximately $4 million in 2012, about half went on staff remuneration, a quarter was spent on infrastructure and the remaining $1 million had to cover research, training, consumables and services. With such a high number of centres, the Institute's funding levels appears to be one of the causes of its current staffing problem and an indication of poor appreciation by the Government.

As shown in figure XII, the Institute's budget for staff emoluments accounted for just 27 per cent of total expenditure in 1970. By 1990, that proportion had risen to 30 per cent and it peaked in 2000 at almost 100 per cent. Since then, the proportion of staff-related remuneration as a percentage of the total budget has remained at about 80 per cent. Inversely, the share of research and capital grants has declined from 73 per cent in 1970 to 12 per cent in 2013. Moreover, although the Institute's total budget has increased from about $1.3 million in 1970 to $4.1 million in 2013, at constant 1970 dollars, the 2013 budget of $4.1 million in 2013 is equivalent to only $880,000, which represents a fall of 32 per cent between 1970 and 2013.

Figure XII: Personnel emoluments, research and capital grants



Source: National Institute for Scientific and Industrial Research records.

5.2.6 Looking forward

The National Institute for Scientific and Industrial Research records will need to focus on expanding its research, and in particular, contract research from the Government. The Institute is well positioned to be, and indeed should position itself as the institute of choice for all government R&D contracts. One of its senior management posts may have to be dedicated to marketing and securing contracts in order to expand its funding base.

The Institute can capitalize on its technological contributions, which have benefited some of Zambia's largest firms, generated millions of dollars in exports and tax revenue, and improved the operation of small and medium-sized enterprises and rural communities, when repositioning itself. Marketing the Institute's successes and redefining its role in national development is no doubt a top priority. Nevertheless, it also presents the greatest challenge because the lack of clear guidelines on technology commercialization policies at both national and institutional levels, in addition to weak technology transfer, marketing and commercialization mechanisms (e.g., technology transfer officers, incubators), have made it extremely difficult to bring products to market.

Another challenge for the Institute is its location in the Ministry of Science and Technology. While the Institute may not be able to change its affiliation, it should seek to build stronger links with the Ministry of Trade and Industry as most of its activities are related to industrial development. This could allow it to expand its linkages with industry, access the incentives that the Ministry of Trade and Industry provides to private firms, and collaborate closely with the Zambia Development Agency and the Citizens Economic Empowerment Commission. If the Institute can be successfully elevated to the same level, the salaries of staff will be much higher than at present. More importantly, the Zambia Development Agency is responsible for providing tax incentives, and the Citizens Economic Empowerment Commission has a well-endowed fund (about $50 million) that helps domestic firms to improve their production and supports entrepreneurs in launching businesses. The Institute should strategize activities to tap into these resources, with a view to recovering and fuelling its development.

5.3 Council for Scientific and Industrial Research and the Institute of Industrial Research, Ghana

5.3.1 Overview

The Institute of Industrial Research is one of the 13 leading research institutes of Ghana's Council for Scientific and Industrial Research, which is the country's main science and technology R&D institution. The Institute of Industrial Research was formed from the merger of the Industrial Research Institute and the Scientific Instrumentation Centre in 1998. In 1996, the Parliament charged all public research institutes under the umbrella of the Council for Scientific and Industrial Research to generate 30 per cent of their annual budget from private sources. Government funding mainly covers the payment of salaries and the cost of general services.

The mandate of the Institute is to undertake research into process and product design and development; promote adaptive technology, scientific instrumentation and calibration; and repair of precision equipment. The overall aspirations of the Institute are to assist in poverty reduction through the creation of opportunities for generating and increasing incomes within small and medium-sized enterprises; contribute towards food security; generate foreign exchange earnings; and apply cost-effective industrial technologies that are both environmentally friendly and commercially viable.

5.3.2 Key programmes and departments and their achievements

The R&D activities of the Institute are conducted in four core programmes: the information management programme; the energy technologies programme; the environmental management programme; and the materials and manufacturing programme. The Institute's current programmes include the development and promotion of renewable energy technologies; industrial processes,; new materials; improved sanitation; local equipment fabrication; and information and communications technology. The information management programme is collaborating with the Government of Ghana on the national digital migration project.

The energy technologies programme focuses on researching second-generation biofuels; wind and solar energy; and energy audits of institutions and firms for the realization of energy efficiency and power consumption assessment. The Institute has been successful in promoting the use of solar lighting systems in rural households in Ghana, thereby contributing towards the reduction in dependence on wood and fuel for lighting. The Institute's Metrology Unit has over the years been specializing in undertaking calibration, repairs and maintenance of scientific and laboratory equipment for both public and private organizations.

The Institute has developed and transferred technology for the construction and installation of biosanitation systems (biogas plant and biomethanation sewage treatment plants). The institute has helped the local salt industry in various salt processing technologies, such as iodization. Under the Africa Knowledge Transfer Partnership, which is sponsored by the British Council in Ghana, the Institute has successfully helped the local pottery industry in Ghana by transferring ceramic and glaze technologies.

The Institute has been instrumental in designing and fabricating small-scale agro-industrial machinery targeting the local agro-processing industry. Computer-aided designs of laboratory-scale equipment (e.g., compost pelletizer, compost mixer and pulveriser) were produced and have helped the small scale agro-industry.

The Institute has provided demand-driven services in glass blowing, kiln and incinerator construction and maintenance services to clients. Some notable beneficiaries of these activities include the Ghana arm of Kosmos Energy, the Ghana Metrological Agency, hospitals and sister Institutes. There has been research into developing wood-plastic composite material using plastic waste and sawdust. The Institute has been helping universities and other academic institutions by providing practical training for students.

5.3.3 Key challenges

The Institute has been facing a lack of funding for research activities over the years. Currently, government support is in the form of paying the workers rather than funding for research and infrastructure development. The Institute depends on scare internally generated funds and external sponsorships to run research projects. In terms of infrastructure, the Institute is faced with a lack of some standard laboratory equipment. Some laboratories are underequipped, and there are too few highly qualified, specialized research staff and technologists. The number of research scientist has continued to fall over the years, and staff who leave are not replaced (see table 6). All of that has directly hampered the research outputs of the Institute because it means research is often slow and or even at a standstill.

Table 6: Changes in staffing levels between 1995 and 2013

	1995	2000	2005	2010	2013
Scientists	25	27	25	22	19
Technical	27	37	46	35	27
Management/support staff	100	71	52	60	63
Total	152	135	123	117	109

Source: Institute of Industrial Research records.

Out of the current research staff of 19, just 3 have doctorates. Of the others, 3 have only a bachelor's degree and the rest hold master's degrees. In addition, there is a lack of interest from private industries in partnering with the Institute.

5.3.4 Way forward

The Institute seeks to address all the critical areas identified and position itself more effectively in the world. The imperatives define its focus and provide a guide for its R&D activities. Performance targets and specific plans are based on the assumption that these strategic imperatives, including objectives and action plans, are vigorously pursued.

The Institute's strategic imperatives are to:

a. Build competitive advantage by focusing on technology delivery in the its areas of expertise;

b. Become financially independent by developing sustainable internal sources of revenue;

c. Collaborate globally with the relevant research centres and industries;

d. Focus on attracting, maintaining and developing the best research minds;

e. Pursue measures and actions that empower and inspire staff.

These strategic imperatives will be achieved through the activities of R&D programmes and departments.

5.4 Summing up the three cases

The R&D centres surveyed have all delivered on their mandates to transfer technology in one way or another. They have acquired, adapted and developed a variety of technologies that they have successfully transferred to industry. Building on these successes has remained a challenge following the major economic difficulties that Africa faced in the 1990s. It may well be time for Africa to redouble its efforts to ensure the success of R&D institutions built at great expense after gaining independence.

The centres employed a variety of technology transfer strategies and practices. In general, the following observations were made:

a. Training, consultancy and demonstrations are the most common methods used to transfer or diffuse technologies;

b. Direct sales of products and services from an institution's wholly or partly owned start-ups and production units were also common;

c. Licensing of technologies to established firms is rare.

By contrast, ownership of intellectual property rights is rare, partly due to the lack of R&D capacity to generate novel technologies and a poor understanding of technology-based business strategies. For instance, Zambia's National Institute for Scientific and Industrial Research did not protect the name of its Maheu drink, nor did it attach any performance payments to its transfer to the private partner. Trade Kings, the private partner, marketed the drink as Super Maheu and different versions of the drink soon emerged, including by some large multinational firms. More importantly, the success of the Maheu technology, which uses specific enzymes in the fermentation process, did not earn the Institute any money.

The following challenges were identified by the centres:

a. Limited funding for product development and commercialization;

b. Lack of multidisciplinary teams of scientists and non-scientists – and in some cases dwindling numbers of scientists – to support product development and commercialization;

c. Lack of critical business support services (logistics, customer relationship and services, etc.);

d. Lack of clear guidelines and policies for benefit-sharing of revenues generated from the research outputs;

e. Disregard of technologically simple but commercially viable products that could be commercialized to meet existing problems;

f. Inertia in reorienting to changes in the operational environment;

g. A limited focus on market conditions (costs, competition, partnerships and customers).

Governments may also wish to restructure the institutions to ensure that marketing and awareness-raising become one of the areas of focus. Centres such as the Kenya Medical Research Institute have a high dependence on external resources, including a large proportion of staff employed by partners outside Africa. While that is admirable and has ensured the Institute's growth and its position as one of the top centres in Africa, growing and diversifying its funding base at home may ensure that the Institute responds adequately to domestic needs.

The current efforts of the Kenya Medical Research Institute to harness its international partnership and government funding to develop a relatively sophisticated production centre are a step in the right direction. The Institute will soon be able to serve as a delivery vehicle for innovative products that are urgently needed at home and in the region. Some of its products are basic but highly needed, such as hand sanitizers specifically designed for the African health-care market, where examination rooms are overflowing with patients and access to clean running water is sometimes limited. In such situations a hand-sanitizer solution becomes invaluable in limiting the transfer of pathogens from patients to health workers.

On the other hand, the National Institute of Scientific and Industrial Research may have to expand its industrial partnerships or narrow the scope of its mandates. It may also wish to make sure that policymakers are aware of its success and contributions to the development of well-known firms and products, which could enable it to receive a more favourable hearing in the Parliament and in the Cabinet. The Institute may also wish to tap into foreign resources. More importantly, it should expand its relationships with key ministries and relevant government departments (e.g., industry, defence and health) and position itself as the preferred partner in a wider spectrum of technological and industrial development.

As noted earlier, Governments may wish to rethink their earlier decisions, made in the 1990s, to make such centres semi-autonomous or autonomous for budgetary reasons, although the fact that the Institute of Industrial Research has witnessed a similar decline in staff numbers suggests that the model may not be viable. While the Institute of Industrial Research has performed well given its limited human and institutional resources, it may be time for Ghana to increase its investments.

Alternatively, the Institute of Industrial Research could convince the Government to develop public-private partnerships with strategic domestic and foreign industrial partners that have the necessary resources (human, management, technological and financial resources). That would support its growth and impact on the development objectives of the country. Like the National Institute of Scientific and Industrial Research, many industrial research institutes continue to be hampered by a shortage of critical resources despite the current economic boom. Strategically positioned between academia and industry, industrial research centres serve both as a bridge between basic research and industrial production, and as specialized knowledge developers in areas of little interest to academia but of significant interest to society. They could be said to be key actors in the process of technology adoption and transfer as they focus largely on adapting, designing and prototyping.

6. Conclusion

The present study is a first attempt to understand some of the key challenges facing R&D institutions in Africa. It has looked at the opportunities available and existing institutional arrangements and practices used by such institutions in terms of taking their research outputs to market. The study has revealed a number of issues that African policymakers and their development partners need to address to ensure that R&D research outputs, which are generated at great expense to the taxpayer, reach the intended users. Furthermore, it looks at how these issues impact the way R&D institutions in Africa contribute to the transformation of the continent from one dependent on natural resources to one dependent on knowledge and innovation.

Among others, the research has revealed that:

a. Dedicated R&D centres in Africa have limited, and in some cases declining, R&D capacity;

b. R&D centres attach limited importance to technology transfer at the institutional level.

In terms of the first observation, the research has shown that some African R&D centres have registered a decline over the past four decades in the absolute number of researchers and in the proportion of funding dedicated to research activities and capital investment. The fact that nearly 80 per cent of the budgets of some of the top centres goes towards staff salaries suggests that funding levels have declined, if one takes into consideration inflation.

As a result, the decline in R&D capacity has led to a fall in the number of potentially viable technologies developed, protected and transferred to market. In this regard, policymakers may wish to consider a number of areas:

a. Delink R&D institutions from the public sector to offer them greater flexibility in terms of manpower and financial management;

b. Provide greater autonomy in procurement and disposal of property;

c. Elevate R&D centres to the same level as revenues authorities, investment and development agencies, and security wings to enable them attract researchers from universities.

By allowing R&D centres to use and reinvest resources that they raise themselves, it could act as an incentive and help to build a decent funding base. That is not a new concept as universities in all three countries surveyed already enjoy some of these elements. However, it should not be based on the models of the 1990s, where institutions were made autonomous so that Governments could cut funding; instead, it should be similar to those of universities where the resources they raise are supplementary to, rather that substituting for, government support.

The second category refers to a number of factors related to the importance attached to technology transfer. In this regard, the three specific challenges that need urgent attention are the lack of funding for technology transfer, the lack of clear guidelines, and the low prioritization of technology transfer as a core activity. For policymaking purposes, particular attention should be placed on those items that have significant implications for other factors. Those include the provision of clear policies, guidelines and incentives for protection, ownership and transfer of publicly funded research[11][11] and reaffirming technology transfer as a core activity of R&D centres. Other measures

11 These have now become common practice. For a review see: Graff, G.D. (2001). Echoes of Bayh-Dole? A survey of IP

could include training some members of staff specifically in technology transfer arrangements, recruiting skilled technology transfer managers, encouraging the formation of technology transfer and business development units (e.g., innovation hubs and incubators) and provision of funding specifically for technology transfer related activities.

In terms of practices or mechanisms for taking technology to market, significant opportunities may be realized through policy interventions that strengthen existing mechanisms such as training, consultancy and demonstrations undertaken by R&D institutions. Those interactions may encourage an exchange of views between key technology users and R&D institutions, which may influence the research agenda of R&D institutions, improve their understanding of the needs of the private sector and improve the products and services they offer.

Some of the centres expressed concerns over the lack of multidisciplinary teams of scientists and non-scientists, the lack of critical business support services (logistics, customer relationship and services, etc.), the limited importance attached to simple but commercially viable research products, and the limited focus on and awareness of market conditions (costs, competition, partnerships and customers). It is not anticipated that R&D institutions will overcome many of those aspects in the short-term. However, it is expected that developing the necessary policies and associated initiatives to recruit or train technology transfer personnel, encourage partnerships with the private sector, along with general national and institutional technology transfer policies, is vital to adequately improve African R&D institutions' research capacities and to create value and benefits for the market and society through technology transfer.

In summary, the survey demonstrates that the basic elements needed to facilitate technology development and transfer exists. A number of centres have contributed to the development of firms, the acquisition of intellectual property rights and the provision of certain business, professional and technical services to the private sector. This should be better recognized, articulated and promoted as a key starting point to further build a truly innovation-based economy in which institutions and firms interact to bring new and better services to improve the general wellbeing of the society. More comprehensive research may be needed to better understand differences in terms of sectors (e.g., health, agriculture, industry and education) and over a longer period of time.

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Annex : Selected ECA publications on technology and innovation

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