BUILDING SCIENCE SYSTEMS IN AFRICA

Conceptual Foundations and Empirical Considerations

Edited by
Rebecca Hanlin
Aschalew Demeke Tigabu
and Gussai Sheikheldin

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Contents

Foreword

Science, Technology and Innovation (STI) are key factors that can contribute to the acceleration of sustainable development of the African continent. Knowledge production and innovation are essential for the creation of wealth in African states.

In the research, science and innovation ecosystems in Africa, research funding organizations play a leading role as they allocate resources to actors and institutions involved in the production and promotion of knowledge.

This book comes at a time when actors in these different systems, across the continent, are collaborating more with each other. Not long ago, African scientists, research managers, science policymakers, and innovation leaders were collaborating more with counterparts in other continents than with ones in neighbouring African countries. Furthermore, they were voluntarily divided across linguistic borders – the Francophones, the Anglophones, the Lusophones and the Arabophones. Although some common frameworks allowed for basic exchange and communication (such as some African Union and United Nations science-related agencies), studies have shown African science actors were more eager to collaborate with counterparts from outside of Africa with shared official languages than with African neighbours, even when the science agenda and priorities were largely shared with these African neighbours. However, this general trend is changing.

The Science, Technology and Innovation Strategy for Africa 2024 (STISA-2024) reinforces this trend by giving more coherence, visibility and synergy between the different African actors involved in the field of STI.

The authors of this book and the editors, met and collaborated through projects, activities and agenda that came together under the umbrella of the Science Granting Councils Initiative (SGCI), an Africa-wide undertaking that began in 2015 and continues until now. The initiative brought together councils, networks, centres and organizations from over 15 African countries, along with scholars, schools, and agencies from outside Africa. All of the above- mentioned are involved in fostering science and technology research in Africa and spurring innovation related to that research. The overall objectives of the initiative are to strengthen the capacity of science granting councils to manage scientific research, design and monitor research programmes based on the use of robust indicators, and support knowledge generation and exchange between and among the councils and other key science system actors. This initiative has been very beneficial to the partnership, the pooling of resources and the exchange of good practices between African research funding organizations.

This book is one of the outcomes that came out from such collaborations that continue to seek a better environment for science, technology and innovation in Africa.

Two important, related themes run across the book: science systems and science granting councils. Science systems are broad and complex (this will be explained in the introductory chapter) while science granting councils – the main beneficiaries of the initiative under which this book was conceived – are central actors to science systems in their countries. The book specifically recognizes that Science Granting Councils in Africa operate in a system made up of other organizations and governance frameworks, which create an enabling environment for research and innovation. Institutional capacity strengthening programmes designed and implemented by appreciating the systems approach could result in better outcomes and sustained impact in building strong research and innovation systems in Africa. Both themes are very important to African countries and regions, and African science actors are becoming more aware of their importance as well as more active in actualizing that importance.

Policy for science, technology and innovation plays an integral role in making the objectives and aspirations of these science system actors come to fruition. Africa is currently enhancing the quality of its scientific research and the translation of research results into useful products and services through regional and national policies. To achieve this, the SGCI promotes increased interaction, coordination, and exchange of knowledge between science granting councils, other science system actors and the broader society. Informed and sound policies can catalyse and operationalize all of that.

Readers of this volume, from various backgrounds and for various purposes, will find it both empirically informative and conceptually useful.

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The authors come from various backgrounds and affiliations. Many of them are affiliated with the organizations that participated in the SGCI. Besides the organizations of Theme 3, mentioned above, important contributions came from authors from the Southern African Research and Innovation Management Association (SARIMA), the African Technology Policy Studies Network (ATPS), the Malawian National Commission for Science and Technology, the Tanzania Commission for Science and Technology (COSTECH) and the Uganda National Council for Science and Technology (UNCST). In addition to these organizations, other authors are from various universities and research institutes inside and outside Africa.

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On behalf of all the authors, and the editorial team, the editors sincerely thank all the above mentioned.

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1

Introduction: The Role of Science Councils in Building African Science Systems

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Abstract

This book discusses science systems and advocates for more attention to be given to science councils as a key actor within African science systems. This chapter introduces science councils as boundary managers; critical for building a broadly defined 'science system'. Specifically, we recognize the simplicity of thinking in terms of 'science councils' and 'science systems' but argue that science councils work in a much more varied set of systems relating to knowledge, research, technology and innovation. The boundaries of these systems are not strong in many African countries and science councils have a vital role to play in managing the activities of a broadly defined science system and ensuring it works in the best interest of society. Science councils must therefore embrace a wide range of roles and not just the issue of research funding as is often their focus. This includes roles related to policymaking and influencing the policy process. Efforts such as the Science Granting Councils Initiative provide a significant opportunity for science councils to

exert their boundary manager functions. Alongside such activities, and the reason for this book, is an increased need for 'science on science' – or research that interrogates how science and its related knowledge, research, technology and innovation systems work to ensure sustainable and inclusive development that is focused on the needs and demands of African contexts.

A history of African science

The history of African science is bound up in a history of colonialism with the main organs of science in African countries – universities – often being set up and structured using Western approaches to education (Mamdani, 2018). The study of the history of science has predominately been a Western one; with the history of science often focusing on science in 'the West' from the European Enlightenment period onwards (Delbourgo, 2019). However, there is a significant scientific tradition in Africa that predates and occurred within European colonial expansions (Tilley, 2018; Tilley 2019; Mazrui, 1999). This spans from a patronage of medical sciences in 12th century Egypt (Ragab, 2015) and the first steps in understanding how metals work in Mesopotamia, Meroë and Western Africa (Metz, 1991; Diop, 1988) to rice cultivation methods being taken from Africa to America as a consequence of the slave trade (Lovejoy, 2014).

More recently, the establishment of ministries of science, technology and/or innovation or the inclusion of these into other allied ministries since the 1980s (Mouton et al., 2015) and the formation of the African Academy of Sciences (AAS) in 1985 provides the starting point for a new history of African science. These ministries of science, technology and innovation (STI) or more independent units – many of which are referred to as 'science councils' – and the AAS were developed as there was increasing recognition of the important role STI play as tools for economic and social development.

As such, this book is situated within the history (or multiple histories) of efforts to build what some term 'developmental states' (Mkandawire, 2001). A developmental state is the idea of a "legitimate state leading a planned capitalist economy with a competent and autonomous bureaucracy spearheading industrialization efforts in profound collaboration with the private sector" (Hillbom, 2019). In the 1980s and 1990s there was an increasing focus on understanding how newly industrializing countries in East Asia had developed through industrial policies and a strong state (Booth, 2015; Chang and Woo-Cummings, 2010).

By the 2000s these debates – explicitly and implicitly – had created an increased emphasis on the role of STI on economic (and more recently also on social) development. The result has been that by the end of the period of global efforts to achieve the UN's Millennium Development Goals in 2015, there was world-wide recognition of the importance of STI on development efforts – both economic and social – leading to the successor Sustainable Development Goals having a specific goal on industrialization with innovation (Goal 9) and many of the other goals focused on STI solutions for their achievement.

At a continental level, the African Union has implemented the Science, Technology and Innovation Strategy for Africa 2024 (STISA-2024) aimed at ensuring Africa's transition to an innovation-led, knowledge-based economy. It is set within the framework of a broader African development plan, the AU Agenda 2063, which has STI as tools and enablers to drive manufacturing, industrialisation, and economic development efforts of the continent.

Nationally, African governments are giving increasing focus to STI in the organization of state departments and have been writing and updating related policy documents. In many countries, national development plans mirror Agenda 2063 by placing STI as a fundamental pillar to the achievement of economic and social development goals.

All these efforts mean that the African continent is now at a critical juncture. We are witnessing an increasing recognition of the importance of science and its application in society with allied efforts to enhance scientific, technological and innovation efforts on the continent.

The organizations involved in the science system are expected to conduct science "for the public good" and make sure that "the direction of science is shaped and steered by a nation's most pressing socio-economic needs" (Mouton, 2018, p.4). However, few African science systems can do this because historically they suffer from:

1. Weak scientific institutions: fragile research centres and institutes, non-sustainable scientific journals, ineffectual scientific societies and academies of science;
2. Dependence on international funding for research and development (R&D);
3. Individualism in research rather than institution building;
4. Inadequate reproduction of the scientific and academic workforce (decline in the number of doctoral programmes and doctoral students); and
5. Weak inscription of science in African societies (Mouton, 2018).

Enhanced knowledge of how the science system works and how to strengthen that system is required to overcome these barriers and weaknesses. This book aims to help fill this gap; adding to a burgeoning set of 'science on science' that is focused specifically on the needs and requirements of African science systems.

A definition of science and science systems

The focus of this book is on science systems, but what is 'science' and what is a 'science system'? Science is traditionally seen as the study and accumulation of knowledge and is regularly therefore equated to research. However, as the preceding section has highlighted, rarely does recent policy discussion speak solely about science in this narrow manner anymore. Instead, science is often placed together with 'technology' and 'innovation'. This comes with a recognition that scientific advances do not automatically lead to innovation and advancement of societies. There is increasing recognition of the need to consider science in a broader perspective; it has been acknowledged for some time that the concept of science is interconnected with technology and innovation (Freeman and Soete, 1997). There are two aspects to this interconnection.

First, is the symbiotic relationship between the three activity types: science, technology and innovation (S, T and I). This is sometimes wrongly interpreted to be a linear relationship whereby 'science', defined as research within universities or private research laboratories (basic or applied research), results in the invention of products or technologies that are then commercialized into the economy (innovation); sometimes known as the 'science-push' model of innovation. In fact, scientific practice requires technology in the form of instruments and techniques to advance, while the questions and demand from innovation drive the pursuit of scientific endeavour (Brooks, 1994).

Second, is the impact of society and social relations on S, T and I that determine and shape the relationship between the three activity types (Pavitt, 1998). The recognition of the fallacy of the impartiality of the scientific endeavour is not new – and is the basis of modern sociological debates since the 1800s. The degree of emphasis that is placed on each of these three elements and how they interact is determined by people, their personal relations, cultural beliefs, and everyday activity (Knorr et al., 1981). A key part of this is the political economy in which science councils and S, T and I activities take place (Chataway, et al., 2019). Specifically, how wealth and power are distributed and how these impact on the type, amount, and impact that S, T and I activities have at national and continental levels in Africa.

In this book we see how the application of science is essential for Africa's future. Science therefore, for us must be seen in a broader context. What is important is not just the study and accumulation of knowledge through research but also its application in technology and different forms of innovation – these are all elements of the scientific endeavour. As such, science here is not just the hard or classical sciences of biology, chemistry and physics but all forms of knowledge across the science, technology, engineering and mathematics (STEM) fields as well as the equally important fields of the social sciences, arts and humanities. It includes codified knowledge but also tacit knowledge and indigenous knowledge.

This book focuses specifically on science systems or "the entire network formed by institutions, actors, policies, information and communication channels that together determine the pathways and content of scientific enterprise in any given society" (Sheikheldin and Mohamed, this volume).

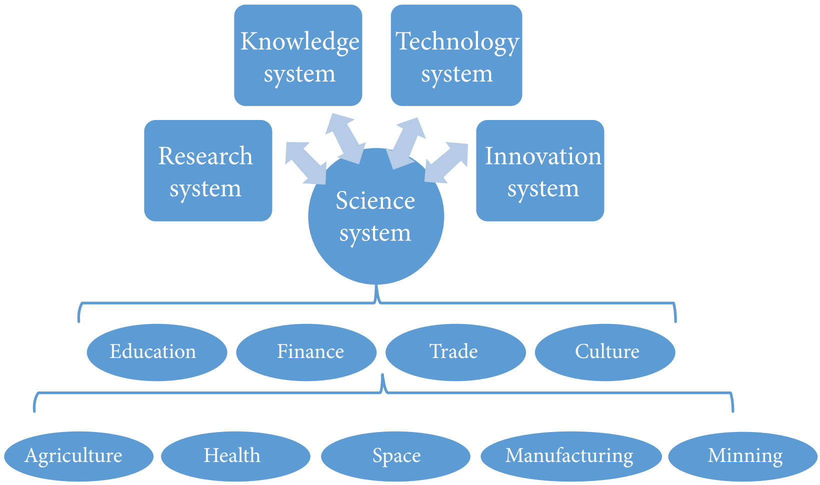
That being said, different authors in this book use different systems terms: 'knowledge systems', 'research systems', 'technology systems' and 'innovation systems'. Each has its own historical and epistemological beginnings and is relevant for use at different times and in different contexts. They will also be introduced as they are discussed in each of the forthcoming chapters.

This book sees 'science systems' as being strongly interrelated with these other systems. In fact, we focus explicitly on science systems because of the emphasis given to them in policy rhetoric while recognizing that they cannot be divorced from the related systems of research, knowledge, technology or innovation. This will be contentious to some; given the continuing dominance of the science push model in many African countries that puts a premium on research and development coming out of universities and a focus on building strong university-industry relations. However, this dominant view is also the place from which we must start. The narrative on STI is still heavily focused on the S more than the T and the I. In commenting on the South African 2020 STI indicators report, one National Advisor stated that 'research' (a.k.a. science) is "the kernel around which we build out the innovation and development…the knowledge-based economy" (Nordling, 2020). The first place to start changing this narrative is to recognize the systemic nature of science and its interconnections with areas such as technology and innovation.

Our definition of a science system broadly encompasses the actors involved in the study, accumulation *and* use of knowledge (see Figure

1.1); the science system cannot be considered in isolation from the research, knowledge or innovation systems in which it is connected. In addition, these are all influenced by – and influence – a range of other systems of education, finance, trade, culture, and sector specific systems such as agriculture, health, space, energy, mining, and manufacturing.

Figure 1.1: A Broader Conceptualization of the 'Science System'



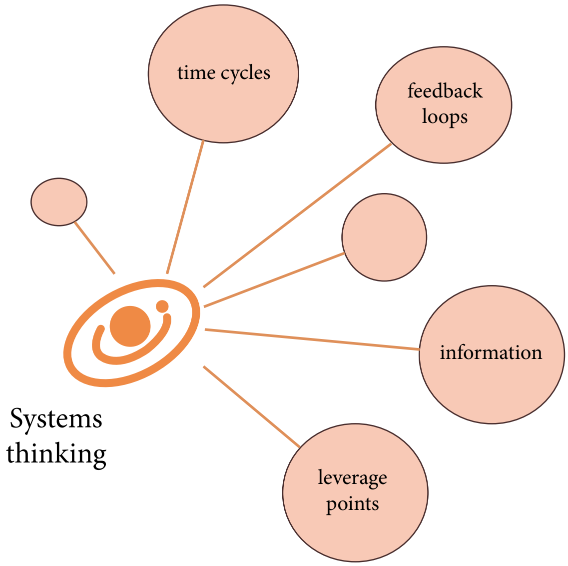
Source: Authors

Systems thinking

Systems thinking begins with articulating what a system is, and then ventures to highlight major features to look for in systems and major instruments (mental and practical) that allow for influencing systems. For this, we begin to say that systems can be briefly defined as sets of "things – people, cells, molecules, [machines, procedures, etc.] – interconnected in such a way that they produce their own pattern of behaviour over time" (Meadows, 2009, p. 2). This emergence of 'own patterns of behaviour over time' is what necessitates systems to be treated as whole units or stocks, as it would be difficult to understand the patterns by focusing only on parts of the system, or on each part separately. Thus, systems thinking is concerned with recognizing and understanding patterns, relations and functions or purposes that systems epitomise – and the goal behind such recognition and understanding is to be able to influence them; particularly in ways that are favourable. When we talk about science systems, it is easy to realize why we would want to influence them.

If one is to have a crash course in systems thinking, they would probably need to know four concepts or phenomena and how they relate to each other briefly: time cycles, feedback loops, information, and leverage points (see Figure 1.2).

Figure 1.2: Four Key Concepts Within Systems Thinking



Source: Authors

Time cycles and feedback loops should always be considered together because the effects of feedback loops manifest in time. It is important to consider that, in decisions or actions taken within a system, significant outcomes and impacts tend to take a considerable amount of time to show (delays). This is important to consider in order to manage expectations from systems and decisions, and to watch for unintended consequences over time. To avoid unintended consequences, interventions within a system should have a relative, realistic estimate of delays and when interventions are expected to show and be measurable. Additionally, understanding the system's feedback loops can help with predicting how each intervention may influence other factors and actors than the ones originally intended and how that overall can have turnouts that were not planned or anticipated. A feedback loop is a type of causal loop that is a "closed chain of causal connections from a stock, through a set of decisions or rules or physical laws or actions that are dependent on the level of the stock, and back again through a flow to change the stock" (Meadows, 2009, p. 27). Feedback loops can either be reinforcing (i.e. tends to significantly increase or decrease stocks over time if left to run without intervention) or balancing (i.e. tends to balance stock or conditions over time, without intervention). A system would often have multiple, overlapping feedback loops.

Information is to a system like blood arteries and veins to a living body. Information keeps the system's operations flowing, in one trajectory or another; hence, information quality and timeliness make a big difference. "Delayed, biased, scattered, or missing information can make feedback loops malfunction. Decision makers can't respond to information they don't have, can't respond accurately to information that is inaccurate, and can't respond in a timely way to information that is late" (Meadows, 2009, p. 173). Therefore, it appears that a lot of what could go wrong in systems – from unmanageable delays to wrongly defined goals to uncontrolled feedback loops – is largely due to how information is treated in that system. Therefore, systems thinkers emphasize the importance of honouring and respecting information and making it accessible.

Leverage points, on the other hand, are points of intervention in the system in a way that would have a rippling or significant effect throughout the system (Meadows, 2010). These leverage points can come in the form of numbers (such as taxes or subsidies), material stocks and flows, control of information, management of feedback loops, rules of the system, as well as paradigms of systems (Meadows, 2010).

With these concepts or phenomena in mind, this book recognizes this complexity and the interconnected nature of knowledge, research, science, technology and innovation, and uses these to view things in a light that cannot be viewed otherwise, hence giving a chance to make recommendations and decisions on interventions with deeper impacts on the system. In essence, any good systems thinking approach to problem-solving will include understanding the system; locating the most efficient leverage points for goals intended to design interventions; and monitoring, changing and adjusting accordingly.

In this way, systems thinking is closely related to 'research policy'. As noted by one of the authors of this book elsewhere: "[t]his type of research is characterized generally as research that is undertaken with the purpose of informing policy or studying the consequences of policy" (Diyamett, et al., 2019, p. 36). It is research that informs policy in multiple ways, and enhances the policy environment (Eboh, 2014). Recently, a new proposed name for this field appeared: 'the

Science of Science Policy' (Fealing, et al., 2011) generally referring to a scientific approach (i.e. using scientific strategies) to improve science systems. Policy is particularly relevant here because there is evidence that, in modern history, policies can make or break successful stories of industrialization. "Comparative results from (Africa and Asia) case studies suggest that policy choices are largely responsible for the differences in industrialization outcomes" (Newman, et al., 2016, p. 20).

When we apply systems thinking to science systems, we get 'science systems thinking' or 'systems thinking and science.' As the name indicates, this endeavour is about using systems thinking to make national science systems work better. In this book, most of the chapters can fall under this endeavour.

A special mention for science councils

A modern science system (narrowly defined) is expected to have a multitude of different scientific organizational forms (universities, research institutes, laboratories, think tanks, journals/academic publishing houses, etc.) that each have a clear and defined role (Mouton, 2018). These organizational forms are joined in the system by actors, institutions and information/communication flows and channels.

Actors, or system agents, vary from scientists to engineers and technicians, to administrators and decision makers, to entrepreneurs or business folk, to legal professionals, to development and innovation partners, and community early adopters of innovation.

Institutions are durable and embedded in rules and norms that structure social interactions (Hodgson, 2001); in a sense, institutions are the enabling environment within which systems actors or agents interact with a level of familiarity.

Actors, institutions, and organizations do not interact in a singular, defined manner but are impacted by power, politics, and knowledge flows within the system which, in turn, are influenced by culture and historical context. The result is a complex system of elements which are joined together with actors, institutions and organizations from other related systems of research, knowledge, technology and innovation with feedback loops, time delays, bottlenecks, stocks and flows, and leverage points.

In recent years, attention has been placed on one organizational form that is seen as key to the success of a science system: the science council. These sit in an intermediary space between the state and the research community – able to influence the actors, organizations and institutions of the system – defining and executing a significant part of the state's science policy (Braun, 1998). They are in this way seen as 'boundary organizations' as they "allow members of different communities to work together around them, and yet maintain their disparate identities" (Guston, 2000, p. 29 quoted in Braun and Guston, 2003, p. 305). Braun and Guston (2003) go on to argue that science councils can be boundary organizations because they facilitate co-creation of 'knowledge and social order'; they bridge the different worlds of politics and science and act as a mediator between the two different 'worlds' to bring stability.

Science councils are key players in the STI landscape of a country. They are responsible for granting funds for research (and development) activities as well as, in some cases, the funding of innovation actions. However, many also – implicitly or explicitly – have roles to play in policy discussions in their countries as STI policy champions. Mouton et al. (2015, p. 148) identify at least six roles that science councils can be responsible for: "disbursing funds for research and development (R&D); building research capacity through appropriate scholarships and bursaries; setting and monitoring research agendas and priorities; advising on STI policies; managing bilateral and multilateral science and technology (S&T) agreements; and assessing the communication, uptake and impact of publicly funded research." As such science councils manage multiple mandates (Kruss et al., 2016).

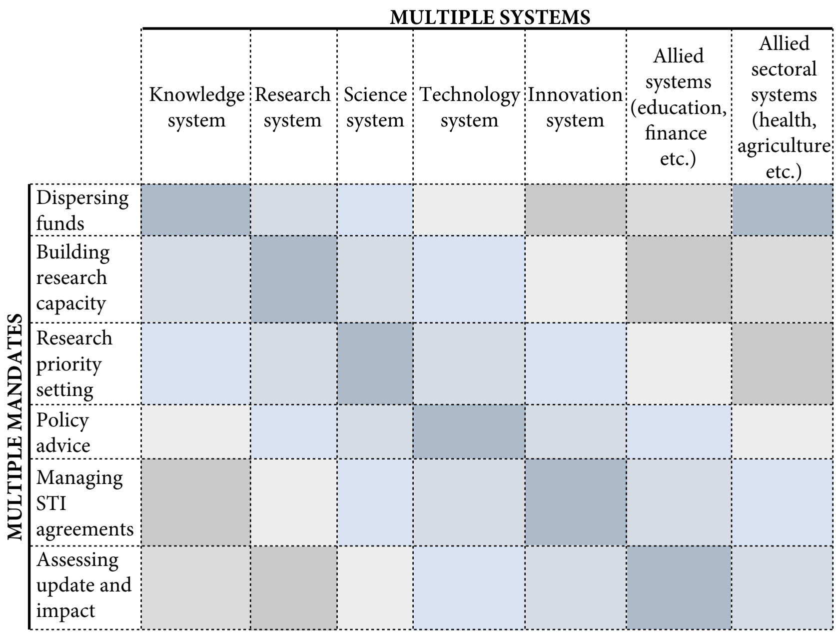
This book is based on the premise that science councils are what might be called 'boundary managers' and not just boundary organizations (Hanlin et al., 2020). Specifically, that councils recognize not just that they have multiple mandates and must manage relationships with multiple stakeholders but that they must be proactive in managing these relationships. As we write elsewhere:

> "there is a clear role for SGCs to be more directly engaged in influencing the direction and flow of research funding and in adjudicating the many different players in this field (both agents and principals). This requires shaping their work to ensure that they are salient, credible and legitimate in what they do and are evaluated against these criteria" (Hanlin, 2020, p. 11).

A key element of managing boundaries is being able to move beyond the agent and principal relationships that can dominate the interactions science councils have with other stakeholders; which are often determined by asymmetries of information (Braun and Guston, 2003). In this way they can be an important check on government dominance on research funding while also recognizing the independence of scientific institutions (Klerkx and Leeuwis, 2008).

Science councils must manage the needs of actors, organizations and institutions within a variety of different systems – not just the narrowly defined science system – as they fulfil their multiple mandates. The many boundaries that they must manage are graphically depicted in Figure 1.3. Each science council will have a different set of mandates and boundaries to manage. Some will be wholly focused on a narrow set of mandates – often the top left nine boxes of Figure 1.3. All of them will – whether they explicitly recognize it or not – manage boundaries with allied systems on the right-hand side of Figure 1.3.

Figure 1.3: The Multiple Boundaries Managed by Science Councils



A country may have one or many science councils, focused on the production, promotion and use of knowledge in a variety of natural and social sciences. They sometimes have the words 'research', 'technology' or 'innovation' in their titles, and they might be called 'commissions', 'offices' or 'departments' instead of 'councils' depending on their legal status and level of independence. These councils fulfil many roles including: granting funds for scientific research and its application; writing policy; or lobbying not only on the importance of science but also the downstream areas of technology and innovation. They may conduct one or more of these roles and several others too. They range from councils that have been established for many years (e.g. Burkina Faso established its first Science and Technology Ministry in 1978 and Ghana followed a year later) while others are newer (e.g. Ethiopia got its own Science and Technology Ministry in 2012). Some countries now have dedicated ministries of science, technology and/or innovation (such as Ethiopia) while others have a research or science council embedded in a Ministry of Higher Education (e.g. Mozambique). In other countries (e.g. Kenya) the science council is semi-autonomous, and its functions are actually separated across three separate entities: a National Commission for Science and Technology; a National Research Fund; and a National Innovation Agency.

Unfortunately, the African science council – until very recently – as an actor in a broadly defined science system has traditionally been ignored – or not given duly deserved attention – in African policy circles. This book is premised on the argument that national science councils should play a central role in the science system landscape by providing guidance and funding to ensure all forms of knowledge are recognized and scientific research related activity supported. African science councils play an active role in shaping the social and economic development paths of their nations and the continent. As such, and as discussed in more depth in Chapter 2, this book is also premised on the idea that in becoming better boundary managers science councils have a key role to play. Specifically, they play an important role in making sure that all the elements of the system find each other, work together, and achieve the desired outputs, outcomes and impacts from a country's scientific endeavours. As such, we argue that science councils can become more effective policy champions if they recognize their role as boundary managers more explicitly.

A caveat: The desired outcome of scientific endeavour

As the science systems of Africa strengthen and science councils manage their mandates becoming stronger boundary managers, one aspect of this will be the relative focus given to research excellence and/or development impact. We see increased funding for different types of S, T and I but meeting the demands of research excellence and impact is, and will remain, challenging.

The ethos of science complicates these debates and the work of science councils. Specifically, science discourse is regularly discussed in terms of a tension between a focus on research excellence and societal impact (Sutz, 2020) which is related to the power and politics existing within the science system (Chataway, et al., 2017). Research excellence refers to a contested and ever changing focus on ‘the best’ science or that which is measured as the best; based on the research outputs publication in the top academic journals or total number of high ranking journal publications a researcher has (Kraemer-Mbula, et al., 2020). On the other hand, a focus on societal impact is not just about the degree to which science has the greatest impact but also the type of impact in terms of meeting societal needs (Ciarli and Rafols, 2019).

The Science Granting Councils Initiative

One initiative that has been trying to assist African science systems rejuvenate through an empowerment of science councils is the Science Granting Councils Initiative in sub-Saharan Africa (SGCI). The SGCI seeks to strengthen capacities of science councils in Eastern, Southern, and Western Africa to support research and evidence-based policies that will contribute to economic and social development. In Phase 1 (2015–2019) the SGCI was jointly funded by the United Kingdom’s Department for International Development (DFID), Canada’s International Development Research Centre (IDRC), and South Africa’s National Research Foundation (NRF). In 2018/9, it was joined by two additional funders: the Swedish International Development and Cooperation Agency (Sida) and Deutsche Forschungsgemeinschaft of Germany. The SGCI has been focused on strengthening science systems in 15 African countries namely: Botswana, Burkina Faso, Côte d’Ivoire, Ethiopia, Ghana, Kenya, Malawi, Mozambique, Namibia, Rwanda, Senegal, Tanzania, Uganda, Zambia, and Zimbabwe.

The SGCI revolves around strengthening the ability of participating science councils to: (i) manage research; (ii) design and monitor research programmes, and to formulate and implement policies based on the use of robust science, technology and innovation (STI) indicators; (iii) support knowledge exchange with the private sector; and (iv) establish partnerships with other science system actors. From 2019 there has also been an emphasis on gender equality and inclusivity. Implementation of these activity areas is achieved through several modalities including customized regional training courses, individualized on-site training sessions, online training, webinars, collaborative research, and public-private partnership projects.

The SGCI's principal outputs include: (i) more effective research management practices among councils; (ii) strengthened ability of councils to design and monitor research programmes, and to formulate and implement policies based on the use of robust science, technology and innovation (STI) indicators; (iii) increased knowledge exchange with the private sector; and (iv) increasingly coordinated and networked councils. This is premised on the notion that councils will strengthen national science and research systems, and ultimately lead to nationally led, regional and cross-regional collaborative research that contributes to sustainable development in participating countries.

This book builds on the experiences of the authors as members of collaborative technical agencies who provided support to the science councils in Phase 1 of this initiative or as members of the science councils themselves. Other authors provided technical evidence and research to the initiative to assist councils and the initiative more broadly to make informed decisions.

This book: a call for more 'science on science'

This book is the culmination of five years of action research by the authors within the African science system as part of the Science Granting Councils Initiative. It is also part of a broader demand for knowledge and understanding of how African science systems work and as such is a 'call to arms' for increased 'science on science'. It therefore focuses on key issues that are important for a conceptual understanding of science systems (Part 1 of the book) and a series of important empirical considerations affecting science councils as boundary managers (Part 2 of the book).

Many of the authors in this book are part of a burgeoning academic field in Africa which lags other parts of the world: the multidisciplinary field of science, technology, and innovation studies. This term encompasses everything from the established fields of study in many other parts of the world of the history of science; science and technology studies; innovation studies; innovation and/or technology management; the sociology of scientific knowledge amongst others. All these fields of study ask us to examine how science (and its allied technology and innovation) are being conducted. Such study is the only way in which we can effectively analyse our science and related systems and understand how they function, the barriers and opportunities facing them and how we can improve them in the future.

Part 1: Conceptual Foundations

This book starts by introducing the key role that science councils play in African science systems. It places these within the context of the broader innovation and knowledge systems in which they operate. These chapters effectively ask us to not only take a broad definition of the African science system but also ensure that it focuses on the key issues and challenges facing the continent. More specifically, Part 1 of the book asks us to consider multiple systems as being in existence on the continent and the need for these to include a broader range of actors and knowledge. By doing so, it will allow us to ensure science systems achieve their role of responding to societal needs.

Thus, in Chapter 2, Tigabu and Khaemba discuss the functions of science councils in Africa and illustrate how they relate to the functions of innovation systems. They argue that science councils in Africa are central actors in innovation systems because they play multiple roles that contribute to the functioning of these systems. Tigabu and Khaemba conclude that science councils could be 'catalysts' of the functioning of innovation systems in Africa.

Diyamett and Ngumia in Chapter 3 take structural transformation and the innovation system as their points of departure. They focus on the concept of reduced systems of innovation where concepts such as the functions of the innovation systems, innovative clusters and the triple helix are brought in as important analytical tools. Diyamett and Ngumia pay special attention to the innovation systems components associated with the relationships between research and productive sectors, and in so doing, emphasize the role of science councils in matchmaking, funding, and coordination of the systems.

Chapter 4 by Atela et al. starts from where Diyamett and Ngumia, and Tigabu and Khaemba leave off and critique current approaches to innovation systems. They state that countries still lack evidence on how effective STI systems could look like in practice, including what interventions to pursue for optimal outcomes. They argue that this is exacerbated by reliance on global theories and concepts that have not been effectively domesticated in the African context. Thus, they argue for a new way of clarifying and informing STI policies and interventions. Atela et al. propose the concept of the knowledge system (KS) as a way of informing STI interventions in various contexts to bridge the gap between STI theory and practice.

Part 2: Empirical Considerations

Following this more conceptual overview, the book – in Part 2 – addresses several key issues facing science councils. This is made up of seven chapters that focus on issues of research funding, skills, the role of the private sector and the place of public-private partnerships in research and how councils manage research that is funded. Part 2 finishes with a discussion on learning and how it can be monitored, evaluated, and disseminated to enhance the opportunities for science councils to address the barriers and opportunities faced.

In Chapter 5, Mugwagwa and Banda discuss three key issues on the funding of STI and research: first – how Africa has historically funded STI and the reasons behind adoption of certain approaches; second, the shortcomings of historical and current funding models; and third, innovative funding models from the continent and elsewhere that can be adopted to accelerate local research and innovation activities. Adopting a historical and contemporary approach, the chapter explores how private and public actors across Africa can play a significant role and imbue resilience in financing research and innovation. The chapter also explores various strategies and measures that research organizations use to align their activities with national development policies.

Sheikheldin and Mohamed in Chapter 6 discuss key circumstances surrounding skills and opportunities for researchers in STI, as well as highly trained STI policymakers and research managers in Africa. They argue that so-called 'brain drain' – the phenomenon of massive skilled labour migration from developing countries to developed and industrialized countries – applies continuous pressure on local human resource capacities for development in African countries; not least science systems. The chapter presents a comprehensive review of the challenges and opportunities resting on the role of highly skilled African migrants in African science and STI systems. It reviews how science systems are affected by 'brain drain' and demonstrates the main approaches that respond to it in Africa and beyond.

In Chapter 7, Bolo and colleagues move the discussion to the contribution of knowledge-generating organizations, their linkages with the private sector, and the potential for knowledge exchange and technology transfer. They argue that public-private partnerships (PPPs) in research and innovation present an opportunity for co-creation and exchange of knowledge and associated products with the private sector. They do this through providing examples of PPPs that have been funded by the science councils of Malawi and Uganda. The chapter uses a case study approach to discuss five projects funded under the PPP Grant Scheme in Malawi and Uganda within the SGCI. The analyses of the cases are presented alongside four over-arching sub-themes: (i) stakeholder engagement; (ii) institutional strengthening; (iii) contribution to policy processes; and (iv) organizational culture and practices. A final concluding section looks at the lessons and prospects for the future as the emerging findings on new technologies and products; new business opportunities; and the diversified use of locally available raw materials.

Vallejo and colleagues continue the theme of PPPs in Chapter 8, which takes a broader analysis of PPP experiences in Africa, based on a systematic literature review, and supplemented by interviews with representatives of 12 African science councils. In comparing what it terms 'PPPs in research and innovation' with the experiences of a broader set of PPPs in health, education and infrastructure, it discusses the role PPPs in research and innovation should play in facilitating partnerships that help drive science-based innovation in African businesses and industries.

Chapter 9 by Jackson et al. focuses on the development of the research management field in science systems. The authors provide an overview of findings from a comprehensive capacity-building programme in research management that was established as part of the SGCI activities to address some of these systemic challenges. This chapter presents the elements of the programme as well as the challenges, successes and lessons learnt.

Chapter 10 by Ozor et al. takes us back to the concept of knowledge and discusses the knowledge exchange and networking (KEN) process which brings together researchers, users of research and wider public and private groups, communities and entrepreneurial individuals to exchange ideas, evidence and expertise. It argues that KEN is about developing mutually beneficial partnerships to support innovation and find solutions to the most pressing global challenges. Done effectively, KEN allows all participants to add value and impact to new ideas through engagement and collaboration. The chapter explores key concepts of and mechanisms for KEN and identifies the mechanisms which work most effectively in an African context with particular focus on the science councils and other science system actors in sub-Saharan Africa.

The final chapter of the book, Chapter 11 by Dhlamini et al. reflects on the role of monitoring, evaluation, and learning (MEL) and its importance for African science councils. The chapter argues that the capacities of councils, level of government commitment to funding research, quality of research outputs and research relevance are some of the indicators used to measure the strength of a national science system. This chapter aims to de-mystify MEL and provide simple steps that SGCs could use to institutionalize MEL. The chapter describes findings from the work done by the Association of African Universities in Cote d'Ivoire, Senegal, and Burkina Faso in reviewing the capacities of their MEL systems. The chapter demonstrates the link between the Council MEL systems and the strength, focus and relevance of a country's science system for its economic, social, and political development.

Moving forward

This second part of the book paints a bleak picture of challenges facing science councils. However, it also points to examples of success and opportunities for improvement and strengthening.

As such, this book adds to a growing – but still small – literature by African academics on African science systems. There are still significant issues that need consideration. These include a more detailed discussion of gender inequities within science systems in Africa. An Africa-wide study of trends and challenges among African scientists, conducted recently by Beaudry et al. (2018) brought to light important information about gender and science in Africa. From a somewhat representative example, female respondents to the survey of the study were 30 per cent of all respondents, with the age group of 39-or-younger yearshaving 33 per cent of respondents as females. Overall, it seems that currently, female African scientists dominate the fields of health and medical sciences, while a considerable gap seems to exist between them and male scientists in, for example, the fields of engineering. Some of the challenges reported by female scientists, that were unique to them, were related to family-work balance and to limited accommodation – if any – for motherhood aspects such as maternity leave and career continuity. Overall, in science systems in Africa, gender is an elephant in the room – despite an increasing number of studies and initiatives being placed on the subject. It is encouraging to see that the SGCI in Phase 2 has a dedicated focus on gender and diversity to start to address this.

Another area that requires further attention is intellectual property rights and/or efforts towards more open innovation. The protection of scientific discoveries and their development (or the ability to exploit scientific discoveries from elsewhere) is regularly a key issue brought up by African scientists. It is used to explain the lack of impact of scientific research or the low recognition of innovation efforts in the private sector, both formal and informal. Critical and crucial work is being done in this area by initiatives such as the Open African Initiation Research Partnership (OpenAIR) as well as Phase 2 of the SGCI.

The discussion above shows the importance of information (on the different actors, the time cycles and potential time lags, etc.) for science councils in ensuring that they can identify and utilize leverage points as they arise to manage the system effectively. We believe that science councils must become more active 'boundary managers'; they have a key role to play in managing the system and ensuring the system works – by breaking down the boundaries that exist in the system. The most well-known of these boundaries are those between the public (academic, research) and private (business, enterprise) sector system actors (Chapters 7 and 8, this volume). But there are also other relationships and flows of information that do not work as effectively as they should. These also feature in the management of research and its timely funding, implementation, and results feedback (Chapter 9, this volume). Such research depends on the right relations between different actors to ensure the right skills are available (Chapter 6, this volume) and funding is available (Chapter 5, this volume).

As we note above, science councils can be boundary organizations because they facilitate co-creation of 'knowledge and social order'; bridging the different worlds of politics and science, and acting as a mediator between the two different 'worlds' to bring stability. But we would argue that science councils must go further and become managers of these boundaries. This isn't just in terms of managing competing interests and discourses with regards to how money is spent, where it is spent and what impact the research funding should have (Hanlin et al., 2020); and where most of the attention is often placed by science councils. It is also because councils have important roles to play in policy areas (Chapter 3, this volume) and in determining what knowledge is promoted (Chapters 4 and 10, this volume).

This is not to argue that science councils are the only important actors in the system. However, in thinking from a systems perspective – and the usefulness of analytical systems models – councils are placed at a unique position within the S, T and I systems to enable them to analyse these systems in which they work; understand all the different actors within said systems and allied systems (many of whom are not necessarily traditional S, T, and I actors, for example the financial and trade sectors of government and the economy) and the information flows between them. In so doing, councils can better identify leverage points that will enable them – or others – to break down boundaries in the system which are causing the science system to function less effectively.

References

Beaudry, C., Mouton, J., and H. Prozesky, H. (eds.,) 2018. *The next generation of scientists in Africa*. Cape Town: African Minds.

Booth, D., 2015. *Towards a developmental state concept that is fit for purpose (in the 21st century, in Africa).* London: Overseas Development Institute.

Braun, D. (1998) The Role of Funding Agencies in the Cognitive Development of Science', *Research Policy,* 27/8, pp. 807–21

Braun, D. and Guston, D.H., 2003. Principal-agent theory and research policy: an introduction. *Science and Public Policy*, 30(5), pp.302–308.

Brooks, H., 1994. The relationship between science and technology. *Research Policy*, 23, pp.477–486.

Chang, H.J. and Woo-Cumings, M., 2010. How to 'do' a developmental state. *Constructing a democratic developmental state in South Africa.* Pretoria: HSRC, p.88.

Chataway, J., Ochieng, C., Byrne, R., Daniels, C., Dobson, C., Hanlin, R. and Hopkins, M., 2017. *Case studies of the political economy of science granting councils in sub-Saharan Africa*. Nairobi: Science Policy Research Unit (SPRU) and African Centre for Technology Studies (ACTS).

Chataway, J., Dobson, C., Daniels, C., Bryne, R., Hanlin, R., Tigabu, A., 2019. Science granting councils in sub-Saharan Africa: trends and tensions. *Science and Public Policy*, pp.1–12. doi: 10.1093/scipol/scz007.

Ciarli, T. and Ràfols, I., 2019. The relation between research priorities and societal demands: the case of rice. *Research Policy*, 48(4), pp.949–967.

Delbourgo, J., 2019. The knowing world: a new global history of science. *History of Science*, 57(3), pp.373–399.

Diop, C. A., 1988. *Precolonial black Africa*. Chicago Review Press.

Diyamett, B., Makundi, H. and Gussai, S., 2019. *Science, technology and innovation (STI) policy training for Africa: basic module on reconciling theory, practice and policies.* A handbook prepared by STIPRO for the Science Granting Councils Initiative (SGCI). [Online] Available at: https://bit.ly/35cyEgC (Accessed 20 August 2020).

Eboh, E. C., 2014. *Using research to influence public policy: what works and how.* Abuja: Institute for Public Policy Analysis and Management.

Fealing, K. H., Lane, J. I., Marburger III, J. H. and Shipp, S. S. eds., 2011. *The science of science policy: a handbook.* Stanford University Press.

Freeman, C. and Soete, L., 1997. *The economics of industrial innovation*. Psychology Press.

Guston, D. (2000). *Between Politics and Science: Assuring the Integrity and Productivity of Research*. Cambridge: Cambridge University Press.

Hanlin, R., Tigabu, A., Chataway, J., Dobson, C. and Daniels, C., 2020. Science granting councils as boundary organizations: evidence from a political economy study of five countries in sub-Saharan Africa. *ACTS Working Paper*. Nairobi: ACTS.

Hillbom, E., 2019. The possibility of developmental states in Africa. [Online] In: W.R., Thompson, ed. *Oxford Research Encyclopaedia of Politics*. Oxford University Press. Available at: https://oxfordre.com/politics/ (Accessed 31 August 2020).

Hodgson, G. 2001. Institutional Economic Thought. In: N.J. Smelser and P.B. Baltes, eds. *International Encyclopaedia of the Social & Behavioural Sciences,* pp.7543–50.

Knorr, W.R., Krohn, R. and Whitley, R.P. eds., 1981. *The social process of scientific investigation*. Springer Science & Business Media.

Kraemer-Mbula, E., Tijssen, R., Wallace, M. L. and McLean, R. eds., 2020. *Transforming research excellence. New ideas from the Global South*. Cape Town: African Minds, pp.19–38.

Lovejoy, P.E., 2014. *African contributions to science, technology and development*. [Online] UNESCO resource. Available at: http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/CLT/pdf/P_Lovejoy_African_Contributions_Eng_01.pdf (Accessed 1 August 2020).

Mamdani, M., 2018. The African University. *London Review of Books*, 40(14), p.29.

Mazrui, A., 1999. Linking modern science to African culture. *World Conference on Science*. [Online]. Available at: https://www.nature.com/wcs/c14.html (Accessed 8 July 2020).

Mkandawire, T., 2001. Thinking about developmental states in Africa. *Cambridge Journal of Economics*, 25(3), pp.289–314.

Mouton, J., Gaillard, J. and Milandré Van Lill, M., 2015. Functions of science granting councils in sub-Saharan Africa. In: N. Cloete, P. Maassen, and T. Bailey, eds. *Knowledge production and contradictory functions in African higher education*. Cape Town: African Minds, pp.148–170.

Mouton, J., 2018. African science: a diagnosis In: C. Beaudry, J. Mouton and H. Prozesky, eds. 2018. *The next generation of scientists in Africa*. Johannesburg: African Minds.

Meadows, D. H., 2009. *Thinking in systems: a primer*. London: Earthscan

Meadows, D. H., 2010. Leverage points: places to intervene in a system. *The Solutions Journal*. 1 (1), pp.41–49.

Metz, H. C. ed. 1991. *Sudan: A country study*. Washington: GPO for the Library of Congress.

Newman, C., Page, J., Rand, J., Shimeles, A., Söderbom, M. and Tarp, F. 2016. *The pursuit of industry*. In: C. Newman, J. Page, J. Rand, A., Shimeles,

M. Söderbom, and F. Tarp, eds. 2016. *Manufacturing transformation: comparative studies of industrial development in Africa and emerging Asia. Oxford:* Oxford University Press. pp.1–24.

Nordling, L. (2020) South African science was slipping before the pandemic. [Online]. Available at: https://www.researchprofessionalnews.com/rr-news-africa-south-2020-9-south-african-science-was-slipping-before-the-pandemic/ (Accessed 5 November 2020).

Pavitt, K., 1998. The social shaping of the national science base. *Research Policy*, 27(8), pp.793–805.

Ragab, A., 2015. *The medieval Islamic hospital: medicine, religion, charity.* New York: Cambridge University Press.

Sutz, J., 2020. Redefining the concept of excellence in research with development in mind. In: Kraemer-Mbula, E., Tijssen, R., Wallace, M. L. and McLean, R. eds., 2020. *Transforming research excellence. New ideas from the Global South*. Cape Town: African Minds

Tilley, H., 2018. The history and historiography of science. In: *Oxford Research Encyclopaedia of African History*.

Tilley, H., 2019. A great (scientific) divergence: synergies and fault lines in global histories of science. *Isis*, 110(1), pp.129–136.

PART 1

BUILDING SCIENCE SYSTEMS IN AFRICA: CONCEPTUAL FOUNDATIONS

2

Science Councils in Africa: Catalysts of Innovation for Sustainable Development?

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Abstract

African countries are increasingly mainstreaming science, technology and innovation (STI) as one of the key agendas in national development policies. Despite such efforts, STI institutional capacity remains weak. As one way of enhancing STI and research capacity, many African countries have created various national STI funding agencies, which we collectively refer to as Science Granting Councils (SGCs). In this chapter, we discuss the functions of SGCs in Africa and illustrate how they relate to the functions of innovation systems. We argue that SGCs in Africa are central actors in innovation systems because they play multiple roles that contribute to the functioning of these systems. Based on such preliminary insights, we conclude that SGCs could be 'catalysts' of the functioning of innovation systems in Africa.

Introduction

African countries are increasingly committed to harnessing science, technology and innovation (STI) to achieve national development objectives. STI is not only mainstreamed as one of the key agendas in national development policies but STI projects are also increasingly implemented as a cross-cutting and 'multi-functional tool' of achieving inclusive and sustainable growth (AUC, 2014). The African Union's Science, Technology and Innovation Strategy for Africa 2024 (STISA-2024) and Agenda 2063, which promote sustained investment in scientific research and innovation in key sectors (AUC, 2014, 2015), as well as national STI policies across various countries, give credence to the assertion that there is increased attention to STI in the continent.

Despite such efforts, STI institutional capacity in Africa remains weak compared to many parts of the world. For example, no African country is ranked among the top 50 countries in its innovation achievement in the 2018 Global Innovation Index (Cornell University, INSEAD, and WIPO, 2018). As of 2015, Africa's share in the global gross domestic product (GDP) was about 5 per cent whereas its contributions to research and development (R&D) was at 1.3 per cent. Africa also accounts for only 2 per cent of world research outputs and 0.1 per cent of world patents (UNESCO, 2015). Supporting this, the African Capacity Building Foundation (ACBF, 2017, p. 6) reported that Africa is characterized by "… poor STI infrastructure, a small pool of researchers, low patronage of science and engineering programmes, weak intellectual property frameworks, and minimal scientific output relative to the rest of the world". Based on a comparative analysis of research and innovation management in Ghana, Kenya, and Uganda, Jowi and Anie (2013, p. 32) similarly reported that despite "clear focus on the inter-connectedness between STI" in policy frameworks and development plans, the level of coordination, coherence and integration among policies, programmes and STI institutions is weak.

To enhance STI institutional capacity, many African countries have created various national science funding agencies, hereinafter collectively referred to as Science Granting Councils (SGCs). SGCs have been instrumental in funding local research and managing research grants in line with national development priorities (Mouton, Gaillard and van Lill, 2014; Chataway, et al., 2019). SGCs are traditionally considered as central actors in national research systems. Mouton, Gaillard and van Lill (2014) reported that many countries in sub-Saharan Africa (SSA) have increasingly appreciated having separate streams of funding for research and innovation. An example is Kenya with its tri-agency approach that has the National Research Fund (NRF) to fund research, the Kenya National Innovation Agency (KeNIA) to fund innovation, and the National Commission for Science, Technology and Innovation (NACOSTI) to regulate STI.

Importantly, however, many such organizations in Africa share similar visions of driving STI for sustainable development and visions of fostering a knowledge-based economy by promoting STI[1]. Hence, SGCs in Africa are also increasingly acknowledged as one of the key actors among a group of actors and institutions involved in the development and diffusion of new technologies and practices in economic settings – analytically referred to as innovation systems (Mouton, Gaillard and van Lill, 2014; 2015). Despite this, systematic studies on the role of SGCs in the context of the broader innovation system framework and sustainable development in Africa have been scant (Mouton, Gaillard and van Lill, 2015). The major purpose of this chapter is to briefly reflect on this issue and generate some insights and questions for further research. This chapterhighlights the functions of SGCs, their potential role in the functioning of innovation systems by reviewing and reflecting on existing studies and reports[2].

The remainder of this chapter is structured as follows: Section 2 reflects on the theoretical foundation of the chapter by defining an innovation and innovation systems as well as providing the link between innovation, innovation systems and sustainable development. Section 3 reflects on the functions of SGCs by reviewing existing studies. Section 4 briefly highlights how the functions of SGCs fit into innovation system functions in the literature on the basis of the theoretical insights from Section 2. Finally, Section 5 provides concluding remarks.

Innovation and innovation systems

Innovation entails the introduction and implementation of new or improved products, processes, services, methods, policy practices, and business models in new settings (Edquist and Johnson, 1997; OECD, 2005). In this sense, innovation may be broadly defined as the process of creating, accessing, adapting, assimilating and using knowledge, information or technology to create new products, processes, services, techniques, and approaches that satisfy economic needs. Thus, innovation is widely regarded as the engine of economic development (see, for example, Verspagen, 2004). In addition, innovation has increasingly been viewed as providing solutions to pressing global environmental and social challenges, such as deforestation, land degradation, desertification, air and water pollution, climate change, poverty, energy poverty, and social exclusion. This indicates the crucial role of innovation in the three dimensions of sustainable development: economic growth, social equity, and environmental sustainability (Pociovălişteanu et al., 2016).

But, under what conditions does innovation take place? What are the conceptual frameworks and models that underpin innovation processes? Crucially, how can the rate and direction of innovation be influenced or shaped? Such questions have been central for innovation practitioners, policy-oriented researchers and policymakers. One of the profound observations in innovation studies has been that innovation is an interactive, cumulative and path-dependent learning process, in which economic agents with complementary knowledge and resources interact and learn under specific institutional arrangements, leading to a new, combined or improved knowledge (Edquist and Johnson, 1997). The role of institutional factors on the innovation process has often been conceptualized and analysed by the innovation systems framework. Freeman (1987, p. 1) defined innovation systems as "… networks of institutions, public or private, whose activities and interactions initiate, import, modify, and diffuse new technologies". This means that an innovation system encompasses a range of actors, such as firms, government agencies and their interactions; institutions, such as public policies, routines and customs, as well as infrastructure involved in innovation activities.

The innovation system framework has been developed into several approaches that share a basic conceptual foundation (i.e. innovation having a systemic nature in which interactive learning is a core process) but take different analytical units. These include a national innovation system (NIS) delineated over a nation's boundary, a regional innovation system framework (RIS) having a territorial delineation, a sectoral innovation system (SIS) bound around an industrial or economic sector, and a technological innovation system (TIS) delineated around a specific technology[3].

The systemic nature of innovation processes explains why innovation is a complex, lengthy, and uncertain process. The interdependent nature of actors, networks, and institutions and technologies also justifies why it is often difficult to ascertain and predict on which particular innovation system element interventions should be targeted at and what impact such measures result in (Hekkert et al., 2007). This is even more complicated when innovation entails competition between innovation systems of established technologies and practices, and innovation systems of new alternative technologies and services. On this, Hekkert, et al. (2007, p.

415) stated that "after all, the rate and direction of technological change is not so much determined by the simple competition between different technologies [and actors], but predominantly by the competition between various existing innovation systems, both fully developed and emerging ones."

The focus on sustainability[4] with the aim of understanding the conditions under which innovation systems around sustainable technologies (e.g. renewable energy technologies) emerge, develop and replace unsustainable incumbent technologies and practices has led to a recent focus on understanding the dynamics of technology-specific innovation systems (see for example, Suurs, Hekkert and Smits, 2009; van Alphen, Hekkert and Turkenburg, 2010). A key development in this research is that innovation systems perform key activities and processes that contribute to the overall performance of an innovation system, i.e. the development, diffusion and adoption of a technology (Hekkert et al. 2007; Bergek et al., 2008). According to Hekkert et al. (2007) innovation systems perform seven key functions: *entrepreneurial activities, knowledge development, knowledge diffusion, guidance of search, resource mobilization, market formation* and *creation of legitimacy* (see Figure 2.1 for simplified definitions). Certain activities and events performed by structural elements of innovation systems (i.e. actors, networks and institutions) are believed to contribute to each innovation system function, providing analytical indicators to map these functions at structural levels[5] (see Figure 2.1).

Figure 2.1: Functions of Innovation Systems, their Simplified Definitions and Example Indicator Activities in Africa

Functions of innovation systems	Simplified definition	Example indicator activities in Africa
Entrepreneurial activities	Commercial activities or entrepreneurial experimentations around a new technology	Business startup; entry of firms
Knowledge development	Local research activities about the socio-economic, technical and market issues of a new technology.	Conducting basic/applied research; developing new designs/ prototypes; conducting market surveys/feasibility studies/pilots, performance testing; developing promotional materials; adapting or

Functions of innovation systems	Simplified definition	Example indicator activities in Africa
		modifying new models; developing complementary technologies;
Knowledge diffusion	Knowledge sharing and diffusion channels or networks amongst key actors, such as partnerships, workshops and extension services.	Training; conducting awareness campaigns; organizing conferences/ workshops/ seminars/meetings, demonstrations and exhibitions
Guidance of search	Guidance, indications or directions to actors to mobilize resources by creating expectations.	Setting targets; designing favorable regulations and policies; setting expectations; providing awards; providing directions/showing interest; publicizing research outcomes and policy notes; providing innovation awards
Market formation	Creation of protected market spaces that shield new technologies from market competitions with mature alternatives.	Subsidization (sharing the cost of investment); Standardization; setting tax incentives; public procurement; regulatory reform.
Resource mobilization	Mobilization of human, financial and infrastructural resources for research and other innovation activities.	Providing financial incentives, grants (funding); providing loans (credit); funding human resources development, such as scholarships; providing scientific equipment.
Creation of legitimacy	Advocacy, lobbying and promotion efforts of actors to attain buy-in and support by key actors, such as policymakers.	Conducting advocacy activities (lobbying)

Source: Based on Tigabu, Berkhout, and van Beukering, 2015; Tigabu, 2018.

Research shows that innovation system functions interact with one another, i.e. the fulfilment of one function causes the fulfilment of other innovation system functions, creating a virtuous cycle of causation between functions[6] (Suurs and Hekkert, 2009). The intensity of the functions and their interactions can provide insights into the strengths and weaknesses of innovation systems. From this perspective, a hallmark of innovation policy is strengthening the functioning and functional build-up of innovation systems, through a wide range of public policies aimed at addressing functional weaknesses (Bergek et al., 2008).

Innovation system research in developing countries increasingly suggests that STI policies should not only focus on technology transfer from western countries to developing countries but also on building local content. Romijn and Caniëls (2011, p. 360), for example, stated that "…developing countries should move towards a more pluralist technological strategy that does not continue to lean solely on assimilation of western technologies, but also attempts to emphasize – more than before – domestic capabilities for creative innovation catering to local needs and requirements even at relatively early stages of development." Recent research suggests that innovation system functions build innovation capability in developing, diffusing and applying technologies that contribute not only to poverty alleviation, for example inclusive digital innovation for financial inclusion (Kingiri and Fu, 2019), but also access to sustainable and clean energy services (Tigabu, Berkhout and van Beukering, 2015). This is critical for development policy since the development of technological capabilities in developing countries has long been viewed as a precondition not only to developing new technologies but also adapt, apply and benefit from existing technologies (Fagerberg, Srholec and Verspagen, 2010; Lee and Mathews, 2013).

Besides, ideas from the innovation system approach have become salient features of 'transition' frameworks that have traditionally been applied to make sense of long-term transition processes (i.e. 'major technological transformations') within socio-technical systems providing specific societal functions, such as mobility, energy services, and sanitation, in developed economies. Recent research, however, suggests that such ideas could help us understand economy-wide transition processes (e.g. from a predominantly agrarian economy to sustainable industrialization) in developing countries. For example, Berkhout, Angel and Wieczorek (2009, p. 225) suggested that sustainable economic development may be viewed as "… the emergence of new socio-technical systems, replacing or radically altering traditional and early modern systems in key sectors, including energy, transport, agriculture and food, water and urban development. These new systems emerge through the interplay between new knowledge and practices on the one hand, and the prevailing institutional and social contexts on the other." This is consistent with recent literature on 'transformative change', which views complex and multi-faceted challenges of our times, such as climate change, inequality and underdevelopment, as externalities of socio-technical systems built around unsustainable and inefficient production and consumption patterns (Schot and Steinmueller, 2018). Based on this, a transformative innovation policy – aiming at a bottom-up socio-technical transition by experimentation, learning, networking and participation of all actors cutting across governments, markets and civic society – is needed to address grand societal challenges (Chataway et al., 2017; Schot and Steinmueller, 2018).

Researchers have begun conducting research in developing countries in line with this approach. Okereke, et al. (2019), for example, examined Ethiopia's recent efforts of sustainable industrialization with a particular focus on the articulation of landscape pressures for a 'green' development trajectory, for example, the global decarbonization agenda, and the functioning of the 'nascent' Ethiopia national innovation system in supporting the emergence of 'sustainable' industrial systems. One of the conclusions from this study is that the strength of local innovation systems in tapping into global opportunities while at the same time creating an enabling environment for local content is critical for sustainable industrialization – which is an integral element of the UN's Sustainable Development Goals (SDGs). Policymakers' appreciation of support to local creative capacity as well as the need to stimulate technology development at local levels may explain Ethiopia's recent reorientation of its national grants to applied research (Tigabu, 2017).

These insights, in general, suggest that innovation systems are not only crucial in creating an enabling environment for the emergence and diffusion of technologies that contribute to economic development, but also central enablers of transitions to a sustainable society. This underscores the transformative potential of innovations in addressing grand challenges and bringing about transformative change (Diercks, 2017). It is, therefore, crucial to reflect on the increasing role of SGCs in the functioning of innovation systems; that is, how do the functions of SGCs contribute to innovation system functions based on the indicators provided in Figure 2.1? This may shed some light on why strengthening SGC capacities in sub-Saharan Africa is crucial for the continent.

SGCs and their functions

SGCs are national-level science/research funding agencies that are referred to in various terms, such as Research Councils and Funding Agencies (Chataway et al., 2019). These are "quasi-public organizations financed by the state in order to define and execute a large part of the science policy" (Braun, 1998, p. 810). Braun (1998) argued that funding agencies are established to serve three key functions: the scientific community (science-based agencies); sectoral priority interests (strategic funding agencies); and ministerial interests (political funding agencies). In their review of the existing literature on the functions of SGCs, Mouton, Gaillard and van Lill (2015, p. 156) concluded that generally "funding agencies are tasked with quality control, allocation decisions and (developing/implementing) research policy." These three levels of decision making by funding agencies have also been elaborated by Braun (1998) stating that the structures and interaction norms of stakeholders determine funding policies, activities, and performance of funding agencies. Similarly, Caswill (2005) identifies tasks, such as providing resources for research and maximizing organizational resources, suggesting that SGCs are primarily mandated to disburse and manage time-bound project grants to researchers (Thèves, Lepori and Larédo, 2007). This is supported by Braun (1998) who stated that SGCs could be compared to banks in certain respects. "They are investing money into promising projects or are giving credits to trustworthy and hopefully innovative scientists" (Braun, 1998, p. 811).

However, SGCs are increasingly broadening their missions to include a wide range of knowledge brokering, production and translation functions (see, for example, Cordero et al., 2008; Holmes et al., 2014; Tetroe et al., 2008). In the context of this chapter, therefore, we broadly define SGCs as national agencies that provide resources for STI (i.e. research, technology and innovation funding agencies) in Africa.

A study on the functions of SGCs in Africa (Mouton, Gaillard and van Lill, 2015) shows that SGCs in Africa build research capacity through scholarships and bursaries; set and monitor national research agendas and priorities; advise national governments on STI policies; assess the communication, uptake and impact of publicly funded research; and catalyse innovation. Figure 2.2 summarizesfunctions of SGCs, performed at different degrees, by 17 SGCs in Africa.

Figure 2.2: Key Functions of SGCs

Functions of Science Granting Councils
Management and disbursement of research grants – inviting research proposal applications – managing research proposal peer-review process – disbursing research grants
Management and disbursement of scholarships for graduate studies – inviting scholarship applications – managing selection process of scholarship awardees – disbursing stipends
Support for STI infrastructural development – developing process manuals, guidelines and development plans
Valorization of research ideas and results – organizing sandpit exercises – publishing scientific reports – assisting outreach platforms by sponsoring scientific workshops and conferences – organizing national innovation prizes
Advocacy for STI – assisting in the formation and consolidation of STI professional and academic associations – sponsoring STI exhibitions and seminars
Collection of data and statistics on STI and R&D – undertaking surveys on STI information, analyzing and disseminating results
Training, advisory and infrastructural support – training researchers in research proposal development – supporting institutions in research logistics, such as laboratory equipment – advising government on issues of STI policy formulation and evaluation (setting agendas, targets and instruments)
Policy advice – advising government on science and innovation policy – preparing policy notes to inform policymakers, scientists and the public on matters related to technology forecasting, assessment and transfer – regulating STI research
Setting research agenda/research priorities – advising government or determining national research priorities and new initiatives

Functions of Science Granting Councils
Management of scientific collaborations and agreements – managing science agreements and research collaborative networks – developing partnerships and networks among different stakeholders through the creation of technical working groups
Coordination of the national innovation system – ensuring coordination and harmonization of the country's STI policies

Source: adapted from Mouton, Gaillard and van Lill, 2015

A review of key STI policy documents of 15 African countries shows that SGCs have indeed outlined these functions in their policy documents and have been implementing them in carrying out their mandates (see Figure 2.3). One of the main highlights is the fact that all SGCs are mandated to perform the policy advice role and the management and disbursement of funds as their key functions. For instance, the Department of Research Science and Technology (DRST) under the Ministry of Infrastructure, Science and Technology in Botswana has played a lead role in the revision of the National Policy on Research, Science, Technology and Innovation, and the Implementation Plan (MIST, 2019). Uganda's National Council for Science and Technology (UNCST) on its part set in place an online research management system for efficient management of proposals, proposal review processes and award of research projects to fulfil its fund disbursement function (UNCST, 2019).

SGCs are often viewed as autonomous and professional organizations (Braun, 1998). However, there are several actors with various active roles in the research funding arena. This may include government ministries, higher education institutions, international organizations, private sector sponsors, advisory organs, scientific referees, funding administrators, and political and industrial representatives (OECD, 2011). The fact that SGCs have multiple functions and entail the involvement of multiple decision processes from multiple agents makes these organizations' grounds of interest contentious. This may include tensions in research funding priorities (e.g. basic vs. applied research) (Chataway, et al., 2019; Gulbrandsen, 2005) and contestations in research council-research community relationships, ideology dilemmas, organizational paradoxes and disagreements in disciplinary focuses, project selection, and grant management approaches (Gulbrandsen, 2005).

Figure 2.3: Functions of SGCs as Mandated by Policy Documents

Functions of SGCs	DRST, Botswana	FONRID, Burkina Faso	PASRES, Cote d'Ivoire	MiNT, Ethiopia	MESTI, Ghana	NRF, KENIA, NACOSTI - Kenya	NCST, Malawi	FNI, Mozambique	NCRST, Namibia	NCST, Rwanda	DFRSDT, Senegal	COSTECH, Tanzania	UNCST, Uganda	NSTC, Zambia	RCZ, Zimbabwe
Managing and disbursement of research grants															
– Inviting research proposal applications	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
– Managing research proposal peer-review process	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
– Disbursing research grants	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Managing and disbursement of scholarships for graduate studies															
– Inviting scholarship applications	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
– Managing selection process of scholarship awardees	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
– Disbursement of stipends	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Support for STI infrastructural development															
– Developing process manuals, guidelines and development plans	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Functions of SGCs	DRST, Botswana	FONRID, Burkina Faso	PASRES, Cote d'Ivoire	MiNT, Ethiopia	MESTI, Ghana	NRF, KENIA, NACOSTI - Kenya	NCST, Malawi	FNI, Mozambique	NCRST, Namibia	NCST, Rwanda	DFRSDT, Senegal	COSTECH, Tanzania	UNCST, Uganda	NSTC, Zambia	RCZ, Zimbabwe
Valorization of research ideas and results															
– Organizing sandpit exercises	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
– Publication of scientific reports	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
– Assisting outreach platforms by sponsoring scientific workshops and conferences	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
– Organizing national innovation prizes	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y
– Advocacy for STI		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
– Assisting in the formation and consolidation of STI professional and academic associations,	N	U	U	N	U	Y	U	N	N	N	Y	Y	Y	U	U
– Sponsoring STI exhibitions and seminars	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Collection of data and statistics on STI and R&D															
– Undertake surveys on STI information, analyze and disseminate results	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Functions of SGCs	DRST, Botswana	FONRID, Burkina Faso	PASRES, Cote d'Ivoire	MiNT, Ethiopia	MESTI, Ghana	NRF, KENIA, NACOSTI - Kenya	NCST, Malawi	FNI, Mozambique	NCRST, Namibia	NCST, Rwanda	DFRSDT, Senegal	COSTECH, Tanzania	UNCST, Uganda	NSTC, Zambia	RCZ, Zimbabwe
Training, advisory and infrastructural support															
– Train researchers in research proposal development	N	Y	Y	U	U	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
– Support institutions in research logistics, such as laboratory equipment	U	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
– Advisory support to government on issues of STI policy formulation and evaluation (setting agendas, targets and instruments)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Policy advice															
– advising government on science and innovation policy	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
– preparing policy notes to inform policy- makers, scientists and the public on matters related to technology forecasting, assessment and transfer	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Functions of SGCs	DRST, Botswana	FONRID, Burkina Faso	PASRES, Cote d'Ivoire	MiNT, Ethiopia	MESTI, Ghana	NRF, KENIA, NACOSTI - Kenya	NCST, Malawi	FNI, Mozambique	NCRST, Namibia	NCST, Rwanda	DFRSDT, Senegal	COSTECH, Tanzania	UNCST, Uganda	NSTC, Zambia	RCZ, Zimbabwe
– Regulation STI research	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Setting research agenda/research priorities															
– Advise government or determine on national research priorities and new initiatives	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Management of scientific collaborations and agreements															
– Management of science agreements and research collaborative networks	Y	Y	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
– Developing partnerships and networks among different stakeholders through the creation of technical working groups	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y
Coordination of the national innovation system															

Functions of SGCs	**DRST, Botswana**	**FONRID, Burkina Faso**	**PASRES, Cote d'Ivoire**	**MiNT, Ethiopia**	**MESTI, Ghana**	**NRF, KENIA, NACOSTI - Kenya**	**NCST, Malawi**	**FNI, Mozambique**	**NCRST, Namibia**	**NCST, Rwanda**	**DFRSDT, Senegal**	**COSTECH, Tanzania**	**UNCST, Uganda**	**NSTC, Zambia**	**RCZ, Zimbabwe**
– -Ensuring coordination and harmonization of the country's STI policies	Y	Y	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Sources	MIST Website	GoBF (2011)	PASRES website	GOE (2012)	MESTI website	GoK (2013), NRF Website	GoM (2003)	RoM (2006)	GoN (2004)	GoR (2013)		GoT (1986)	GoU (1990)	GoZ (1997)	GoZim (1986)

Notes:

- Some of these functions are not explicitly stated in policy documents but have been taken by the authors to imply the said role for example capacity building to imply strengthening the capacity of researchers on proposal writing.

Key:

- Y = YES
- N=NO
- U=UNKNOWN

Sources:
GoBF (Government of Burkina Faso) (2011) Décret N° 2011- 828 /PRES/PM/MRSI/MEF; GoE (Government of Ethiopia) (2012) Science Technology and Innovation Policy; GoK (Government of Kenya) (2013) Science Technology and Innovation Act; GoM (Government of Malawi) (2003). Science and Technology Act 2003; GoN (Government of Namibia (2004) Research, Science and Technology Act 2004; GoR (Government of Rwanda) (2013a) Decree No.80/2013; GoT (Government of Tanzania (1986) Tanzania Commission for Science and Technology Act; GoU (Government of Uganda) (1990) Uganda National Council for Science and Technology Act; GoZ (Government of Zambia) (1997) Science and Technology Act No. 26; GoZim (Government of Zimbabwe) (1986) Research Act 1986; MESTI (Ministry of Environment, Science, Technology and Innovation) Available at: http://mesti.gov.gh/. (Accessed: December 2019); MIST (Ministry of Infrastructure, Science and Technology) Botswana. Available at: http://www.gov.bw/en/Ministries--Authorities/Ministries/MIST-Events/. (Accessed: December 2019); NRF (National research Fund). Available at: https://researchfund.go.ke/. (Accessed: December 2019); PASRES (Programme d'Appui Stratégique à la Recherche Scientifique) (2019). Available at: http://www.csrs.ch/pasres/. (Accessed: December 2019); RoM (Republic of Mozambique) (2006). Mozambique Science, Technology and Innovation Strategy (MOSTIS)

The literature, although not developed in the African context, therefore shows that the role of SGCs may go beyond performing specific sets of research grant-management related functions to serving as 'fair and disinterested' mediators and stabilizers of contested interests and tensions between the state and science, and their various jurisdictions (Van der Meulen and Rip, 1998; Mouton, Gaillard and van Lill, 2015; Kruss et al., 2016). These stabilizing and intermediary agencies working at the boundary between the science and decision-making interface have been framed as 'boundary organizations (see, for example, Guston, 2001). The concept of boundary organizations in the context of science funding appears to have built on the 'principal-agent' theory, which proposes that institutional relationships could be viewed as (contractual) delegation of roles from principals (e.g. financiers) to agents (e.g. grant managing institutions managing research funds or researchers conducting basic or applied research). See, for example, Braun, 1993 and Braun, 1998.

However, this concept advances the principal-agent proposition further, claiming that such organizations exist in the "frontier of the two relatively different social worlds of politics and science", with distinct lines of accountability to two principals (Guston, 2001, p.401). Being accountable to each principal, boundary organizations create 'boundary objects' and perform activities that are beneficial to each principal. By doing so, they attempt to appeal to both sides (Guston, 2001). They facilitate cooperation between scientists and non-scientists by responding to their specific demands and interests. Their success, therefore, is determined by the degree of stability of the relationship and complementarity of goals and interests between scientists and decision-makers over time. A crucial question in public policy, however, is eliciting the critical factors that determine the stability of such relationships under potentially conflicting interests and across various contexts and operational circumstances (Leith et al., 2016).

The agendas, goals, functioning and organization of a research funding field have also been influenced by theoretical framings, such as the 'triple helix' approach, 'knowledge-based economy' or 'inclusive innovation'. Benner and Sandström (2000) and Gulbrandsen (2005) stated that theoretical concepts, such as linkages between higher education institutions, political systems, and the private sector, influence the goals and norms of evaluation and organization of research funding and knowledge production. By analysing the changing roles of science councils in South Africa, Kruss et al. (2016) also noted that SGCs in

South Africa are increasingly assuming new mandates that have led them to interact not only with knowledge producers but also knowledge users, especially excluded and marginalized groups. This suggests the increasing role of SGCs in innovation, poverty reduction and inclusive economic development in Africa perhaps as a result of the rise of the 'inclusivity' narrative in the academic discourse.

Other studies related to the functions of SGCs in Africa highlight economic and political factors that influence the functional performance of SGCs and research funding dynamics in general. Chataway et al. (2019) reported that research funding agendas (of SGCs) are determined by national political or governance cycles and corresponding development strategies and priorities of governments, external actors and debates (both international, e.g. donors, foreign universities and development agendas, and local, e.g. private sector actors), as well as institutional structural arrangement of SGCs and coordination across government ministries and sectors. Other challenges include lack of autonomy and ownership, lack of coordination among (sectoral) funding agencies and programmes with multiple and sometimes conflicting mandates and interests, absence of within-country and cross-country interactions and knowledge sharing between SGCs, limited human and financial resources and governance issues (Mouton, Gaillard and van Lill, 2015). Similarly, a recent study on research excellence in Africa found out that local and cross-country research collaborations between SGCs and researchers are limited owing to inadequate and inefficient legal frameworks, leading to a 'silo mentality' by researchers (Tijssen and Kraemer-Mbula, 2018).

To address some of these challenges, capacity strengthening projects have been initiated, the most notable being the Science Granting Councils Initiative (SGCI) in Sub-Saharan Africa[7]. The SGCI aims to strengthen the capacity of 15 SGCs to design and monitor research programmes, formulate and implement policies based on the use of robust STI indicators, support knowledge transfer to the private sector, and establish partnerships with one another, and with other innovation system actors. This is achieved through, inter alia, funding collaborative research, on-site mentoring and coaching sessions, annual and regional training events and meetings, and webinars (SGCI, 2019).

The role of SGCs in the functioning of innovation systems

In the preceding section, we have discussed the functions of SGCs in Africa. In this section, we reflect on how these functions contribute to the functioning of innovation systems based on the indicators of (technological) innovation system functions provided in Figure 2.1.

Literature on technological innovation systems shows that innovation systems mobilize financial and human resources to support research and development, and entrepreneurial activities (Hekkert, et al., 2007). Examples of such resources could be R&D grants by governments aimed at generating knowledge or grants available to test new prototypes or develop market information for new technologies (Hekkert, et al., 2007). In this regard, SGCs disburse and manage research grants and scholarship stipends and support STI research infrastructure development, indicating that SGCs play a crucial role in the fulfilment of the *resource mobilization* function of innovation systems (see Figure 2.4).

Figure 2.4: Specific Functions of SGCS and their Contributions to Innovation System Functions Based on the Indicator Activities of Innovation System Functions Provided in Figure 2.1

Specific functions of Science Granting Councils	Functions of innovation systems
– Disbursing research grants – Disbursing stipends and scholarships – Developing process manuals, guidelines and development plans for STI infrastructural development – Supporting institutions in research logistics, such as laboratory equipment	Resource mobilization
– Organizing sandpit exercises – Undertaking surveys on STI information, analyzing and disseminating results	Knowledge development
– Training researchers in research capacity development – Managing science agreements and research collaborative networks – Developing partnerships and networks among different stakeholders through the creation of technical working groups – Publication of scientific reports – Assisting outreach platforms by sponsoring scientific workshops and conferences – Sponsoring STI exhibitions and seminars	Knowledge diffusion

Specific functions of Science Granting Councils	Functions of innovation systems
– Advising governments on issues of STI policy formulation and evaluation (setting agendas, targets and instruments) – Preparing policy notes to inform policymakers, scientists and the public on matters related to technology forecasting, assessment and transfer – Regulating STI research – Advising governments to determine national research priorities and new research initiatives – Organizing national innovation prizes	Guidance of search
– Assisting in the formation and consolidation of STI professional and academic associations,	Creation of legitimacy

Source: Authors

Knowledge development (i.e. technological, social, managerial and organizational learning) and *knowledge diffusion* through networks are the core functions of innovation systems (Hekkert et al., 2007). SGCs can assist knowledge development efforts by innovation system actors. This, for example, includes supporting sandpit exercises, in which multi-disciplinary researchers and potential users of research outcomes explore research problems and ideate potential interventions, and by doing so, valorise new research ideas and innovative research projects (Dundee, 2004). They also sponsor and facilitate scientific workshops and conferences between public-private actors, including research users, contributing to learning-by-interacting and learning-by-using processes (Lundvall and Johnson, 1994). For instance, in 2019, the Research Council of Zimbabwe (RCZ) held its 12th International Research Symposium and published research findings in a book titled, 'The Nexus between Research and Industry: Key to Innovation and Sustainable Development'. Through these symposiums, RCZ sought to inform participants about new research insights and disseminate research findings on the complex link between research, usage of research findings and decision-making processes (RCZ, 2019). SGCs may also undertake surveys on STI information, analyse and disseminate results to assist further research and strategic decision making in STI. For example, the Ethiopian Science and Technology Information Center (STIC) undertakes and publishes research on STI indicators (STIC, 2014). It also conducts the Ethiopian Innovation Survey, the Technology

Capacity Assessment, and Indigenous Technologies survey – aimed at informing policy and promoting technology development in Ethiopia (STIC, 2014). Ghana's Council for Scientific and Industrial Research (CSIR), under the Ministry of Environment, Science, Technology and Innovation (MESTI), also maintains a digital repository of research outputs, including publications, reports, and surveys among others (MESTI, 2019). All these activities contribute to the *knowledge development* function of innovation systems (see Figure 2.4).

When it comes to *knowledge diffusion*, SGCs contribute by publishing scientific reports and assisting outreach platforms by sponsoring trainings, scientific workshops, conferences, and other scientific networking and collaboration platforms (see Figure 2.4). For instance, Burkina Faso's Fonds National de la Recherche et de l'Innovation pour le Développement (FONRID), trained 118 researchers on research writing in 2019 as one of a series of capacity development trainings it organizes every year (FONRID, 2019). Concerning networking and scientific platforms, Zambia's National Science and Technology Council (NSTC), Mozambique's Fundo Nacional de Investigação (FNI) and the German Research Foundation (DFG) organized a joint symposium on solar energy in 2019 (NSTC, 2019).

Innovation systems also provide guidance towards innovation activities in several ways, such as setting targets, goals, and expectations; providing incentives, such as taxes and standards and favourable policies (Hekkert et al., 2007). In this regard, SGCs advise governments on or determine national research priorities and new initiatives, prepare and publicize policy notes to inform policymakers, scientists and the public on matters related to technology forecasting, assessment and transfer (see Figure 2.4). Another mechanism that has been recognized to stimulate innovation is periodically awarding prizes to innovators that produce successful innovations. Such prizes aim at encouraging innovators to: identify new (and efficient) ways of addressing societal challenges; demonstrate the feasibility of new techniques, approaches or technologies; and promote and (commercially) diffuse such innovations in economic systems (Stine, 2009). Figure 2.2 shows that SGCs play crucial roles by valorising research ideas and results through national innovation prizes. Namibia's Commission for Research, Science and Technology has been running Innovation Challenge projects, such as the National Innovation Challenge for Women (NICW), that aim to identify, train and award winners (NCRST, 2019). Similarly, the Ethiopian Ministry of Innovation and Technology (MInT) organizes a Science, Technology and Innovation Award. As of 2019, the Government had awarded a total of 1,890 individuals for their outstanding contributions to STI. In Cote d'Ivoire, the Programme d'Appui Stratégique à la Recherche Scientifique (PASRES), the Ministère de l'Enseignement Supérieur et de la Recherche Scientifique (MESRS) and the Ministère de la Femme, de la Famille et de l'Enfant (MFFE) also organise similar awards to outstanding students in Science, Technology, Engineering and Mathematics (STEM) (PASRES, 2019). Malawi's National Commission for Science and Technology (NCST) holds annual science fairs and awards over 10 winners each year under various categories, including on innovation and value addition (NCST, 2019). Such activities of SGCs may contribute to the *guidance of search* and *creation of legitimacy* functions of innovation systems.

New innovations are useful when put into economic use. Therefore, commercial experimentations are key activities of entrepreneurs in innovation systems (Hekkert et al., 2007). As part of their research management role, SGCs could as well have a crucial function of linking research to use (Cordero et al., 2008; Holmes et al., 2014; Tetroe et al., 2008), and by doing so, facilitate entrepreneurship and new technology start-ups. They may fund, for instance, technology piloting programmes, exhibitions, information campaigns, and innovation champions. The Tanzania Commission for Science and Technology (COSTECH), for instance, supported the development and roll-out of Maxmalipo, an innovative payment system that was deployed for use by the Tanzania Revenue Authority (TRA). Maxmalipo has expanded its usability and application on different platforms including retailers and banks, among others (Rajabu, 2014). SGCs can thus contribute to the *entrepreneurial activities and market formation* functions of innovation systems.

Finally, in Section 2, we noted that innovation system functions interact and influence one another. So, an SGC contributing to one or more of the innovation system functions could also positively influence other innovation system functions. This may set the functioning of entire (technological) innovation systems into motion, eventually leading to enhanced innovative activities and entrepreneurial experimentations. By doing so, SGCs could position themselves as crucial actors within innovation systems to stimulate the emergence and growth of niches around key technology areas, which could offer significant opportunities for sustainable socio-economic development (Romijn and Caniëls, 2011).

Concluding remarks

In this chapter, we sought to reflect on the key theories of innovation and innovation systems in relation to the functioning and role of organizations that fund and support STI in Africa – that we broadly referred to as Science Granting Councils (SGCs). By reviewing existing studies, we qualitatively highlighted the multiple roles that SGCs in Africa perform, going beyond availing and managing research grants. These, among others, include management of scholarships and bursaries, STI and R&D data collection and dissemination, STI advocacy, science communication and outreach, STI policy advice, research capacity building, supporting translation of research-to-use, and managing the boundary between decision-makers and the research community. We briefly reflected on such functions in the context of the theory of the functions of innovation systems and suggested that SGCs in Africa could be central actors in innovation systems by playing multiple roles that contribute to the functioning of innovation systems. On the basis of such preliminary insights, SGCs could be regarded as 'catalysts' of the functioning of innovation systems and sustainable development in Africa.

These preliminary insights suggest that through systematic investment, SGCs could strategically "promote collaborative research and networking initiatives … by attaching relevant conditions to their funding", and by doing so, stimulate the development of technologies and socio-technical niches that may lead to broader transitions to sustainable development (Caniëls and Romijn, 2008, p.264). They do so by "… ensuring coordination and harmonization of a country's STI policies, so that STI activities are comprehensive, complementary and reinforcing across all sectors and ministries" (Mouton, Gaillard and van Lill, 2015, p.162). Based on the transformative innovation policy approach, Chataway et al. (2017, p.12), reported that a crucial issue in 'experimental initiatives'[8] of 'transformative change' is "…how we connect these initiatives, upscale them and make them transformative... This connecting up work might be an important role for national funders and innovation agencies."

A wider role of SGCs in Africa may entail stimulating (and perhaps coordinating) and supporting the build-up of networks of (collaborative) actors, institutions and capabilities focused on researching, developing, adapting, and marketing sustainable innovations, which contribute to sustainable development (see Wakeford, et al., 2017; Okereke, et al., 2019 and Lee and Mathews, 2013 for some useful insights). In other words, SGCs could facilitate the emergence and sustenance of public-private partnerships (PPPs) in research and (sustainable) innovation (Oyeyinka, Vallejo, and Vasudev, 2018). To do so, the functions of innovation systems could provide useful guidance to the SGCs in targeting the different elements of an innovation system more broadly. For international cooperation capacity-building initiatives, such as the SGCI, this may mean focused support to SGCs on innovation-capacity and 'systemic' partnership building in addition to research management.

However, there are several issues worth noting. First, we identified multiple SGC functions by reviewing existing studies. But this does not imply that the reported SGC functions are typical, exhaustive or equally performed across all SGCs in Africa. This is even more critical when there has been an increasing distinction of funding arrangements and organizations dedicated to research and innovation in African countries (Mouton, Gaillard and van Lill, 2014). Further systematic research on the specific mission and vision of SGCs and their functions, and how these are determined and prioritized in national settings is pertinent. This may assist in tailoring future interventions to priority missions, visions, functions and capacity needs. Second, positioning the role of SGCs in the context of a broader network of actors and institutions, which not only explore and tap into emerging 'windows of opportunities' but also build local technological and innovation capabilities, has several implications. It calls for the appreciation of the role of other innovation system actors, such as other government agencies, industry and local and international development partners, and their functions (Silvestre and Neto, 2014). What interventions should be undertaken to boost the contribution of such actors to the functioning of SGCs? Third, the fact that SGCs operate within innovation systems embedded in specific techno-economic and national institutional environments also imply that there may be a need to design specific measures that not only respond to the peculiar political-economy constraints and capacity needs of SGCs in specific settings, but also address the specific capacity needs of other innovation system actors in relation to the functioning of SGCs. Would future interventions of strengthening the capacities of SGCs also consider such specificities as well as the unique capacity needs of other key actors in relation to research and innovation? Finally, in view of the crucial role of SGCs in mediating contestations between science and politics, what roles do future interventions in addition to deepening and consolidating capacity gains of past interventions play so that many SGCs in Africa become 'capable' boundary managers between decision-makers and the science community? Besides, what interventions are necessary so that several other SGCs in Africa, which are 'embedded' within their 'principal' (e.g. a department, directorate or sub-directorate within a science and technology – or innovation – ministry) (Mouton, Gaillard and van Lill, 2014), broaden their remit and become relatively autonomous boundary managers of research and innovation funding?

Notes

[1] See for example, the missions and visions of the Tanzanian Commission for Science and Technology (COSTECH) and the National Commission for Science and Technology (NCST), Malawi.

[2] A limitation of this chapter is that it only highlights the potential broader role that SGCs could play without sufficient basis on primary data. Future studies may map the actual contributions of SGCs in Africa in the functioning of innovation systems and the achievement of the goals of global and continental development agendas.

[3] Klein et al. (2016) provides an extensive review of the research on these innovation system approaches.

[4] Underpinned by the three elements of environmental sustainability, social equity and economic development.

[5] Whereas there are no agreed set of indicators for these functions (largely due to context specificities), researchers have identified example indicators for analytical purposes. For example, Tigabu (2018) has identified a set of indicators of innovation system functions for small-scale renewable technology innovation systems in East Africa, which are provided in Figure 2.1.

[6] As complex systems, feedback loops between innovation system functions are often unpredictable. Lack of system functions or activities that negatively impact one function can negatively influence other functions. In this case, a vicious cycle of causation may materialise (Suurs and Hekkert, 2009).

[7] Other pan-African and cross-border initiatives of building up broader STI capacities include: The Partnership for Skills in Applied Sciences, Engineering and Technology (PASET); The African Institute for Mathematical Sciences (AIMS); The Network of African Science Academies (NASAC) (more details on these initiatives can be found on Kooperation international, 2018).

[8] Small-scale niche experiments, i.e. new socio-technical innovations nurtured and shielded from existing dominant alternative technologies and practices (Chataway et al., 2017).

References

ACBF (African Capacity Building Foundation), 2017. *Building capacity in science, technology and innovation for Africa's transformation: the role of higher learning and research institutions*. Harare: The African Capacity Building Foundation.

African Union Commission. 2014. *On Wings of Innovation, the AU Science, Technology and Innovation Strategy for Africa 2024 (STISA-2024)*. [Online]. African Union Commission. Available at: https://au.int/sites/default/files/newsevents/workingdocuments/33178-wd-stisa-english_-_final.pdf (Accessed 12 November 2019).

African Union Commission. 2015. *Agenda 2063: The Africa We Want*. [Online]. African Union Commission. Available at: http://www.un.org/en/africa/osaa/pdf/au/agenda2063.pdf (Accessed 12 November 2019).

Benner, M. and Sandström, U., 2000. Institutionalizing the triple helix: research funding and norms in the academic system. *Research Policy*, 29(2), pp. 291–301. doi: 10.1016/S0048-7333(99)00067-0.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A., 2008. Analyzing the functional dynamics of technological innovation systems: a scheme of analysis. *Research Policy*, 37(3), pp. 407–429. doi: 10.1016/j.respol.2007.12.003.

Berkhout, F., Angel, D. and Wieczorek, A., 2009. Asian development pathways and sustainable socio-technical regimes. *Technological Forecasting and Social Change*, 76, pp. 218–228.MIST (Ministry of Infrastructure, Science and Technology Botswana). 2019. *MIST Events*. [Online]. Available at: http://www.gov.bw/en/Ministries--Authorities/Ministries/MIST-Events/. (Accessed 5 December 2009).

Braun, D., 1993. Who governs intermediary agencies? principal-agent relations in research policy-making. *Journal of Public Policy*, 13(2), pp. 135–162. doi: 10.1017/S0143814X00000994.

Braun, D. 1998. The role of funding agencies in the cognitive development of science. *Research Policy*, *27*(8), pp.807–821. doi.org/10.1016/S0048-7333(98)00092-4

Caniëls, M. C. J. and Romijn, H. A., 2008. Strategic niche management: towards a policy tool for sustainable development. *Technology Analysis and Strategic Management*, (e-journal) 20(2), pp. 245–266. doi: 10.1080/09537320701711264.

Caswill, C., 2005. Whose agency? looking forward to the virtual research council, *Information, Communication & Society*, (e-journal) 8(1), pp. 1–29. doi: 10.1080/1369118042000284623.

Chataway, J., Chux, D., Kanger, L., Ramirez, M., Schot, J., & Steinmueller, E.., 2017. Developing and enacting transformative innovation policy: a comparative study. *8th International Sustainability Transitions Conference*. Available at: http://www.tipconsortium.net/wp-content/uploads/2019/05/Developing-and-enacting-Transformative-Innovation-Policy-A-Comparative-Study.pdf (Accessed 19 February 2020).

Chataway, J., Dobson, C., Daniels, C., Byrne, R., Hanlin, R., and Tigabu, A., 2019. Science granting councils in Sub-Saharan Africa: trends and tensions, *Science and Public Policy*, pp. 1–12. doi: 10.1093/scipol/scz007.Cordero, C., Delino, R., Jeyaseelan, L., Lansang, M. A., Lozano, J. M., Kumar, S., ... and Tugwell, P., 2008. Funding agencies in low- and middle-income countries: support for knowledge translation, *Bulletin of the World Health Organization,* 86(7), pp. 524–534. doi: 10.2471/BLT.07.040386.Cornell University, INSEAD and WIPO. 2018. *Global Innovation Index 2018: Energizing the World with Innovation*. Ithaca, Fontainebleau, and Geneva.

Diercks, G.A., 2017. *Transformative Innovation Policy: Assessing Discourse Institutionalism of an Emerging Policy Paradigm*. A thesis submitted to Imperial College, London for the Degree of Doctor of Philosophy.

Dundee, J.G., 2004. Sandpit initiative digs deep to bring disciplines together. *Nature*, *427*, pp. 187.

Edquist, C. and Johnson, B., 1997. Institutions and organizations in systems of innovation. *Systems of Innovation: Technologies, Institutions and Organizations*, pp. 41–63. doi: 10.1016/S0024-6301(98)90244-8.

Fagerberg, J., Srholec, M. and Verspagen, B., 2010. Innovation and economic development. *Handbook of the Economics of Innovation*, 2(1), pp. 833–872. doi: 10.1016/S0169-7218(10)02004-6.

FONRID. 2019. *Résultats de l'avis de formation en rédaction de projets de recherche et d'innovation*. [Online]. Available at: http://www.fonrid.bf/index.php?option=com_content&view=category&layout=blog&id=16&Itemid=109. (Accessed on 31 August 2020).

Freeman, C., 1987. *Technology policy and economic performance: lessons from Japan*. London: Pinter.

Gulbrandsen, M., 2005. Tensions in the research councils' community relationship. *Science and Public Policy*, 32(3), pp. 199–209. doi: 10.1038/315710b0.

Guston D. H., 2001. Boundary organizations in environmental policy and science: an introduction. *Science, Technology, & Human Values*. 26(4), pp. 399–408.

Hekkert, M. P., Suurs, R. A., Negro, S. O., Kuhlmann, S., and Smits, R. E., 2007. Functions of innovation systems: a new approach for analysing technological change. *Technological Forecasting and Social Change*. 74(4), pp. 413–432. doi: 10.1016/j.techfore.2006.03.002.Holmes, B. J., Schellenberg, M., Schell, K., and Scarrow, G., 2014. How funding agencies can support research use in healthcare: an online province-wide survey to determine knowledge translation training needs, *Implementation Science*. 9(1), pp. 1–10. doi: 10.1186/1748-5908-9-71.Jowi, O. J. and Anie, M. O., 2013. Research and innovation management: comparative analysis. *Programme on Innovation, Higher Education and Research for Development IHERD*, Paris: OECD. p. 35.

Kingiri, A. N. and Fu, X., 2019. Understanding the diffusion and adoption of digital finance innovation in emerging economies: M-Pesa money mobile transfer service in Kenya. *Innovation and Development*. pp. 1–21. doi: 10.1080/2157930x.2019.1570695.

Klein, M. and Sauer, A., 2016. *Celebrating 30 years of innovation system research: what you need to know about innovation systems*. Hohenheim Discussion Papers in Business, Economics and Social Sciences, No. 17-2016, Universität Hohenheim, Fakultät Wirtschafts- und Sozialwissenschaften, Stuttgart. [Online]. Available at: http://nbn-resolving.de/urn:nbn:de:bsz:100-opus-12872 (Accessed 20 November 2019).

Kooperation international, 2018. *Science and Innovation in Africa: International Funding and Cooperation*. ITB infoservice Special Edition No. 12 – 03/18.

Kruss, G., Haupt, G., Tele, A., and Ranchod, R., 2016. *Balancing multiple mandates: the changing role of science councils in South Africa*. Johannesburg: Human Sciences Research Council.

Lee, K. and Mathews, J., 2013. *Technology and Innovation for Sustainable Development*. CDP Background Paper No. 16 ST/ESA/2013/CDP/16. Department of Economic and Social Affairs.

Leith, P., Haward, M., Rees, C., and Ogier, E., 2016. Success and evolution of a boundary organization. *Science Technology and Human Values*. 41(3), pp. 375–401. doi: 10.1177/0162243915601900.Lundvall, B. and Johnson, B., 1994. The learning economy. *Journal of Industry Studies*, 1(2), pp. 23–42. doi: 10.1080/13662719400000002.

Ministry of Environment, Science, Technology and Innovation (Ghana), 2019. Available at: http://mesti.gov.gh/ (Accessed 8 December 2019).

Ministry of Devolution and Planning. 2017. *Implementation of the Agenda 2030 for Sustainable Development in Kenya.* Ministry of Devolution and Planning, Government of Kenya.

Mouton, J., Gaillard, J., and van Lill, M., 2014. *Science granting councils in sub-Saharan Africa.* Final report. Stellenbosch: Centre for Research on Evaluation, Science and Technology (CREST)

Mouton, J., Gaillard, J. and van Lill, M., 2015. *Functions of science granting councils in sub-Saharan Africa*. Stellenbosch: Centre for Research on Evaluation, Science and Technology (CREST)

Mugabe, J. O., 2011. *Science, technology and innovation in Africa's regional integration: from rhetoric to practice*. ACODE Policy Research Series No.44. Kampala: ACODE.

National Academy of Sciences. 2007. *Innovation inducement prize at the National Science Foundation*. Washington, D.C.: The National Academies Press.

National Commission on Research, Science and Technology. 2019. *National innovation challenge for women*. [Online]. Available at: http://www.ncrst.na/news/196/National-Innovation-Challenge-for-Women-NICW-and-the-FemBioBiz-Season-III/ (Accessed 31 August 2020).

National Commission for Science and Technology of Malawi. 2019. Available at: https://www.ncst.mw/. (Accessed 12 December 2019).

National Science and Technology Council. 2019. Available at: http://www.nstc.org.zm/. (Accessed 12 December 2019).

Okereke, C., et al., 2019. Governing green industrialization in Africa: assessing key parameters for a sustainable socio-technical transition in the context of Ethiopia. *World Development*. The Authors, 115, pp. 279–290. Doi: 10.1016/j.worlddev.2018.11.019.

Organization for Economic Co-operation and Development. 2005. *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*, 3rd ed. Paris: OECD Publishing

Organization for Economic Co-operation and Development. 2011. *Public Sector Research Funding*. OECD Innovation Policy Platform, 17.

Oyeyinka, B., Vallejo, B., and Vasudev, S. 2018. *Towards effective public-private partnerships in research and innovation: a perspective for African Research Granting Councils*. [Online]. Available at: https://sgciafrica.org/en-za/

resources/Resources/Masterclass%20Paper%20on%20PPP%20in%20Research%20and%20Innovation.pdf (Accessed 20 November 2019).

Pociovălişteanu, D. M. et al., 2016. Innovation for sustainable development. *Journal of Cleaner Production*, 133(October), pp. 389–390. doi: 10.1016/j.jclepro.2016.05.152.

Programme d'Appui Stratégique à la Recherche Scientifique. 2019. Available at: http://www.csrs.ch/pasres/. (Accessed 12 December 2019).

Rajabu, J., 2014. *Tanzania moving towards cashless society through mobile innovations. Tanzania*. [Online]. Available at: Tanzict.wordpress.com (Accessed 31 August 2020).

Republic of Botswana, 2011. *National Policy on Research, Science, Technology and Innovation*. Gaborone: Ministry of Infrastructure, Science and Technology.

Research Council Zimbabwe, 2019. Available at: http://www.rcz.ac.zw/ (Accessed 12 December 2019).

Romijn, H. A. and Caniëls, M. C.J, 2011. Pathways of technological change in developing countries: review and new agenda. *Development Policy Review*, 29, pp. 359–380. doi: 10.1111/j.1467-7679.2011.00537.x.

Schot, J. and Steinmueller, W. E., 2018, Three frames for innovation policy: R&D, systems of innovation and transformative change. *Research Policy*, 47(9), pp. 1554–1567. doi: 10.1016/j.respol.2018.08.011.

Science and Technology Information Center, 2014. *Science and Technology Indicators Report.* Addis Ababa: STIC.

Science Granting Councils Initiative. 2019. Available at: https://sgciafrica.org/en-za/home

Silvestre, B. S. and Neto, R. E. S., 2014, Capability accumulation, innovation, and technology diffusion: lessons from a base of the pyramid cluster. *Technovation*. Elsevier, 34(5–6), pp. 270–283. doi: 10.1016/j.technovation.2013.09.007.

Stine, D. D., 2009. *Federally funded innovation inducement prizes*. CRS report for Congress. [Online]. Available at: https://fas.org/sgp/crs/misc/R40677.pdf (Accessed 31 August 2020).

Suurs, R. A. A. and Hekkert, M. P., 2009. Cumulative causation in the formation of a technological innovation system: the case of biofuels in the Netherlands. *Technological Forecasting and Social Change*, 76(8), pp. 1003–1020. doi: 10.1016/j.techfore.2009.03.002.

Suurs, R. A. A., Hekkert, M. P. and Smits, R. E. H. M., 2009. Understanding the build-up of a technological innovation system around hydrogen and fuel cell technologies. *International Journal of Hydrogen Energy*, 34(24), pp. 9639–9654. doi: 10.1016/j.ijhydene.2009.09.092.

Tetroe, J. M. et al., 2008. Health research funding agencies' support and promotion of knowledge translation: an international study. *Milbank Quarterly*, 86(1), pp. 125–155. doi: 10.1111/j.1468-0009.2007.00515.x.

Thèves, J., Lepori, B. and Larédo, P., 2007. Changing patterns of public research funding in France. *Science and Public Policy*, 34(6), pp. 389–399. doi: 10.3152/030234207X229501.

Tigabu, A., 2017. Political and economic constraints influencing science granting councils and R&D in Sub-Saharan Africa: the Case of Ethiopia. In: Chataway, J. et al. *Case studies of the political economy of science granting councils*. International Development Research Centre (IDRC). Available at: https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/56811/IDL-56811.pdf?sequence=2&isAllowed=y (Accessed 13 November 2019).

Tigabu, A. D., 2017. Analysing the diffusion and adoption of renewable energy technologies in Africa: the functions of innovation systems perspective. *African Journal of Science, Technology, Innovation and Development*. doi: 10.1080/20421338.2017.1366130.

Tigabu, A. D., Berkhout, F. and van Beukering, P., 2015. The diffusion of a renewable energy technology and innovation system functioning: comparing bio-digestion in Kenya and Rwanda. *Technological Forecasting and Social Change*, 90, pp. 331–345. doi: 10.1016/j.techfore.2013.09.019.

Tijssen, R. and Kraemer-Mbula, E., 2018. Research excellence in Africa: policies, perceptions, and performance. *Science and Public Policy*, 45(3), pp. 392–403. doi: 10.1093/scipol/scx074.

Uganda National Council for Science and Technology. 2019. Available at: https://www.uncst.go.ug/. (Accessed 12 December 2019).

United Nations Educational, Scientific and Cultural Organization. 2015. *Towards 2030: UNESCO Science Report*. Paris.

Van Alphen, K., Hekkert, M. P. and Turkenburg, W. C., 2010. Accelerating the deployment of carbon capture and storage technologies by strengthening the innovation system. *International Journal of Greenhouse Gas Control*. 4(2), pp. 396–409. doi: 10.1016/j.ijggc.2009.09.019.

Van der Meulen, B. and Rip, A., 1998. Mediation in the Dutch science system. *Research Policy* 27(8), pp. 757– 769

Verspagen, B., 2004. Innovation and economic growth. In: Fagerberg, J., Mowery, D. and Nelson, R.R. (eds.) *The Oxford Handbook of Innovation*. Oxford: Oxford University Press, doi: 10.1093/oxfordhb/9780199286805.003.0018.

Wakeford, J. J. et al., 2017. Innovation for green industrialization: an empirical assessment of innovation in Ethiopia's cement, leather and textile sectors. *Journal of Cleaner Production*, 166, pp. 503–511. doi: 10.1016/j.jclepro.2017.08.067.

3

Innovation Systems Building and Structural Transformation

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Abstract

Taking structural transformation as its point of departure, this chapter discusses a candidate for the best way to analyse and build African systems of innovation towards poverty eradication. It focuses on the concept of *reduced* systems of innovation – as opposed to the broader concept of national systems of innovation – where concepts such as *functions of the innovation systems*, *innovative clusters* and the *triple helix* are brought in as analytical tools. Drawing on examples from the literature, it discusses the status of innovation and innovation systems in Africa to prepare grounds in search of an appropriate strategy for innovation systems building in Africa. Considering the crucial importance for the region to quickly move up the innovation capability ladder, the chapter has paid special attention to the innovation system components related to the relationships between research and productive sectors, and in so doing it emphasizes the role of the Science Granting Councils (SGCs) in match-making, funding and coordination of the systems.

Introduction

Innovation has been accepted as a powerful instrument of social and economic development, including poverty eradication – for poor countries such as those in Africa. In economic terms, innovation is about market introduction of new or improved products, processes and new business models. Innovation enables opening up new, competitive and growing businesses in countries. The outcome and ultimate impact of innovation is structural transformation of economies – moving from low to high-knowledge content businesses, thereby increasing opportunities for decent employment and raised income for the masses. Historically, this is how it happened in now-developed countries: through technology learning and innovation, they structurally transformed their economies gradually by diversifying from agriculture and natural resources to manufactured goods. This led to a booming manufacturing sector that increasingly became knowledge intensive and diversified. At the highest level, structural transformation leads to the dominance of knowledge-intensive service sectors and high levels of income.

In terms of employment, structural transformation moves labour and other productive resources from low to high productivity economic activities. It does this by simultaneously generating productivity growth within sectors and shifting labour from lower to higher knowledge content sectors, thereby creating more and decent jobs. A point of departure for agricultural states has always been increased agricultural productivity, thereby shifting labour and other resources from agriculture to higher knowledge content and more productive and decent employment in the manufacturing sector. More specifically, a successful structural transformation enables the agricultural sector – through increased productivity – to provide food, labour, and even savings to the process of industrialization and urbanization; and as economies move up the ladder of development, service sectors would gain importance (Timmer, 2007).

Of all the sectors in the process of structural transformation, the manufacturing sector is of critical importance: apart from being rich in employment, the sector has a pull effect on other sectors of the economy by stimulating demand for agricultural produce, and more and better services such as banking, insurance, ICT and transport, and thereby contributes to further job creation. Accompanied with well-crafted policies, therefore, the manufacturing sector has potential – more than any other sector – to provide employment opportunities to most people, including the poorest in the country.

However, structural transformation cannot happen without a conscious effort to accumulate productive capabilities which allow a country to increase its agricultural productivity followed by deepening manufacturing capabilities, producing increasingly diverse and complex products (Kauffman, 1993). This means that a country cannot get rid of poverty without first deepening its productive capabilities. According to Lee, Juma and Mathews (2014), the variance in income levels across countries comes basically from differences in capabilities in many aspects, including in the production and commercialization of internationally competitive products for a prolonged period. Such capabilities can be diverse, but very important ones are technological and innovation capabilities.

African countries that are currently poverty stricken, with economies still dependent on agriculture and natural resources, need to deepen their productive capabilities to enable the region to structurally transform towards knowledge intensive and diversified manufactured goods, thereby radically addressing poverty by increasing decent jobs for the masses. This need has somewhat been realized as indicated in the AU Agenda 2063: The Africa We Want. For instance, in the first of the seven aspirations in this document: "a prosperous Africa based on Inclusive Growth and Sustainable Development," two of the affirmations in this aspiration are precisely on structural transformation, which are: first, "*economies are structurally transformed to create shared growth and decent jobs for all*"; and second, "*modern agriculture for increased production, productivity and value addition contribute to farmer and national prosperity*" (AUC, 2014, p 11).

The above notwithstanding, however, there has emerged a counter argument that, given what is currently happening to most African countries, that is, pre-maturely being service oriented, some scholars are suggesting a need for Africa to follow a different path for structurally transforming their economies; Rodrik (2014), for instance proposes three other alternatives in addition to the industrialization path, which are: first, agriculture-led growth, based on diversification into non-traditional agricultural products; second, to generate rapid growth in productivity in services, which is already evident. The third is natural resources, with which many African countries are amply endowed. However, Rodrik's analysis ended up with a very narrow possibility for any of these other alternatives working; the main argument being lack of historical examples of countries that have pulled off such strategies. As authors of this chapter – partly because of the conclusions from

Rodrik (2014) that no other path seems feasible – we believe that industrialization, through adding value to huge natural resources that Africa is blessed with, is still the way towards sustainable growth and poverty alleviation for most African countries. Granted, given the changed global environment, it is much harder now for the region to succeed through the industrialization path than it was then, but so far it is the only way with some light –however dim it may be. Therefore, with carefully crafted innovative policy directives, it is still possible to grow through industrialization. What we are saying here is that although Rodrik (2014) has interestingly raised issues that seriously hamper African success through industrialization, we believe it is still possible – however challenging it may be to propose alternative strategies under a changed environment; and this is our position as we proceed with the rest of the content of this chapter.

As already alluded to, at the centre of structural transformation is capability in science, technology and innovation (STI), which fortunately Agenda 2063 also realizes (see AUC, 2014, p 11). The major problem, however, is that, although things look rosy in blueprint, in practical terms – especially building of capabilities in STI – many African strategies have serious flaws: for most countries, either there is no strategy or the strategy is inappropriate. This chapter attempts to contribute to addressing this problem; specifically, a proposal on workable approaches to innovation system building in support of structural transformation. The chapter is organized as follows: section two following this introduction is a brief status of innovation and innovation systems in Africa, focusing on industry and agriculture as two major important sectors during the onset of the structural transformation. It is a very important section of the chapter that lays fruitful grounds for our proposal for approaches to systems building in an African setting. Section three is on theoretical and practical approaches to systems building in an African setting, while section four is on the role of the Science Granting Councils (SGCs) in *reduced* systems of innovation, for example, cluster initiatives; and finally, section five gives concluding remarks.

Status of innovation and innovation systems in Africa

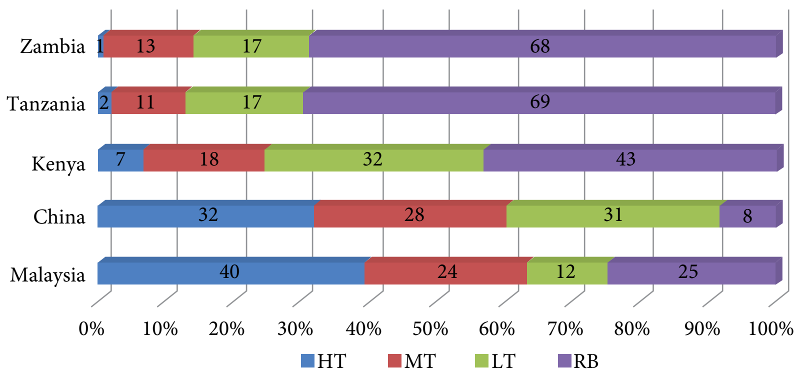
The manufacturing sector: size, innovativeness and linkages

Experience elsewhere has shown that at the climax of the structural transformation, the contribution of the manufacturing sector is 40 per cent of the GDP. The African manufacturing sector is currently very far from this figure; it was under 10 per cent in 2018, – down from almost 15 per cent in 1975 (Rodrik, 2014), supporting some arguments, including Rodrik himself, that Africa is actually de-industrializing. For two other indicators of industrial development – manufacturing value added (MVA) and manufacturing exports – Africa overall lags far behind the rest of the world, even among developing regions. In 2017, sub-Saharan Africa's MVA was only about US$145 billion. In contrast, developing countries in East Asia are far ahead and approaching developed countries' levels where the figures stand at about US$5000 and US$6500 respectively (Signe, 2018). Worse still, this dismal contribution is made by only four more industrialized countries of the region, namely South Africa, Egypt, Tunisia and Morocco (Signe, 2018). On the other hand, the manufacturing industries' share of employment currently stands well below 8 per cent, while the first wave of industrialization in Britain, Germany and other countries, put more than 30 per cent of their labour force in manufacturing before they began to de-industrialize (Rodrik, 2014).

While the foregoing picture is difficult to redress under any circumstances, it is certainly impossible without the requisite capabilities in STI. To a large extent – according to existing information – the current African industrialization situation can be explained by challenges around innovation capabilities. The data from the world innovation indicators, for instance, place all the African countries at the bottom (see for example, Cornell University, INSEAD, and WIPO, 2018, 2019). A few other surveys and studies indicate that Africa is involved in innovation of the lowest degree of novelty, that is, minor modifications and imitation of low-tech products and processes (see for instance, Cirera and Maloney, 2017; NEPAD, 2010; NEPAD, 2014; Diyamett and Mutambala, 2014; Diyamett, 2010). Along with these statistics on low levels of novelty of innovation, studies on the technology intensity of the African manufacturing sector indicate that most of the African manufacturing sector is resource-based, with very little value addition as shown in Figure 3.1.

More worrying is that, even the low-tech sector is very small for most African countries – as indicated by country cases in Figure 3.1, implying that industrialization has not really taken place for most African countries. Africa is not even on the verge of structural transformation, largely depending on natural resources for its income. For structural transformation to start taking root, there has to be fruitful value adding investments that depend on the level of technology and overall working of the national systems of innovation. Limited studies on the working of the national systems of innovation indicate that the innovation system in most African countries is disjointed and weak. This is even more serious when it comes to linkage between knowledge institutions and industrial firms. Chaminade, et al. (2009), for instance, state that innovation systems in less developed countries are fragmented and are only in the making – with some systems' parts stronger than others. This conclusive statement by Chaminade and colleagues is supported by the recent UNESCO publication which documents findings of a pilot project that includes five African countries, namely Ethiopia, Kenya, Tanzania, Rwanda and Uganda (UNESCO, 2019). This publication reports that policies relevant to innovation are still putting emphasis on knowledge transfer under traditional linear models and lack proper coordination.

Figure 3.1: Structure of Manufactured Exports by Technology Classification



Source: Adapted by authors from the Tanzania Industrial Competitiveness Report (UNIDO, 2012: p.34) (HT=High Tech, MT=Medium Tech LT=Low Tech, RB Resource Based)

Generally, studies on linkages, especially those comparing linkage across sectors, indicate that linkage within and with the manufacturing sector is the weakest. A study by the EAC and UNIDO (2017) on the competitiveness of the East African manufacturing sector, for instance, indicates that the manufacturing sector is the least connected sector of the economy in all the four East African countries included in the report. In addition, a Tanzanian study by Diyamett et al. (2013) on the analysis of sectoral systems of innovation, indicates that linkage between knowledge organizations – such as universities – and producers is weakest for the manufacturing sector. Generally, according to Ssebufuet, Ludwick and Béland (2012), the mandate to establish industry partnerships is a relatively new function for many African universities. This means that the manufacturing sector is largely not innovative because it lacks interactive linkages and learning with important knowledge generators such as the universities.

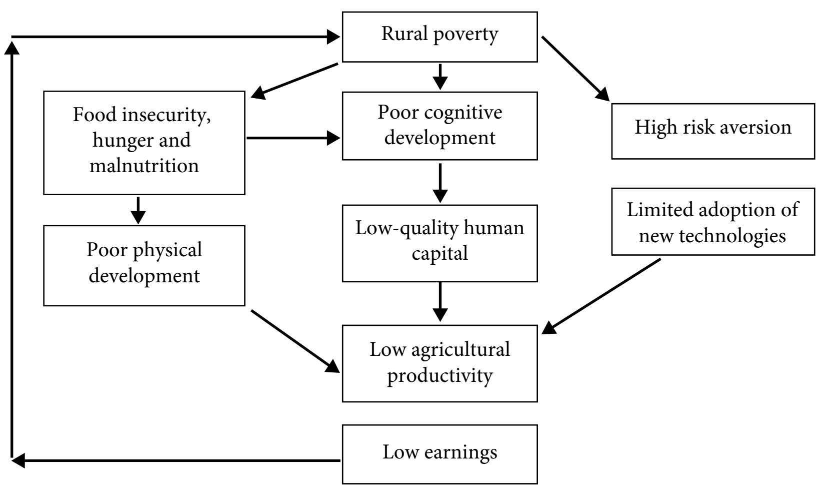
On the other hand, weak linkages between African manufacturing and knowledge generating institutions is to a large extent understandable. It is the result of the current very low level of technological capabilities in the region, which also partly explains the low level of investment in research and development (R&D) in Africa, which is one of the lowest in the world. In Western Europe and North America it is 2.5 per cent of GDP; in East Asia and the Pacific, it is 2.1 per cent; for Latin America and the Caribbean, the figure stands at 0.7 per cent, while Africa is lagging behind at 0.4 per cent (UIS, 2018). Another unfavourable characteristic of expenditure on R&D for Africa is that very little is paid for by the private sector, except for South Africa where the business sector contributed about 40.8 per cent of their 0.77 per cent of GDP spending on R&D in 2015 (SA Government News Agency, 2017). For the rest of Africa, it is negligible – further explaining weak linkages between knowledge organizations and the manufacturing sector.

Linkages between manufacturing and knowledge organizations have many implications on linkages between the manufacturing and the natural resources sectors such as mining and agriculture respectively, because such linkages very much depend on how innovative the manufacturing sector is: a well performing and competitive manufacturing sector is a local market for natural resources, especially the agricultural sector, triggering the expansion, productivity increase and profitability of these sectors. A booming manufacturing sector also benefits the agricultural sector as it manufactures agricultural inputs such as fertilizers. Important linkages and symbiotic relationships between the agricultural and manufacturing sectors have been discussed in literature, but two are of crucial importance: first, agriculture supplies inputs like raw cotton, jute, tea, coffee, etc. needed by agro-based industries; and second, industry supplies industrial inputs, such as fertilizers, pesticides, machinery, etc. to the agriculture sector. For most of the African agriculture and their small, low-tech industrial sector, such linkages are currently very underdeveloped.

Agricultural productivity increases and anchors structural transformation and alleviates poverty

According to literature on structural transformation, before the onset of the transformation, there is usually a sustained productivity increase in the agricultural sector, already pulling the majority out of poverty – dispensing income for increased demand for the manufactured goods. Therefore, the levels and growth of agricultural productivity affect not only structural transformation of economies of least developed countries (LDCs) but also their well-being; and the symptoms of poverty eradication become evident even before the onset of structural transformation. This is perhaps the reason why there is a popular belief that exclusive focus on the agricultural sector is sufficient for poverty alleviation for countries where the agricultural sector dominates. Based on this notion, the UNCTAD's Countries Report 2015 (UNCTAD, 2015) established a vicious cycle of agricultural productivity and rural poverty (see Figure 3.2), indicating that rural poverty is a major hindrance to adoption of new technologies for agricultural productivity, while at the same time adoption of new technologies is indispensable for addressing rural poverty. Under such circumstances, the most important policy options are those that can break such cycles. In so doing, it is important to connect the agricultural sector to the manufacturing sector for easy access to markets, and to start impacting on the process of structural transformation.

Figure 3.2: The Vicious Circle of Low Productivity and Rural Poverty



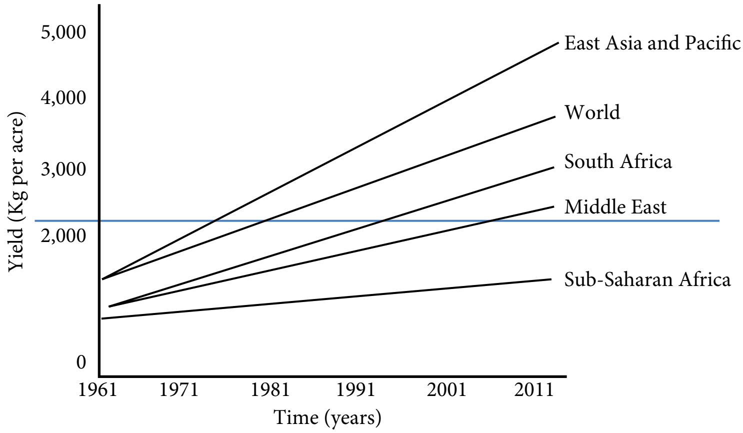
Source: UNCTAD, 2015. Adapted from: The Least Developed Country Report, UNCTAD, p. 41.

Adoption of new technologies in the agricultural sector has positive impact on structural transformation because it increases agricultural productivity, providing surpluses and more incomes that in turn increases demand for industrial goods while reallocating labour force from agriculture to other sectors, especially manufacturing (Murphy, Shleifer and Vishny, 1989). The examples of successful developing countries such as Chile, China, Mauritius and Vietnam (UNCTAD, 2014) speak for themselves. Apart from technology, productivity in agriculture is governed by determinants that complement each other through systemic interaction – labour force, in quality and human capital, is among the key determinants. Others include quantity of conventional inputs; public investment and policies; agro ecological conditions and climate change; and rural diversification (Fuglie and Rada, 2013; Dias Avila and Evenson, 2010).

As indicated in Figure 3.3, trends in agricultural productivity indicate that, while other developing countries are continuously and steadily increasing their agricultural productivity, in Africa, agriculture has remained at almost the same level as it was in the 1960s, indicating that the foregoing enabling conditions are seriously lacking in most African countries. Some challenges related to these conditions have been identified and documented. These include technological innovation, land reforms, irrigation, climate change, trade, value chains and gender gap in resources access (Abebe, Audrey and Amadou, 2018). In addition, UNCTAD (2015) reported a more systemic challenge of uncoordinated changes between structural transformation and the emergence of a diversified manufacturing sector. As a result, the proportion of subsequent increased value on agribusiness compared to that of farming remains the lowest in Africa at 0.6, compared, for example, to 5 in Latin America or 13 in the USA (AfDB, 2016). Thus, challenges of agricultural productivity of the LDCs also impede their structural transformation towards industrialization.

Looking at policy perspectives on the aforementioned challenges, Babeiya, (2015), through a historical perspective, examined the efforts that have been made in Tanzania within the agricultural sector to attain agricultural transformation. The experience from the study emphasized the strengthening of collaboration between public or governmental bureaucrats that usually comprise different sets of leaders, experts, and politicians, as an important strategy towards increased performance of the agricultural sector. This is a systemic policy issue, specifically referring to institutions; it would be impossible to get it right without comprehensive innovation systems analysis. What would be the right approach? As indicated in the introduction, this is the question this chapter is attempting to respond to.

Figure 3.3: Cereal Yields by Region, 1961-2013



Source: Adapted from Abebe, Audrey and Amadou (2018, p 5).

Systems approach in building innovative capabilities for Africa's structural transformation

Ever since the realization that innovation is systemic, that is, depending on the interactive linkages and learning among important innovation actors, there have been studies focusing on the nature and outcomes of these interactive linkages and learning in different socio-economic settings. Given the realization that such interactive linkages and learning are – to a large extent – nation specific, the concept of the national systems of innovation (NSI) was developed, basically referring to the flow of technology, knowledge and information among important actors that are key in the innovation process at the national level. Lundvall (1992) – one of the pioneers of the concept – defined NSI as that system which is constituted by elements and relationships between those elements, which interact in the production, diffusion, and use of new and economically-useful knowledge in a particular nation (Lundvall, 1992). According to many proponents of the NSI concept (e.g. Lundvall, 1992; Edquist, 1997), it consists of two types of elements: institutions and organizations. While organizations are established structures such as firms, their buyers and suppliers, competitors, universities and research organizations – as suppliers of knowledge, institutions include policies such as the incentive structures that influence innovative activities, patent laws and norms that influence the relations between universities and firms (Edquist, 1997).

The context specificity of NSI also recognizes the fact that innovation actors are embedded in much wider socio-economic systems in which context-based political and cultural influences, as well as economic policies, help to determine the scale, direction and relative success of all learning processes and the resulting innovative activities in a given context (Nelson, 1993; Gu, 1999; Edquist, 1997). A book by Nelson (1993) for instance compared different national systems, within individual chapters devoted to 15 countries: six large high-income, four smaller high-income countries and five lower income countries. Each chapter is a detailed explanation of each country's structure and approaches they took in the development of technologies and innovation approaches in different sectors, including R&D expenditures and their influence. Nelson's analysis indicated that differences in the innovative patterns of nations – among others – include size and resource endowments, national security considerations, and historical and social beliefs; further confirming that innovation is indeed a social thing. Although normally used for economic gain and benefits from economic policies, innovation largely emanates from a deep-rooted social fabric of a given society.

However, while in hindsight – as indicated in Nelson's (1993) countries analysis – it is possible to use the concept of NSI to assess the current capabilities of any given national systems of innovation and factors responsible for the observed performance, we do not yet have adequate handles to predict the future of an NSI or to construct a model through which a given NSI can be strengthened. In the words of Chaminade, et al. (2010, p.14), "the transition from an emergent innovation system to a mature innovation system is a rather unexplored research topic". This is one of the major challenges of using the concept of NSI to build innovative capabilities in poor countries with emergent innovation systems such as those in Africa because we do not have a reliable theory or adequate conceptual framework on national systems of innovation – precisely the reason Chaminade and her colleagues are calling for more research on the issue. Through this chapter, we are responding to this call.

Another challenge in the use of the concept of NSI – especially focusing on the national level – to build innovative capabilities for Africa is heterogeneity in the African economies as against the countries studied by Nelson (1993). African countries are so heterogeneous in economic activities to the extent that, it is difficult to talk of a national system of innovation on product and process technologies as there is a mix of sectors such as agricultural, manufacturing, tourism and mineral sectors. Within these there are small, large, formal and informal sectors, which are completely different in characteristics, technology and knowledge requirement, and therefore different innovation systems. African countries are also so diverse in culture, which is one important variable in the national innovation system – as indicated in Nelson's analysis.

Sectoral heterogeneity in African economies is further exacerbated by the diversity in the characteristics of technologies. For Tanzania, for instance, Mgumia, et al. (2015a) demonstrated the 'physical and economic' features of agricultural technologies as essential features of an agricultural innovation system in addition to the previously highlighted 'institutional'-based features by Hall, Mytelka and Oyeyinka (2005). This has necessitated existence of different sets of actors and their alignment in different innovations, and hence a need for innovation intermediaries – such as local government authorities (LGAs), NGOs and R&D to overcome their market and systemic failures (Mgumia et al., 2015a, b). In the current African context, it is therefore more meaningful to talk of the sectoral systems and local systems of innovation until such heterogeneity is reduced – as economies get more formalized and appreciably knowledge intensive to a few leading and dynamic sectors such as the manufacturing sector.

While our discussion will focus on reduced systems of innovation (lower than the national level, such as regional and sub-regional within a state), we will bring in the concept of the sectoral systems, and specifically – important for structural transformation – the agricultural and industrial sectors, not in isolation but rather as combined sectors, invoking the concept of the agro-industrial innovation system as a sectoral system. To put the concept of agro-industrial innovation systems in proper context, we first discuss the notions of sectoral and local systems.

Sectoral and local systems of innovation: African setting

sectoral systems

Within the particular national systems of innovation, the concept of sectoral systems of innovation can be evoked and researchers can focus their analysis at this level rather than at the aggregate national level with different sectors. The sectoral innovation system approach has been advanced by Malerba (2004; 2005) and focuses on the structure, nature, organization and dynamics of innovation and production in different sectors. The main building blocks are also the actors and institutions as stated in the national systems of innovation; additionally, technologies and their characteristics and knowledge are stressed further reinforcing the argument by Mgumia (2015a).

While we are highlighting the issue of focus on sectors rather than nations, owing to heterogeneity of African economies, scholars of innovation believe that, generally, when it comes to innovation system analysis, sectors rather than nations are the appropriate level of analysis. Malerba (2005) for instance argues that different patterns of innovation exist across sectors and that these patterns differ more among different sectors of the same economy than in the same sector across different economies, and according to him this is the reason many scholars hold the opinion that it is more meaningful to talk about sectoral rather than national systems of innovation. Therefore, our focus on sectors is not a new thing but rather an emphasis. However, when one talks of Africa, where context is different from that of more developed countries, focus on both national and sector levels do matter. For instance, the manufacturing systems of innovation for rich and poor countries are completely different. So is the agricultural sector.

Given the close relationships between the agricultural and manufacturing sectors, especially during the early days of structural transformation – and given the fact that such relationships in Africa are still very weak – we invoke the concept of agro-industrial innovation systems as an attempt to bring together the two sectors in our analysis. Here we treat *agro-industry* as one sector. In the past, agriculture and industry (agro-processing) have largely been considered as two independent sectors, hence with independent policies that have very little to do with each other; and very little efforts were made on bringing them together (Krepl, et al., 2016; Nkuba, et al., 2016). The concept of the agro-industrial system – as used here – is not entirely new; it is similar to the concept of the agro-industrial complexes that has been used by some countries. Denmark, for instance, through focusing on agro-industrial complex development, was able to develop international competitiveness for its milk and meat processing, also leading into vast innovations in machinery and equipment for milk and meat processing (Edquist and Hommen, 2008). The Danish industrial policy was largely on the complex, rather than on milk and meat, and manufacturing industry as separate sectors.

For our case, although the focus is on agro-industrial innovation systems as a whole complex, for analytical purposes, we select one part of the system (a sector) as a centre of analysis. Because our aim is to promote value addition, our analysis will focus on the industry (processing) component so that all other system actors, including those on agriculture, contribute to this. There will be supply-side elements that include raw material suppliers (especially farmers), knowledge organizations (those that supply knowledge and skills, e.g. universities), and demand-side factors such as markets (here we consider markets for the processed goods).The smooth working of the agro-industrial innovation system will require carefully thought out public policies and strategies that will make all important actors – especially the government, the private sector and knowledge organization such as the universities – to work together to bring forth innovation, and this brings us to the concept of the triple helix, which we will briefly return to. For effective policies and strategies, however, there is need to rethink the geographical level of agro-industrial systems analysis – whether at the national or local; the following paragraphs are devoted to this.

Local versus national systems

Talking of heterogeneity in culture and societal norms and sectors, sectoral systems of innovation necessitate that we refer to the discussion on the sub-national (local) systems of innovation rather than national because important actors for innovation for a given sector are at this level – although some elements, for example, some broader macro policies and incentive structures that have a bearing on the innovation system, will still remain national. But generally, according to Acs, Mothe and Paquet (1995), most of the system elements are unique at the sub-national level: they cite some case studies that document the importance of proximity and the centrality of community, linguistic and related dimensions as the fabric of the socio-cultural underpinnings on which sub-national systems of innovation are built.

A few elements of learning derived from some of these case studies are outlined as follows:

- A common thread is the way in which relationships develop between private concerns and both the community and the public concerns; and the way in which "enabling agencies" foster collaboration – whether these agencies have materialized in formal mechanisms of governance or have simply crystallized in the form of informal local solidarity and norms.

- Leadership is important because it enables the complex inter-institutional and inter-sectoral partnerships to develop and become operational, and it appears that the ability of communities to shape their future depends much more on social than on technological processes.
- A third common thread that Acs et al. (1995) identified from their case studies is the great fragility of many local systems of innovation because they are "weakly institutionalized"; this is the sort of weakness that suggests the way in which central governments might be of most help in getting the local communities to help themselves, that is, in providing the enabling support to get communities to invent new instruments and design new policy approaches.

These elements – especially point three – suggest the importance of having a framework to be used to both analyse local systems' weaknesses and attempts to build them. We will use the ten functions of the NSI as advanced by Edquist (1997) for this purpose. Because of challenges around using the innovation systems framework in *ex-ante* diagnosis of a given NSI – as already discussed – Edquist came up with the functional approach to analyse the performance of NSIs. The functional approach enables proposition of remedies for strengthening it. We therefore use Edquist's ten functions of the systems of innovation to analyse the agro-industrial innovation systems so that we are able to propose remedial measures.

Following are the ten functions of the NSI:

1. Provision of R&D and creating new knowledge.
2. Competence building (provision of education and training, creation of human capital, production and reproduction of skills, individual learning) in the labour force to be used in innovation and R&D activities.
3. Formation of new product markets.
4. Articulation of quality requirements emanating from the demand side with regard to new products.
5. Creating and changing organizations needed for the development of new fields of innovation, for example, enhancing entrepreneurship to create new firms, diversify existing firms, and create new research organizations, policy agencies, etc.
6. Networking through markets and other mechanisms, including interactive learning between different organizations.

7. Provision (creation, change, abolition) of institutions, for example, intellectual property rights (IPR) laws, tax laws, environment and safety regulations, R&D investment routines, etc. that influence innovating organizations and innovation processes by providing incentives or removing obstacles to innovation.
8. Incubating activities, for example, providing access to facilities, administrative support, etc. for new innovating efforts.
9. Financing innovation processes and other activities that can facilitate commercialization of knowledge and its adoption.
10. Provision of consultancy services of relevance for innovation processes, for example, technology transfer, commercial information and legal advice.

The list above is very helpful in analysing a given local or sectoral system by identifying weak points, that is, functions that are missing or weakly performed. The functions also help in analysing actors for the specific functions – if absent or weak in capabilities. Finally, they help in analysing the strength of linkage in the system, and presence and absence of responsible actors and their capabilities. Knowing these will help in attempting to strengthen the local systems – especially through cluster initiatives as will shortly be discussed.

Proposed framework for strengthening sectoral-local systems of innovation

The discussion will now centre on the agro-industrial innovation system as this is the major focus for structural transformation. We will go further to the sub-national and sub-sectoral levels to look at specific agricultural commodities, focusing on the processing and value addition system component. Using the ten functions of the systems, we assess the system strength and weaknesses. Taking cotton, for example, we identify all activities required from cotton to cloth. Here, most of the system elements for most of the African countries would be missing. For instance, looking at the checklist from the ten functions of the systems of innovation, we see some elements that need to be established or strengthened. Function number five, for example, is crucial: the African manufacturing sector is still very small. Even the low-tech sectors where technology is readily available, are small, which points to a need for the creation of entrepreneurs who can invest – with appropriate incentives – in the missing activities, in turn pointing out to function number seven. Other elements/actors for the rest of the functions can systematically be put in place as required. For instance, quality has always been a major issue when it comes to competitiveness of African manufactured products, where function number four is of essence. In short, most of the elements are necessary; what will be different is only their relative importance and how they get linked. To gauge exactly what is important for Africa and how the actors should be linked, we must have a formal approach to local systems analysis, and we need a theoretical handle to do that. We argue that the concept of cluster initiatives (CI) used together with the concepts of triple helix (explained further on), will suffice. In most literature on local/regional economies, analysis focusing on the triple helix and clusters has always been a norm. Our approach is to build a triple helix within a given agro-industrial innovation system (which can also be referred to as a cluster) bringing in the concept of CI.

The cluster initiative

Clusters, which are groups of firms that gain a competitive advantage through local proximity and interdependence – and therefore innovation – usually offer a compelling framework for local and state leaders to analyse and support their economies. Formal definition of a clustering phenomenon has been offered by various scholars, with Michael Porter of Harvard Business School who studied the clustering phenomenon in great detail, as a pioneer. According to Porter (1998) clusters are geographical concentrations of interlinked companies and institutions in related branches of industry that complement each other by joint relations of exchange of ideas and activities along one or several value creation chains; they include an array of linked industries and other entities important to competition, including suppliers of specialized inputs and providers of specialized infrastructure. In Porter's opinion, clusters also extend downstream to channels and customers; laterally to manufacturers of complementary products; and to companies in industries with common skills, technologies, and inputs.

Both theory and scholarly research suggest that firms and regions benefit from clustering, evidence that has led to widespread adoption of clusters as one important economic development strategy. Examples of globally successful cluster giants include the Silicon Valley, Automotive Clustering in Germany, North Carolina's life sciences investments in Research Triangle Park, and Leather Clustering in Italy. According to many scholars (e.g. McCormick, 2007; Yidiz and Aykanat, 2015; Donahue, Joseph Parilla and McDearman, 2018) clusters do not only involve firms, but also other support organizations such as governmental and other institutions. These may include universities, standard-setting agencies and think tanks, as well as providers of specialized training, education, information, research, and technical support. Understood this way, clusters are actually systems of innovation at the local level – with much the same system elements that provide innovation system functions as advocated by Edquist (1997). The difference is that, for clusters to be innovative and to perform, they must have in-built self-awareness that they are members of a certain cluster: clustered firms must identify themselves as "cluster members" and some kind of coordination mechanism must be set up through the cluster (Yidiz and Aykanat, 2015).

It is more appropriate to refer to clusters rather than systems of innovation, especially for Africa, because while for innovation systems theory – especially at the national level – we do not have a sure strategy for building a weak system, for clusters there is a strategy. Clusters can be described as natural socioeconomic phenomena and they form where there is some location advantage in major cluster businesses such as natural resource endowment; proximity to major markets and suppliers; and local entrepreneurs with tacit knowledge and basic skills in business areas such as trading, design or manufacturing (McCormick, 2007). Generally, clusters are able to survive and succeed, mainly because of their ability to upgrade their business activities towards more diversified and sophisticated products and services, and reach a certain scale through building up a supply-production-distribution value chain, acquiring knowledge and technology (both domestic and foreign) and their dissemination and adaptation. However, evidence indicates that the success of clusters rarely happens naturally, warranting some outside intervention by a responsible authority, normally the government. This outside intervention is popularly known as "cluster initiatives (CI)". A word of caution is important here; being natural phenomena, cluster initiatives are possible only if there are some natural seeds of a cluster that have passed a market test. Governments should therefore reinforce and build on established and emerging clusters rather than attempt to create entirely new ones. Focus should be on removing obstacles and strengthening linkages, relaxing constraints, and eliminating inefficiencies that impede productivity and innovation in a cluster. One very important component in successful clusters – just like in mature systems of innovation – is linkages with knowledge organizations such as universities and research organizations, both private and public. Because of the business environment surrounding most African countries, especially lack of effective demand for high quality, and relatively expensive, innovative goods and services, the demand for knowledge for innovation from the private sector is relatively poor. However, given the increasing importance of knowledge-based production in the face of stiff competition in the global economy and rapid technological change, national governments need to provide incentives for demand for knowledge from the private sector; and the development of the triple helix will be very useful in this regard.

The triple helix model and the role of knowledge organizations in cluster

The "Triple Helix" is a conceptual framework invoked as a result of observed mutual and beneficial relations – in terms of innovation – between and among the private sector, academia and the government. The initial roles of these actors were simpler and distinct: universities carry out research, especially the basic form, while industries take on much of the applied research and final production of goods and services. The governments, on the other hand, deal with policies to facilitate interactive learning between the universities and the private sector, including ensuring a conducive business environment. However, as social and economic environments changed in societies, former distinct roles between the three organizations evolved to become flexible and overlapping with each of the three organizations taking some parts of the role of the other. For instance, universities have become entrepreneurs through spin-off companies and incubator facilities; industry an educator through company universities and other forms of support to education; and governments, venture capitalists through provision of subsidies – the examples such as the Small Business Innovation Research (SBIR) and other programmes (Etzkowitz, Gulbrandsen and Levitt, 2000) are instructive here. Government has also encouraged collaborative R&D among firms, universities and national laboratories to address issues of national competitiveness (Wessner, 1999).

Within the triple helix, we emphasize the role of the university or any knowledge generating institution, not because this is more important than the other two, but because for poor developing countries such as those in Africa, this is the weakest part of the helix, yet very important in the currently competitive and globalized world, with rapid technological change. According to Zeng (2007) who studied 11 clusters in Africa, one of the major problems blocking their growth is inadequate access to knowledge, especially technological knowledge; while at the same time noting that the few that were successful were those with strong links with knowledge organizations – either universities or public research organizations. A similar case is also observed for the Tanzanian innovative cluster initiatives programme initiated in 2004 through the support of Sida (Swedish International Development Agency); one of the very successful cluster initiatives is the one closely working with a university faculty – the Zanzibar seaweed cluster. This cluster initiative is working very closely in collaboration with the Institute of Marine Sciences of the University of Dar es Salaam (UDSM). The cluster was initiated along with eight other clusters in Tanzania in 2006. A group of 21 women from Kidoti in Zanzibar were the first to be trained by the Cl in seaweed powder production for use in soap and body cream products. By 2018, there were eight groups of women trained to plant and sell seaweed on the island, and through further training in value-addition provided by the Cl between 2008 and 2009, over 300 seaweed farmers by 2018 were making more than 50 products, including juices, jam and massage oils – either as groups or individuals (CTA, 2018).

One of the interviewed farmers – Mwajuma Mwinyi – said that before learning new skills through the cluster programme, she used to sell 1 kg of seaweed for TSh 400 (€0.15) before intervention, but after intervention she made up to TSh 30,000 (€11.30) from seaweed soap made from the same quantity of seaweed (CTA, 2018). The success of the seaweed cluster seems to have triggered the close collaboration between other sub-sectors and knowledge organizations; for example, the fish farming and processing cluster has initiated collaboration with the Institute of Marine Science in Zanzibar (COSTECH and Sida, 2015). This collaboration intends to improve technology and products. The same source also reports that an agricultural training institution has also started collaboration with Unguja fruits, vegetable and spice clusters for the same plan. We believe there are similar success stories elsewhere in Africa that need to be closely studied and replicated towards establishing an effective framework for the cluster initiative and use of the triple helix in support of positive structural transformation in Africa.

The cited cases notwithstanding, beyond such isolated success stories there is a major challenge of university-industry linkages in most African countries, as highlighted earlier, due to lack of demand for knowledge for innovation on the part of the private sector, largely because most firms are still in low-tech sectors and are weak in technological and absorptive capacities. Under such circumstances, explicit demand for scientific knowledge in the innovation process might not be evident, as innovation takes place more through experience and interaction within an innovating firm, and between the firms and their environments – termed as DUI (doing using and interacting) mode of innovation. The learning process involves experiences and competences acquired by employees on-the-job as they face new challenges in the production and marketing functions. In the DUI mode of innovation, scientific research is normally used in assisting the learning-based innovation, especially when the degree of novelty is appreciable. Here the skills of workers are key and are related to continuous retraining and learning. Education systems in this case must be informed by industry needs and are in continuous interaction with productive sectors. It does not matter, therefore, whether it is high or low-tech sectors we are dealing with; triple helix is very important for innovation, where the role of firms in informing educational curricular in this case is extremely important.

Given the weak market forces, for effective and efficient interaction between industry and university, governments need to put appropriate incentive structures to facilitate and strengthen such interactions. Policy instruments that have been used elsewhere include tax incentives or direct subsidies and grants for joint research between research organizations and industry. The opposite has also worked elsewhere, where inadequate funding from the government has forced higher learning institutions to turn to industry for research funds (Belkhodja and Landry, 2007); and some governments – especially in developed countries – have used cutting research funds as policy instruments to encourage linkages between university and industry. It is, however, important to note that this is only possible for investments in science-intensive sectors, where demand for knowledge inputs from business is much higher. Others include staff exchange between the industry and the university, where university lectures can have time off to work with industrial firms for a limited period of time; likewise, industry staff can be invited as guest lecturers at universities. Given differences in country contexts, policies for encouraging knowledge exchange and transfer between universities and industry should be context specific, requiring clear understanding of the contexts in which both the university and the private sector are operating. In a similar vein, Mgumia et al. (2019) concluded that for knowledge to be successfully transferred from the sources to potential users, the policies to promote innovation need to be cohesive with polices to support generation of knowledge and permit engagement of the right partners at the right time.

University – clusters linkages: surmounting barriers beyond demand for knowledge

In addition to technological distance between science and university research, and the innovative activities of the private sector in poor countries such as many in Africa, there is another important distance – geographical distance. Taking Tanzania as an example, it is a large country with few universities and other appropriate knowledge organizations that can help many of the start-ups and small-scale enterprises that are located very far away from these knowledge organizations. To address this challenge, could what is normally termed as *incubators without walls* be of help? Incubators without walls are programmes that bring entrepreneurs together within their communities or regions without providing the physical amenities available at most normal incubators. Incubators without walls focus on the core services and resources – from individualized business assistance to networking opportunities – that traditional bricks-and-mortar programmes offer to help entrepreneurs grow successful businesses (Cammarata, 2004). Through this programme, managers of incubators can serve start-ups located miles away from their own offices. Despite challenges of managing incubators without walls, elsewhere, people have opted for this because of many other advantages, top being cost. Incubators without walls are very easy to set up, saving on costs. Another advantage is client mix: unlike normal incubators with walls, these are not limited to a single focus or industry segment, and therefore an incubator facility can reach out to as diverse a clients' range as they are able to manage.

One of the universities in Africa that realized the usefulness of incubators without walls is the University of Dar es Salaam. Through generous support from the Tanzania Gatsby Trust (TGT), Carnegie Corporation of New York and the Government of Tanzania, the University of Dar es Salaam initiated an incubator without walls project in 2002. It was dubbed Business Technology Incubator (BTI) programme because the major focus was on transferring knowledge and technology from the University to SMEs. The target groups for this project were entrepreneurs who were operating or intending to start small and medium enterprises, especially those that involve technology, and which have high potential to grow and bring about positive impact on the lives of a majority of the people in the communities concerned. The focus of the incubation activities included provision of equipment and technology at subsidized prices, business counselling and other business support, information sharing, training, market visibility and access to finance and professional services (UDSM, 2010). Three of the districts where the incubator programme was implemented included Kibaha in Coast Region, Morogoro in Morogoro Region and Lushoto in Tanga Region. All these incubators are related to food processing. After seven years, that is, in 2010, the programme was evaluated to gauge its impact, especially focusing on growth of the clients' firms. The result of the evaluation indicated that although there had been some positive impact through the growth of firms, none of the firms had reached the point of graduation. According to the evaluation report, such shortfalls were largely because the level of services offered by the incubator was not sufficient and sometimes was not timely. Close mentoring was also insufficient because of the wide geographic distribution of clients within the incubators: it must be borne in mind that the clients, apart from being far away from their incubator, were also far away from each other, meaning that they were really not in a cluster. This means that, if the clients were in a cluster, that is, close to each other, the outcome of the project would have been far better, indicating that incubators without walls need to focus on a cluster, rather than individual firms scattered widely.

Another major challenge of incubators without walls is recruitment into an incubator – although this was not exclusively brought to the fore by the UDSM incubator evaluation report, it has been mentioned in some incubator projects elsewhere as one of the major challenges of incubators without walls. One incubator without walls that successfully addressed this challenge is the Eastern Maine in the USA. The Eastern Maine network of three incubators initiated in 1999 covers five counties encompassing some 11,800 square miles. The incubators focus on rural microenterprises and together have served more than 600 businesses. According to one of the managers of these incubators, in the beginning the strategy they used to recruit firms in the incubator was just a release of news – simply explaining what business incubation meant and how it benefits individual businesses (Cammarata, 2004). However, as people joined and graduated from the incubation programme, satisfied customers became its valuable promoters – relying on word of mouth. According to one of the incubator managers, it wasn't that easy; to recruit the first group they had to go door to door and attend community meetings to attract the new businesses they hoped to have in each new session. However, when the incubator started a second group in the same area, they almost had to turn them away because of lack of space

(Cammarata, 2004). One important caution provided in this success story is that clients of incubators without walls have to be extremely self-motivated, as incubator management is normally hundreds of miles away, and therefore, there is very little pampering, which clients of the incubators with walls normally receive.

An additional major challenge, also discussed in the UDSM's incubator programme evaluation is sustainability of funding: such programmes are not supposed to rely on donor funding that is usually not sustainable, but rather, on local funding – whether government or private; or even better, public private partnerships. The UDSM's incubators without walls project was not meant to be an end in itself, but a means to an end, that is, for learning in order to put in place a much firmer strategy for future incubators without walls programmes. However, because it was largely donor driven, there was no second round on which to implement the lessons learnt.

The role of the Science Granting Councils in reduced systems of innovation

SGCs, with slightly different roles in different countries, are basically the custodians of research in their countries – responsible for funding research, designing research policies, and building capacity of researchers. Defined this way, SGCs are embedded in the science and innovation systems of their respective countries; within such systems, they need to have immediate contacts with researchers, industry and policy decision makers that form a triple helix. As custodians of research, SGCs should ensure that research activities they fund have impact on social and economic development of their countries. This means that, they have a responsibility to ensure that such research is connected to users in both public and private entities, and as discussed in this work, this is much easier if it is in the context of reduced systems at local levels such as innovative clusters. SGCs have, therefore, a critical role to play in cluster initiatives; that is, to make sure that the local clusters are innovative by connecting knowledge institutions such as universities to clusters at local levels. This means, the UDSM incubator without walls project – especially in its funding– should have been a major responsibility of the National Commission for Science and Technology in Tanzania. This way, the project would not have ended prematurely.

However, while the UDSM incubator project that started in 2002 did not directly involve the Commission for Science and Technology (COSTECH), some years later the commission was directly involved in a cluster initiative project named '*The Innovative System and Cluster Development Program in Tanzania*' (ISCP -Tz) that was based on a triple helix model. Initiated and initially managed by the UDSM through Sida support, the project management role was transferred to COSTECH in 2008. Starting with eight clusters in 2006, to date there are about 60 cluster initiatives countrywide. On management, guided by the design of the programme, the cluster formulation and facilitation are done by assigned cluster facilitators. Selection of the facilitators is determined by pre-determined personal qualities and professional qualifications. Thus, a facilitator can be among successful entrepreneurs in the respective industry or from the research community or any other relevant institution within the locality and is willing to take up the challenges of facilitating the development of triple helix within the cluster.

At the end of ISCP-TZ phase two in 2015, among the noted successes was increased understanding of the cluster concept, benefit of collaboration and interactions with academic institutions and R&D. However, such positive impacts notwithstanding, some major challenges remain. These include institutionalization of cluster initiatives approaches at the local government authorities (LGA) and central government levels, as well as encouraging in-bound knowledge transfer from cluster firms to universities to promote co-creation and demand-driven research. Some of these challenges are being addressed by the ongoing follow-up programme on *Fostering Innovation for Sustainable Social and Economic Development*. The main focus of the programme is the development of a method and guidelines for replication and scale-up of competitive and innovative clusters in the emerging knowledge society of Tanzania.

Concluding remarks

This chapter on approaches to innovation systems building in Africa argues – as its point of departure – that despite ensuing hurdles under a changed global environment, structural transformation through industrialization is still a valid way to build African economies towards total poverty eradication. This, however, is only possible if issues of low level of innovativeness and systems fragmentation that are major characteristics of African economies are totally addressed. Given that these economies are very diverse, including in culture, economic sectors and nature and size of firms, a focus on reduced systems at local levels, rather than at national levels, through innovation system analysis and building, is the best way to go. Specifically, development of innovative clusters – through incubation without walls and the triple helix model – has been proposed as a useful framework for this purpose. Using cases from Africa, largely from Tanzania – which is the context we know best – the chapter demonstrates the practicability of this approach. However, we argue that this approach is only possible if Africa goes beyond political rhetoric about the importance of STI in social and economic development of the continent by not only putting in place blueprints implementation strategies, but actually following them.

Innovation systems are complex, and frameworks for their analysis and building are still on trials – especially for poor countries such as those in Africa. This means that any strategy that is put in place must be closely followed through monitoring, evaluation and learning and continuously incorporating lessons learnt until something that works relatively well is found. In other words, Africa must learn to work through policy experimentation. Such a strategy will not work with resources from outside the continent, which unfortunately is the current practice; and for us this is more worrying than finding an appropriate framework for analysis and innovation systems building. We hope this work raises an important alarm and the SGCs in the continent take their rightful places as custodians of research and innovation (I&D) in individual countries.

References

Abebe, S., Audrey, V. and Amadou, B., 2018.A. Shimeles et al., eds. *Building a resilient and sustainable agriculture in sub-Saharan Africa* doi.org/10.1007/978-3-319-76222-7_1.

Acs, Z., Mothe, J. and Paquet, G., 1995. *Local systems of innovation: in search of an enabling strategy*. Working-Paper 95-42. Faculty of Administration, University of Ottawa.

African Development Bank, 2016. *Feed Africa: strategy for agricultural transformation in Africa 2016-2025*. Abidjan: AfDB.

African Union Commission, 2014. *Agenda 2063 – The Africa we want*: *a shared strategic framework for inclusive growth and sustainable development and a global strategy to optimize the use of Africa's resources for the benefit of all Africans.* Addis Ababa: AUC. p. 11.

African Union–New Partnership for Africa's Development, 2010. *African Innovation Outlook, I*. Pretoria: AU–NEPAD.

African Union–New Partnership for Africa's Development, 2014. *African Innovation Outlook II*. Pretoria: AU–NEPAD.

Babeiya, E. 2015. A long wait for agricultural transformation in Tanzania: are the policies to blame? *Journal of Policy and Leadership*, 4(2), pp.1 –21.

Belkhodja, O. and Landry, R., 2007. The Triple-Helix collaboration: why do researchers collaborate with industry and the government? What are the factors that influence the perceived barriers? *Scientometrics*, 70(2), pp.301–332.

Cammarata, K., 2004. *National Business Incubation Association*. [Online]. Available at: www.nbia.org (Accessed 4 April 2020).

Chaminade, C., Lundvall, B.Å., Vang, J., Joseph, K., 2009. Designing innovation policies for development: towards a systemic experimentation-based approach. In: Lundvall, B.Å., Joseph, K.J., Chaminade, C., Vang, J., eds.. *Handbook of innovation systems and developing countries: building domestic capabilities in a global setting.* Cheltenham: Edward Elgar. p.360.

Chaminade, C., Lundvall, B-Å., Vang-Lauridsen, J. and Joseph, J., 2010. *Innovation policies for development: towards a systemic experimentation based approach*. CIRCLE discussion papers, paper No. 2010/01, CIRCLE, Lund University.

Cirera, X. and Maloney, W.F., 2017. *The innovation paradox: developing-country capabilities and the unrealized promise of technological catch-up*. Overview booklet. Washington, D.C.: World Bank.

Cornell University, INSEAD, and WIPO, 2019. *The Global Innovation Index 2019: Creating Healthy Lives –The Future of Medical Innovation*. Ithaca, Fontainebleau, and Geneva.

Cornell University, INSEAD, and WIPO, 2018. *The Global Innovation Index 2018: Energizing the World with Innovation*. Ithaca, Fontainebleau, and Geneva.

COSTECH and Sida, 2015. *Innovation systems and cluster development programme*. Tanzania Innovative Clusters Project Report, COSTECH 2018/2019.

Dias Avila, A.F. and Evenson, R. E., 2010. Total factor productivity growth in agriculture: the role of technological capital, Handbook of Agricultural Economics. In: R. Evenson and P. Pingali, (eds.), 2009. *Handbook of Agricultural Economics Ed.1(4)*. North Holland: Elsevier. Chapter 72, pp.3769 –3822.

Diyamett, B., 2010. Inter-organizational linkage and firms' innovativeness in least developed countries: the case of metalworking and engineering sector in Tanzania. PhD Thesis. University of Dar es Salaam.

Diyamett, B., Mneney, E, Liberio, J. and Komba, A., 2013. Science, technology and innovation for poverty reduction in Tanzania: an analysis of the sectoral systems of innovation. Dar es Salaam: STIPRO. [Online]. Available at: www.stipro.or.tz (Accessed 4 April 2020).

Diyamett, B., and Mutambala, M., 2014. Foreign direct investment and local technological capabilities in least developed countries: Some evidence from the Tanzanian manufacturing sector. *African Journal of Science, Technology, Innovation and Development*, 6(5), pp.401– 414.

Donahue, R., Joseph Parilla, J. and McDearman, B. 2018. *Rethinking cluster initiative*. Washington, D.C: Brookings Institute.

East African Community and United Nations Industrial Development Organization, 2017. *EAC industrial competitiveness report 2017: Harnessing the EAC market to drive industrial competitiveness and growth.* [Online]. Available at: https://www.eac.int/press-releases/149-Industrialization-SME-development/891-eac-unveils-Industrial-Competitiveness-Report-2017 (Accessed 31 August 2020).

Edquist, C., 1997. *Systems of innovation: technologies, institutions and organizations.* London: Pinter.

Edquist, C., and Hommen, L., 2008. *Small country innovation systems: globalization, change and policy in Asia and Europe*. Cheltenham: Edward Elgar Publishing Limited.

Etzkowitz, H., Gulbrandsen, M. and Levitt, J., 2000. *Public Venture Capital: Government Funding Sources for Technology Entrepreneurs*. New York: Harcourt.

Fuglie, K. O. and Rada, N. E., 2013. *Resources, policies, and agricultural productivity in sub-Saharan Africa*. Economic Research Report 145368, United States Department of Agriculture, Economic Research Service.

Gu, S., 1999. Implication of national innovation systems for developing countries: managing change and complexity in economic development. *Discussion Paper Series, UNU/INTECH.*

Hall, A., Mytelka, L and Oyeyinka, B. 2005. Innovation systems: implications for agricultural policy and practice. *ILCA Brief 2.* Addis Ababa: ILCA: International Livestock Centre for Africa.

Kauffman, S. A., 1993. *The Origins of Order*. New York: Oxford University Press.

Krepl, V., Kment, P., Rajdlova, G. and Kapila, P. F.. 2016. African countries' agricultural trade value chain assessment case study: Tanzania (cashew nut exports). *Agris on-line Papers in Economics and Informatics*¸ 8(1), pp.45–55.

Lee, K., Juma, C., and Mathews, J., 2014. *Innovation capabilities for sustainable development in Africa.* World Institute for Development Economic Research (UNU-WIDER).

Lundvall, B.-Å., (ed.) 1992. *National Systems of Innovation*. London: Pinter.

Malerba, F., 2004. Sectoral systems: how and why innovation differs across sectors. In: J. Fagerberg, D. Mowery and R. Nelson, (eds.) *The Oxford Handbook of Innovation*. Oxford, OUP, pp.380 –406.

Malerba, F., 2005. Sectoral systems of innovation: a framework for linking innovation to the knowledge base, structure, and dynamics of sectors. *Economics of Innovation and New Technology*. 14(1–2), pp.63–82

McCormick, D. 2007. Industrialization through cluster upgrading: theoretical perspectives. In: Oyelaran-Oyeyinka, B. and McCormick, D., (eds.) *Industrial clusters and innovation systems in Africa: institutions, markets and policy*, pp.20–38. Tokyo and New York: United Nations University Press.

Mgumia, A., Njau, K.N., Msuya, F.E., Njau, F.B., 2019. Constructing sustainability science in Tanzania. In: C. Aquire-Bastos, J, Chaves-Chaparro and S. Arico, eds. 2019. *Co-designing science in Africa: first steps in assessing the sustainability science approach on the ground*. Paris: UNESCO.

Mgumia, A.H., Mattee, Z.A. and Kundi, A.T B., 2015a. Characteristics of agriculture technology and application of an agricultural innovation system in Tanzania. *African Journal of Science, Technology, Innovation and Development*, 7(2), pp.73–83. DOI:10.1080/20421338.2015.1023651

Mgumia, A.H., Mattee, Z.A. and Kundi, A.T. B., 2015b. Contribution of innovation intermediaries in agricultural innovation: the case of agricultural R&D in Tanzania. *African Journal of Science, Technology, Innovation and Development*, 7(2), pp.151–160. DOI: 10.1080/20421338.2015.1023644

Murphy K.M., Shleifer, A. and Vishny, R.W., 1989. Income distribution, market size, and industrialization. *Quarterly Journal of Economics*. 104(3), pp.537–564.

Murphy, K.M., Shleifer, A. and Vishny, R.W., 1989. Industrialization and Big Push.

Journal of Political Economy, 97, pp.1003–1026. doi.org/10.1086/261641

Nelson, R., ed. 1993. *National innovation systems: a comparative analysis.* New York: Oxford University Press.

Nkuba, J., Ndunguru, A. Madulu, R. Lwezaura, D. Kajiru, G. Chalamila, B. Babu, A. and Ley, G., 2016. Rice value chain analysis in Tanzania: identification of constraints, opportunities and upgrading strategies. *African Crop Science Journal,* 24 (supplement s1), pp73–87.

Porter, M., 1998. Clusters and competition: new agendas for companies, governments, and institutions. In: Porter, M. 1998. *On competition.* Boston: Harvard Business School Press, pp.197–287.

Rodrik, D., 2014. An African Growth Miracle?. *NBER Working Paper Series 20188*. [Online]. Available at: http://www.nber.org/papers/w20188 (Accessed 4 April 2020).

SA Government News Agency, 2017. *R&D spending in SA shows signs of recovery.* [Online]. Available at: https://www.sanews.gov.za/south-africa/rd-spending-sa-shows-signs-recovery (Accessed 31 August 2020).

Signe, L., 2018. The potential of manufacturing and industrialization in Africa: Trends, opportunities, and strategies. *African Growth Initiatives, Brookings.* [Online]. Available at:

https://www.brookings.edu/wp-content/uploads/2018/09/Manufacturing-and-Industrialization-in-Africa-Signe-20180921 (Accessed on 4 April 2020).

Ssebuwufu, J., Ludwick, T., and Béland, M. 2012. Strengthening university-industry linkages in Africa: a study on institutional capacities and gap. Accra: Association of African Universities. [Online]. Available at: http://www.heart-resources.org/wp-content/uploads/2015/09/strengthening-university-industry-linkages-in-africa-report-2012.pdf?x30250 (Accessed 4 April 2020).

Technical Centre for Agricultural and Rural Cooperation (CTA), 2018. Revitalizing seaweed farming in Zanzibar: production and value additions. *SPORE Newsletter.* [Online]. Available at: https://spore.cta.int/

en/ production/all/article/ revitalizing-seaweed - farming-in-Zanzibar-sid02fddd9f3-3a82-47de- 97f9-c92c6771faa7 (Accessed 26 June 2018).

Timmer, P., 2007. *The structural transformation and the changing role of agriculture in economic development*. Wendt Lecture, October 30, 2007. Washington, DC: American Enterprise Institute.

UIS (2018). *Global Investments in R&D.* [Online]. Available at: http://uis.unesco.org/sites/default/files/documents/fs50-global-investments-rd-2018-en.pdf (Accessed 4 April 2020).

United Nations Conference on Trade and Development, 2014. *The least developed countries report, 2014: growth with structural transformation: a post-2015 development agenda, Chapter 5 on structural transformation, labour productivity and development policies in selected non-LDCs developing countries.* [Online]. Available at: https://unctad.org/en/PublicationChapters/ldcr2014_ch5_en.pdf (Accessed 11 April 2020).

United Nations Conference on Trade and Development, 2015. *Agricultural productivity: developments, determinants and impacts. The least developed countries report 2015.* Geneva: United Nations.

United Nations Educational, Scientific and Cultural Organization, 2019. *Co-designing science in Africa: first steps in assessing the sustainability science approach on the ground*. Paris: UNESCO.

United Nations Industrial Development Organization and United Republic of Tanzania, 2012. *The Tanzania Industrial Competitiveness Report, 2012.* Dar es Salaam: UNIDO

University of Dar es Salaam School of Education, 2010. *Piloting business technology incubation in Tanzania, evaluation report.* Dar es Salaam: UDSM.

Wessner, C., ed. 1999. *The Advanced Technology Program: Challenges and Opportunities*. Washington D.C.: The National Academies Press.

World Intellectual Property Organization, 2018. Global Innovation Index 2018 rankings. [Online]. Available at: https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2018-intro5.pdf (Accessed 31 August 2020).

World Intellectual Property Organization, 2019. Global Innovation Index 2019: Creating Healthy Lives–the Future of Medical Innovation. [Online]. Available at: https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2019.pdf (Accessed 31 August 2020).

Yidiz, T. and Aykanat, Z., 2015. Clustering and innovation concepts and innovative clusters: an application on techno parks in Turkey. *Procedia - Social and Behavioral Sciences.* 195, pp.1196–1205.

Zeng, D. Z., 2007. *Knowledge, technology and cluster based growth in Africa: findings from eleven case studies of enterprise clusters in Africa*. Washington DC: World Bank Institute.

4

Applying a Transformative Knowledge Systems Perspective to Gain New Insights for STI Policy

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Abstract

A number of low- and middle-income countries such as those of sub-Saharan Africa are adopting science, technology and innovation (STI) policies in their pursuit of sustainable development. Most sub-Saharan countries have developed frameworks and policies aligned to national and continental development visions. However, these countries still lack evidence on how effective STI systems could look like in

practice, including what interventions to pursue for optimal outcomes. STI interventions in these countries so far have not yielded clear development returns in line with the real needs of people. The challenge is exacerbated by reliance on global theories and concepts that have not been effectively domesticated in the African context. There is need to understand emerging ways of clarifying and informing STI policies and interventions. This chapter discusses the concept of the 'Knowledge System' as a way of informing STI interventions in various contexts to bridge the gap between STI theory and practice.

Introduction

Science, technology and innovation (STI) is widely embraced in low- and middle-income countries (LMICs) as critical ingredients to develop knowledge-based economies, where knowledge drives productivity, economic growth and social wellbeing. To this end, several LMICs and in particular those in sub-Saharan Africa (SSA), are attempting to strengthen their STI systems with new policies, institutional arrangements and investments (Frost et al., 2019). These LMICs are motivated by the broader agendas that include the African Union's STI Strategy for Africa 2024 (STISA-2024) a pre-requisite for achieving the AU Agenda 2063, 'The Africa We Want'.

The ambition of most African countries anchored on the overarching desire to speed up Africa's transition to middle and developed economies through an innovation-led, knowledge-based economy is critical. To this end, several African countries have either established their individual STI policies/strategies or are in the process of setting up national systems. The National Science Granting Councils (SGCs), for example, are now key in coordinating national STI-related activities within countries (Mouton, Gaillard and Lill, 2014). Countries are strongly pushing innovation agendas – including green innovation and business – as catalysts for the region's prosperity. Other than the national SGCs and commissions, there are also some national institutions emerging to support and promote STI through innovation development and coordination, research funding, higher education support, or degrees and patents, among others.

These efforts are appreciable and provide incremental support and promotion of STI systems, mainly at the national level. However, there are complex concerns that African countries need to address amidst weak capacities, capabilities, low funding, and available resources. Yet, these are key ingredients required for policymakers to integrate

STI aspects into development planning and in response to societal challenges. For instance, a recent assessment of the STI systems of East African countries shows that there is relatively slow growth in investments and even with this low level investment, there exists a gross mismatch between investments and real needs of countries (Fosci, et al., 2019).

Further, most of the STI systems, by nature, have largely operated at the national level with little clarity on the practical engagements with various systems, for example, non-state actors, informal systems, and strategic interventions relevant to the STI. Specifically, the existing national STI systems continue to struggle with an array of issues: (i) practical means and evidence on what works to promote STI in practice; (ii) the institutions, rules and procedures that facilitate the creation and use of knowledge; and (iii) the role that both state and non-state actors can play in building capacities and capabilities that are critical to catalysing and supporting the design of STI instruments towards a balanced growth agenda.

As part of contributing to addressing the concerns highlighted above, we introduce the transformative knowledge systems (KS) concept as a way of helping further understand or unpack these issues, enabling more informed decision making.

This study is part of a project on understanding knowledge systems and what works to promote science, technology and innovation in Kenya, Rwanda, and Tanzania – dubbed *Knowledge Systems Innovation (KSI)*.

The KS perspective looks beyond the conventional STI analytical and policy framework to envision investments that encompass diverse knowledge actors – both formal and informal – and innovation-related activities that address balanced growth ambitions (Frost, et al., 2019). The study uses the term perspective because it combines a conceptual framework, with a set of analytical tools and provides guidelines based on the conceptual framework about the process of using analysis to arrive at different STI options aligned to the sustainable development agenda in different country contexts. Understanding the nature, process, and specificities from early lessons in application of the concept will provide strategic insights into government policy making and the strategy crafting that informs and shapes the wider application of knowledge for effective STI systems.

A transformative KS perspective helps to highlight components of the KS that are neglected but are important in light of STI being able to deliver more effectively for multiple Sustainable Development Goals (SDGs) and for the needs of diverse local actors. These components may be, for example, actors, conditions, technologies, institutions and governance arrangements configured in ways that will contribute to the building of a transformative KS. We recognize our KS perspective as a complement to other current initiatives continentally, for example, SGCs building science systems and those concerned with STI policy and transformations to sustainability (e.g. UNCTAD, 2019 and Chataway et al., 2017). The former – building the science systems – focuses on natural and social sciences as key enablers in developing a country's knowledge economy. The other two initiatives are working towards the creation of national strategies for re-orientating innovation systems, and for setting up and monitoring experimental policy mixes in order to achieve this. There is clear concern to make national innovation systems meet SDG agendas, but availability of data to support recommendations for particular policy options is patchy. There is limited attention too on how policies which lead to particular types of STI investments link to the pursuit of the SDGs in particular contexts in practice. This is similar to supporting a knowledge-based economy (KBE) where emphasis is on supporting entrepreneurial activities and investments in human capital to create and use knowledge for competitiveness (Asongu and Nwachukwu, 2017). Three pillars underpin KBEs – information communication technologies (ICT), organizational innovation, and human capital (Khalifa, 2019, p. 2) with no clear cut strategies on how the KBE can support achievement of SDGs in particular contexts.

Knowledge systems innovation (KSI) reflects many of the concerns and ambitions of these other initiatives and complements other endeavours. KSI is distinctive in its development of a stakeholder-led approach for identifying realistic STI investment priorities which align with development priorities. KSI-informed investment options are tailored to context-specific KS strengths and embedded in an enhanced understanding of the potential to contribute to systemic change across multiple scales. The approach emphasizes the leverage of diverse sources of knowledge and novel forms of innovation, and the realization of synergies between potential investment options.

We applied the concept in three East African countries to: (i) link the transformative KS concept and its relevance to shaping interventions in STI in East Africa; (ii) understand the status of STI in the countries and the key gaps and challenges; (iii) unpack the key actors and their contribution to knowledge production and use; and (iv) identify practical interventions (drawing on case studies) required to actualize STI and help with decision making in STI investment and planning.

The knowledge systems concept: theoretical perspectives

To harness the transformative potential of STI for inclusive and sustainable growth, the framing of STI needs to consider the socio-economic and technical systems into which innovation is introduced to deliver the necessary change. There have been three framings of STI policy since the World War II (Schot and Steinmueller, 2018).

We reviewed existing evidence and concepts to generate an initial conceptual typology of KS that informs a practical KS concept that guides interventions in STI. A range of mainstream framings of knowledge creation and use which underpin current investment strategies in STI was reviewed and their key shortfalls noted.

Research systems perspectives remain particularly important in framing the development of core science and technology capabilities. However, the perspectives are more inclined and aligned towards formal knowledge production with capacity-building priorities, which are focused on formal knowledge institutions such as universities and research institutes rather than on the processes that shape and enable the demand for and use of knowledge. The research systems perspective also assumes that resource allocation to the research system is rational and evidence based. Recent work by Chataway, et al. (2019) on the SGCs in Africa has revealed deeper problems in the political economy of funding arrangements that often cause priorities to be skewed and determined by specific agendas, groups and players leading to misalignments between resource allocations and social and economic development aspirations. The literature points towards the focus of research systems around science and research excellence. While we acknowledge that these are important, it is vital that the knowledge production and use goes beyond this to incorporate aspects around societal goals and socio-economic outcomes, what Sutz (2020) emphasises as high "quality teaching and relationship building with society".

On the other hand, the innovation systems approach has been based on a system perspective, delivering for economic growth, high productivity and industrial competitiveness (Schot and Steinmueller, 2018) but weak in directionality. While its application has proven useful in some developing countries in developing national styles of innovation, this perspective is misaligned to LMICs' contexts and still faces two main application challenges. First is the misunderstanding of it as a policy and practice blueprint rather than a way of understanding and strengthening context-specific national styles of innovation. Second, the difficulties of coping with country settings where a large proportion of innovation activity is centred in and on the informal sector (Schrempf, Kaplan and Schroeder, 2013)regional and sectoral.

There are increasing efforts to engage in the strengthening of knowledge and innovation systems through the types of development outcomes they are supporting and the distribution of costs and benefits between societal groups of STI interventions from this perspective. This calls for the need to design STI interventions, particularly those that break from the lock-in pathways that the innovation systems approach supports (Anadon, et al., 2016)technological innovation processes do not follow a set sequence but rather emerge from complex adaptive systems involving many actors and institutions operating simultaneously from local to global scales. Barriers arise at all stages of innovation, from the invention of a technology through its selection, production, adaptation, adoption, and retirement. Second, learning from past efforts to mobilize innovation for sustainable development can be greatly improved through structured cross-sectoral comparisons that recognize the socio-technical nature of innovation systems. Third, current institutions (rules, norms, and incentives.

With the shortfalls of these dominant framings, our aim is to support the development of transformational KS thinking and investment approaches. We take as our starting point the definition of KS outlined by Cornell, et al. (2013) "a network of agents, practices and institutions that organize the production, transfer and use of knowledge". The concept of KS is still evolving in its development and application but for now, it presents an alternative form of analysis of STI systems, contrary to the existing or established analyses of STI. A key practical aspect associated with the KS approach is its focus on understanding the interconnections between actors and interventions, as well as outcomes in relation to societal needs, thereby providing clarity on where interventions and investments ought to be made for optimal outcomes (Frost, et al., 2019).

KS in their configuration involve diversity of knowledge sources and the capabilities involved in the production, diffusion, adaptation and use of knowledge. Critically, this perspective explicitly examines the extent to which knowledge and related capabilities are aligned and used to meet social, economic and policy goals.

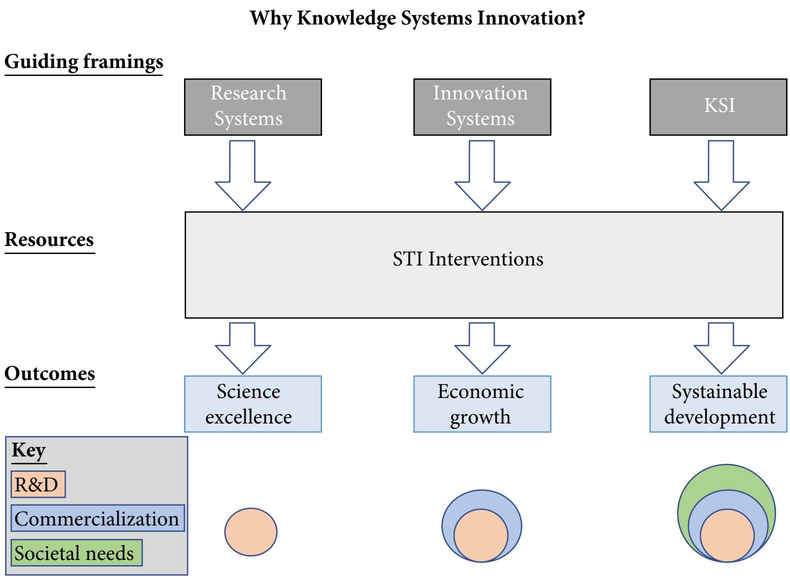
In doing so, the approach champions for an understanding of diverse sources and types of knowledge generation and use by considering different knowledge processes, practices as well as perspectives from different stakeholders and the politics underpinning their interactions. Most importantly, the approach recognizes both formal and informal STI systems and seeks to clarify ways of linking these for more integrated and optimal outcomes. These key lenses of analysis contrast other existing STI frameworks such as research systems or innovation systems which largely target research excellence and economic growth respectively, leaving out key societal elements such as inclusivity and equity. While the innovation system has tried to address these concerns through introducing other facets of innovation such as social innovation or inclusive innovation, these largely emphasise the triple helix, that is, linkages rather than inclusion and equity.

Evidence drawn from sustainability studies shows that the approach enables relevant stakeholders to engage with the research process at every stage including agenda setting, problem framing, knowledge production, dissemination and application of knowledge, thus enhancing sustainability of resulting interventions or decisions and outcomes. Similarly, literature on sustainability transitions embeds the element of KS by enlarging our perspective on various aspects of knowledge and how they might interact with broader processes of change. KS may be envisaged as playing a role in the development and distribution (internal or external to regime) of knowledge and capabilities as well as supporting the coordination of those resources in response to or anticipation of landscape pressures. KS can also be seen as integral to the formation of sustainability policy and planning as well as to the task of anticipating landscape shocks and pressures and informing preparation of responses.

In our attempt to broaden our thinking, we see KS as a perspective that uses a set of integrated analysis and concepts that reveal alternatives to established analyses of STI. We open up and broaden further these concepts to KS elements that help characterize further KS and guides analysis of investments in STI. For example, to meet societal needs and address the issues of inclusion, there is need to develop a transformative and integrated approach by embedding research and development (R&D) in both the "wider landscape of research commercialization and societal needs" (Frost et al., 2019). For example, tackling climate change requires a radical transformation of energy and mobility systems that implies changes in production and consumption patterns. This requires disrupting the existing practice and systems, for example,. a variety of functionally-connected innovations, including new technologies, infrastructure, goods and services, processes, organizational and business models, new knowledge and training programmes, different actor networks as well as new forms of governance and policy frameworks. The objective of STI policy aimed at tackling societal challenges is therefore to foster systemic changes with a potential for transformative impact.

Overall, we argue that KS analysis looks beyond research and innovation systems to re-vision new suites of STI interventions that embed R&D in both the wider landscape of research commercialization and societal needs (Frost, et al. 2019) (see Figure 4.1).

Figure 4.1: Why Knowledge Systems Perspectives are Needed



Source: Adopted from Frost, et al. 2019

Research methods

This research was conducted in three East African countries particularly Kenya, Tanzania, and Rwanda. The countries were selected on the basis of their political and financial commitments, having established their SGCs on science, technology, and innovation although they have a limited evidence base on how to develop an effective STI policy. We began by conceptual literature review that formed part of the planning process for in-country inception workshop consultations. The review highlighted several different approaches to various aspects of KS that imply different goals, types of innovation and sets of actors as central to knowledge production and use. The literature review together with the in-county consultations provided preliminary insights into the current STI situation and environment within each country and formed part of the in-country landscape mapping.

The reviews together with the stakeholders' consultative process provided an opportunity to map the existing target country STI policies, agencies and actors involved in the production and use of knowledge. We also mapped new ways of producing and using knowledge – breaking out of the conventional innovation systems mould to include elements of the wider knowledge system and patterns of investments in STI and their impacts. To validate, triangulate and build on the insights from the in-country literature reviews, we conducted two to three focused group discussions (FGD) each with about 8 to 12 key stakeholders, covering different KS domains and sectors such as research, higher education, agriculture, health, etc. as identified within the in-country literature reviews. This approach guided dialogue around the key drivers for, and the politics of, knowledge production and use; different dissemination routes; and different knowledge into use pathways. Through these discussions, we were also able to identify potential gaps for case studies work for further in-depth analysis.

Targeted in-depth interviews with key informants were conducted to generate greater understanding of the KS arrangements within specific country settings. These interviews sought to understand the key STI priorities and the ways in which these priorities are conditioned by the social, political, policy and governance arrangements in the three countries. The interviews sought to fill any knowledge gaps or discrepancies raised during the FGD. We conducted about 25, 28, 22 key informant interviews in Rwanda, Kenya, and Tanzania respectively, drawn from both state and non-state agencies. Two case studies from each country were identified during stakeholder consultations to further elaborate the nature of the KS arrangements in each country – where this works well, where bottlenecks are emerging and what new opportunities might be arising for effective STI investment options. We examined some key aspects and processes of STI investments in more detail, investigating how and why existing investments have been targeted in particular ways, and the interacting social, political, technical, economic and environmental factors that shape their development and outcomes in relation to SDGs.

Although we explored all these processes, we experienced challenges with the scope of discussions. The KS concept is fairly new, with limited literature, so we explored other innovation systems' literature and related materials. It was also quite an uphill task to build the community of practice to enable people to understand the topic. Case study selection was also biased, based on gaps as perceived by the stakeholders although they needed to address the greatest gaps in the different countries' KSs. We only selected two in each country although there is potential for a number of case studies to address the different facets of the KS and give a clear picture of how the different elements of the KS may be interacting and work for directionality purposes.

Understanding STI policy challenges and how the knowledge systems approach can help

The predominant challenge for African STI policy is capacity development to learn, adopt and use existing and new knowledge and technologies to promote sustainable and inclusive development (Tijssen and Kraemer-Mbula, 2018). Further, the current policy frameworks, design of STI instruments and interventions may not be fit for purpose to address the transformative agenda of STI. This is underpinned by two issues; first, that frameworks for advancing the STI agenda are developed elsewhere, hence not relatable, and applicable for LMICs. Second is a conundrum of governments designing interventions that will not only minimize distortions but continue to support the achievement of the SDGs. To this end, a number of LMICs must be supported in developing coherent frameworks that support knowledge and innovation-related capabilities by supporting an array of actors (formal and informal) who dominate these contexts.

To tap into the potential of new and emerging technologies, an enabling environment that fosters learning and use of knowledge for innovation is required. Therefore, more time and resources need to be located to develop key knowledge sectors of developing countries.

Some countries in LMIC have adopted various approaches to STI policy. A common approach has been the Innovation Systems (IS) approach applied to formulate their national innovation systems – mainly policies and agencies for knowledge production and commercialization (Padilla-Pérez and Gaudin, 2014). In this, most of these countries have used the IS perspective as a framework for developing and implementing their STI policy as a method of understanding STI needs and socio-economic outcomes in a particular context – be it country or region (Chaminade and Padilla-Pérez, 2017). This poses a challenge in the operationalization of these developed STI frameworks because of LMICs' highly heterogeneous contexts characterized by poverty, severe income disparities and health-related issues. Again, many innovation activities are centred in and around the informal sector, yet the IS approach puts a lot of emphasis on the strength and functionality of the formal research systems and their economic returns (Cirera and Maloney, 2017; Chataway, et al., 2019) .

Other than the IS, some STI frameworks remain non-aligned with the tenets of economic growth, and do not show explicit preference for environmentally and socially sustainable agendas, a directionality failure (Schot and Steinmueller, 2018). It is therefore important to consider the following in embracing and building alternative and complementary frameworks.

First, there is no proposed policy blueprint for building an effective STI system. There is a need to include diverse actors and stakeholders, their capabilities, an enabling environment for actors to link with each other and one that can foster learning and use of knowledge for innovation. For example, civil societies may be key in triggering technological change by mediating between technology developers and marginalized groups to promote innovations that address social needs. Therefore, an effective STI policy framework needs to take into account an array of actors and include all types of innovation, aligned by the particular development aspirations of a country's local needs otherwise referred to as the "directionality" of innovation.

Second, there is need for broadening the scope and key priorities of STI policy frameworks to effectively support the transformative changes implied in Agenda 2030. The STI policy should broaden its understanding of the innovation spectrum to address complex societal challenges that span the economic, social and environmental dimensions of development. It needs to provide some directionality elements on technological change and innovation that is consistent with sustainable and inclusive development.

Third, there is a need for cross-linkages and synergies between STI policy and sectoral policies addressing specific societal challenges. Currently and especially in SSA, STI policies are fragmented, poorly coordinated and marred with duplicity in the sectors (Chaminade and Padilla-Pérez, 2017). In Kenya, for example, key national regulatory agencies like the National Commission for STI regulate policies but not those relating to health, environment, agriculture and food as these are regulated by key line ministries. Rwanda has a similar situation. The dissolution of the Ministry of Science, Technology and Scientific Research in 2009 paved a way for the Directorate of Science, Technology and Research within the Ministry of Education as the key regulatory institution of STI. This diminished the power for policy coordination among different line ministries that perform R&D and scientific and technological services (UNESCO, 2015). The result is a lack of cross-sectoral linkages within areas relevant to sustainable development. Addressing such complex cross-cutting issues requires transformative thinking and new governance arrangements with a diversity of actors and organizational reconfigurations involving policy mixes and levels of governance (Schot and Steinmueller, 2018).

Overall, these processes will happen if wider conversations about STI are fostered and identified and STI issues relating to sustainability prioritized. One potential way is by marshalling different evidence through proper research that allows for characterization of the different aspects of the knowledge production and use processes. While it is critical that these processes are pursued to ensure a transformative aspect of STI, it is important that countries in SSA build proper capacities and capabilities to design and implement STI instruments for sustainable and socio-development outcomes.

The KS concept pursued supported all these "lines of inquiries" by organizing a process through which a new conversation on STI takes place. The project team developed analytical tools to support this conversation. The design principles were followed: characterization of the STI landscape by broader conceptual literature review and in-country literature reviews; revisioning of interventions; and prioritization of the STI instruments to mobilize an analysis that can begin a transformative and different conversation about STI. Participation has been a core component of our work that encompasses tactical approaches around convening the wide stakeholder base of the KS. Through these processes, we envisioned countries' STI through the transformative KS perspective that comprises a set of desired characteristics that support KS, and this is further supported by the configuration and elements of a KS.

The approach helps to not only map the formal STI systems – research agencies, universities, science and innovation coordinating agencies, clusters of policies and firms in the formal economy – but also highlight the importance of a large array of knowledge-related activity in the informal sector. The approach demonstrates effectiveness as it challenges the idea that the linear transfer, use and dissemination of research and other knowledge are the key mechanisms driving innovation and development impact. Through processes of research and consultation, this research continuously challenges and develops these ideas, to establish a practical KS concept; a transformative KS by building an evidence base; and evaluation frameworks which will support decision making on KS investments to enhance development impact.

Unpacking the national STI landscape through the knowledge systems approach

Knowledge production

By applying the KS perspective in East Africa to characterize the STI contexts, it is evident that STI arrangements in the three countries are still evolving. On the one hand, the three countries experience generic challenges such as weak 'knowledge into use' systems, unclear priorities on investments in KS; and informal-formal challenges. On the other hand, they are different in their institutional frameworks, and rules and procedures that facilitate the creation and use of knowledge. Both the state and non-state actors play major roles in enabling production and use of knowledge.

For example, while Kenya has liberalized its knowledge production, drawing from both public and non-public systems, in Rwanda the knowledge production system greatly relies on the technical capabilities of its public systems. The state plays the biggest role in financing and setting up of knowledge-producing institutions including innovation hubs and universities. This is largely because of its state-centric nature where eventual success of these knowledge- producing institutions is highly uncertain and potential financiers are too risk-averse to finance its development. In the case of Tanzania, knowledge production is evolving between consolidated and liberal systems, both state and non-state controlled, which are aligned to sectors and emphasize on agricultural co-production through extension services. Significant capacity development of bureaucracies in Rwanda and generally in the region will be required if the states are to continue playing effective roles in knowledge production.

Universities and public research organizations that add to the pool of knowledge-producing actors in each country are important, with significant differences in their organization and roles within the wider STI landscape. Kenya, for example, has embraced a relatively open university system, comprising public and private universities that generate research knowledge, teaching and training. These universities by design focus on specific niches and have managed to pursue the third mission activities that involve general knowledge and technology transfer, policy strategy and governance, stakeholder engagement and culture incentives and capacity (The Scinnovent Centre, 2015). By contrast, Rwanda's knowledge production is centred on the collation of all public universities and their constituent colleges into one single university – The University of Rwanda, a key country 'knowledge hub'. The university's central approach to increased knowledge production is seen through various partnerships with international development agencies. For example, unlike Kenya and Tanzania, the University of Rwanda dominates the hosting of the World Bank Centres of Excellence aimed at developing human resources, capacity strengthening, research management and improving the overall research environment. On the other hand, Tanzania's universities continue to be central to knowledge production through their approach of 'developmental universities' implicitly implied through the triple mission of teaching, research and community engagement (Fussy, 2017).

The outcomes of open or consolidated knowledge production systems vary from one context to another. More open-liberal systems have demonstrated potential for inclusivity, encompassing an array of actors, both formal and informal, producing different types of knowledge as witnessed in Kenya. Nevertheless, coordinating the vast set of actors is a key challenge for the country.

Knowledge use and impact

While knowledge use for impact has been heralded as a key weakness across the three countries, certain configurations of the KS are supporting pathways for impact. Innovation support is one of the pathways the three countries are pursuing for knowledge impact. A plethora of vibrant innovation and entrepreneurship ecosystems exist through innovation hubs although they require further development and support.

The informal sector is growing as an important location of knowledge production, dissemination, and impact. This sector has played a catalytic role in ensuring 'knowledge into use' pathways are supported. For example, it has enabled Kenya to experience the most outstanding innovations led by non-state actors, including the private sector and development partners. The *M-Pesa* innovation is a key example. The initiative uses mobile phone technology to catalyse money transfer, credit facilities and information flows (market information, social and environmental information, among others) between producers and users of various social groups. *M-Pesa's* success has largely been steered through a private company, Vodafone (Safaricom), with the support of DFID (a development partner). Early development stages drew heavily on feedback from low-income user groups and feedback was incorporated into the design. In Kenya institutions such as the banking system, information communication technology (ICT), internet – that support such innovations to thrive have enabled *M-Pesa's* success, although its impact on broader Kenyan policy-making remains unclear.

The Rwandan government, on the other hand, seems to have established clear institutional mandates that set the agenda and enhance clear flows between knowledge production and use, both in the formal and informal sectors. Although this state-led system is younger and less established, the niche pursued is ICT supported and enabled with investments in innovation hubs to link knowledge produced into use. This state system continues to dominate linkages with end users. Currently, half of all university graduates in the workforce are employed by the public sector, an indication that the skills currently acquired through higher education are more relevant for public sector than for private sector employment (UNESCO, 2015).

For Tanzania, findings suggest that its knowledge production and use, although emerging and sectorally aligned, could be strengthened further to ensure more clarity between institutional establishments and mandates. The different public R&D institutions including government-led initiatives, such as innovation hubs, are working hard in linking knowledge produced to the end users who include farmers and the wider society. A case in point is the user-focused technology transfer experienced in Sokoine University of Agriculture. The university is stimulating interactive processes with farmers based on specific agricultural technologies developed through village knowledge centres with the aim of promoting co-creation and co-innovation. The only challenge is that these initiatives rely heavily on international funding and therefore there is need for more public investment to support use of research and knowledge produced.

Funding mechanisms for production and use of knowledge

Financing is a key enabler for production and use of knowledge, although it plays out differently in the three countries. Kenya, Rwanda, and Tanzania have established their SGCs with different funding schemes and targets. Kenya's National Research Fund mainly supports knowledge production through institutional research grants, university research and postgraduate studies (NRF, 2016) but with unclear structural linkages to knowledge use. Even other financial partnerships such as the Newton Utafiti Fund, established in 2016 in partnership with the British Government remain unclear, as regards specified funding for knowledge use.

Until the establishment of the Rwanda Science Granting Council in 2017, Rwanda's funding was more sectorally based as there was no central research funding (Tigabu, 2017). Rwanda's Ministry of Education (MINEDUC's) Directorate of Science, Technology, and Research (DSTR), has been involved in coordinating and managing research activities in Rwanda with certain specific structural linkages to knowledge use: it sets budgets for funding facilities such as industrial incubation centres, product laboratories and so on, implying a more targeted funding for specific industrial outputs and outcomes. However, we now see more targeted funding for R&D activities through the establishment of the National Research and Innovation Fund (NRIF) coordinated by the National Commission for Science and Technology (NCST) (UNESCO, 2015).

In Tanzania, the National Fund for the Advancement of Science and Technology (NFAST) is responsible for financing knowledge production and use although a huge percentage of financing (42 per cent) is derived from foreign institutions (Hanlin and Khaemba, 2017). Agriculture and health still dominate the list of priorities heavily supported by international funding, resulting in "externally controlled knowledge" (Kuntosch and König, 2018), a key feature across the three countries. However, the national funding support in Tanzania's STI ecosystem is similar to the Kenyan STI on research grants, R&D in academia, fellowships, and AWARDS.

Knowledge interactions and inclusion

Formal-informal knowledge links are also emerging as a key enabler of knowledge use. Evidence from the three countries reveals that the informal knowledge sector, for example, the '*Juakali*' sector in Kenya (Ouma, 2010; ITC, 2019) is closely linked to knowledge use because the sector mainly builds on peoples' capabilities (e.g. entrepreneurship skills, needs and aspirations), enabling them to serve and empower people better. Accordingly, strong linkage between informal and formal KS is likely to spur effective knowledge use. Rwanda has made strides in this direction, enacting policies that enable the informal health sector to link to the formal health systems. Other efforts include launching the manifesto dubbed 'Made in Rwanda Policy', in which Rwanda's indigenous systems inform its policies and industrial revolution. Towards this, the State established the Home-grown Department to help promote a set of home-grown solutions (UNESCO, 2015). This department hosts a number of programmes that provide strategic linkages between formal and informal knowledge producers and users, including collaboration with the private sector, and targeted skill development through industrial training. However, this linkage appears to be weak, especially in Kenya and Tanzania where – again – poor coordination and lack of clear structures impedes integration.

The three countries are also pursuing technical and vocational education and training (TVET) to strengthen knowledge creation, dissemination, sharing and use for socio-economic development from the informal to formal sector. In all three countries, the approach is as inclusive as possible incorporating learners from different stages of learning. Rwanda has focused greatly on using TVETs to promote secondary education; in Kenya it is a means to support technical skills, while in Tanzania, areas of support include institutional-based training, apprenticeship, and entrepreneurship. The Vocational Education Training Authority (VETA) in Tanzania reveals that the underlying basic evidence for promoting TVETs is the recognition of prior learning as it appears to widen employability opportunities to enhance knowledge application.

This study found that knowledge production in the different domains of knowledge is pertinent and further interaction within the domain gives impetus to new knowledge and enhances existing knowledge for better use. The potency and significance of interdisciplinary knowledge has improved the essence of life and humanity. The need to strengthen inter-disciplinary linkages as well as interactions between forms of knowledge, that is, formal and informal is critical.

In the three countries, there were efforts to promote such knowledge interactions through promoting interdisciplinary university research programmes despite various challenges. Key areas that are lacking and require further strengthening are: platforms for research and evidence synthesis to enhance both access and usability of knowledge; more funding for knowledge production and use; better coordination and elimination of institutional redundancies; and the establishment of appropriate frameworks to enhance formal and informal knowledge sectors and their linkages.

Case studies and what works in different contexts

We provide a snippet of the findings from the case studies pursued that aim to elaborate STI arrangements and provide examples and opportunities that support the development of a transformative STI system. These cases are drawn from the insights retrieved through mapping the national STI systems and identifying some general gaps that need attention. For example, in Kenya, a framework to support coordination linkage of research into use remains a key gap despite the country's strength in knowledge production through domestic and international collaboration. Hence, we looked into initiatives that have strived to promote the management of research production and their use for societal needs. The *utafiti sera* (Kiswahili for research policy) initiative is one of the many initiatives that have made these attempts.

The initiative has tried to get social science into policy traction. It demonstrates ways of synthesising evidence by involving diverse actors including producers and users of evidence, and further knowledge brokerage through policy champions to ensure use of research evidence. Evidence synthesis in particular areas of focus is organized into 'houses'. The focus for *utafiti sera* on urban governance house is on issues to do with human displacement in roads, human rights and especially the poor affected by infrastructure and social protection in Kenya. The house has managed to influence information transfer mechanisms to various stakeholders including policymakers, businesses, and households through availing such information closer to the recipients. Despite building momentum towards its goals, the initiative faced key challenges on limited funding and limited capacity to enhance research translation beyond advocacy. A key lesson from this initiative is that effective promotion and coordination of knowledge production and use require specific champions whose capabilities have to be enhanced and supported over a long period. Anchoring such an initiative in government systems could enhance sustainability beyond the funding period but again this will require a collective mission and culture shift to embrace inclusivity in decision making and leverage on comparative strengths of various actors.

The second case study conducted in Kenya explored university-industry linkages in different organizational settings. These were a public university – Jomo Kenyatta University of Agriculture and Technology

(JKUAT) and a private university – Strathmore University (SU). The case of SU offered the opportunity to demonstrate the interactions of knowledge producers and users whereby private universities are able to forge new patterns of partnership with private industry. The university has explicitly tried to blend business and community interests through establishment of research centres, specifically as collaboration nodes with industry. Energy and climate innovation research centres are particularly powerful in stimulating sustainability in entrepreneurship, and in driving economic success. The university has successfully managed to link to industry through development of non-traditional capabilities such as knowledge brokerage. There is a need to re-imagine the role of these actors who act as intermediaries to encompass other roles such as problem definition and agenda setting.

On the other hand, JKUAT demonstrated the directionality element of their knowledge-related activities. The types of linkages pursued by JKUAT focused less on formal industry partners and more on small holder agriculture and supporting local communities, partnering with devolved country governments on local development priorities. The university has been highly successful in using tissue culture to distribute disease-free planting material to local communities. This indicates that most of the interactions for the academia and industry are based on the university's orientation; in this case, JKUAT leans more towards agri-food value chains. This case study demonstrated the need to define industry more broadly and facilitate academia interactions with the informal sectors, a key indication of broadening the STI focus.

Overall, governance framework played a huge role around goals pursued by each actor type and the extent of these partnerships. The actor networks bring about unidirectional and interactive pursuit of co-innovation and co-creation of knowledge for various sustainable agenda outcomes. We conclude that to ensure proper linkages with end users, there is need for appropriate governance systems that incorporate diverse actors in governance while pursuing niche areas as demonstrated by both universities.

In Rwanda, the mapping identified a huge opportunity and momentum in building the formal and informal knowledge and innovations to support growth. One of the cases we looked into was on bridging the indigenous knowledge sources into the wider knowledge system and mainstream development activities in the health sector. Traditional healers organized into associations through a loose network are connecting with a cluster of formal research organizations. These formal research entities are organized and established to specifically support and explore traditional remedies. For example, the centre of excellence on biodiversity at the University of Rwanda has built a herbarium to support research and document the knowledge as well as research evidence on the ingredients and concoctions of traditional medicines through better packaging and marketing. This has contributed to dual use of formal and informal health systems by patients. Further, a national agency, the National Industry and Research Development Authority has registered the traditional healers and organized them around associations that have enabled provision of training services. This has also seen supporting institutions to establish partnerships, for example, with UNESCO (organizers of the African day of traditional medicine annually).

This case study revealed the importance of the informal knowledge sector which impacts largely formal systems. The key lesson was on creation of synergies between formality and informality through processes such as regulation, creating opportunities for private sector investments, and capacity-building which could help optimize the health systems and contribute to achieving outcomes.

We also investigated knowledge initiatives to produce and use knowledge by turning viable ideas into business models. We looked at the kLab and Fablab innovation hubs in Rwanda. These centres have promoted and helped with the development of technologies that are embraced by communities to solve their day to day challenges although they are locked in path dependency approaches of ideation, prototyping and letting go to the community. This presents a narrow way of integrating knowledge production and use as it is an iterative process. A key reflection will be around setting up of innovation hubs along with academia and facilitating the interconnected strands of funding, mentorship, user engagements, and monitoring and evaluation of the initiatives.

In Tanzania, we explored newer initiatives enabled by public research systems and how they are linking with end users. The village knowledge centres revealed bidirectional knowledge flows with the end users. Farmers who are the end users use the village knowledge centres to access information from researchers in Sokoine University of Agriculture (SUA) while still helping in co-creation of knowledge through feedback processes. The village knowledge centres have gone beyond the earlier set mandate to promote technology and innovation relevant to small holder farmers and have expanded to identify, negotiate and develop shared value opportunities that benefited small-holders and the private sector – for example, developing milk production, processing and marketing systems. This initiative demonstrates that the institutionalization of community engagement through the village knowledge centres is a key pathway for knowledge-transfer from university to the community and vice versa. However, the design of this should evolve so that the agenda is not mainly science-driven but is rather mutually beneficial to the local communities.

The second case study explored the impacts of innovations in the context of KS supporting formal and informal interactions, capabilities building, inclusiveness and the outcomes and impacts of such investments. We studied the Buni Innovation hub and the VETA programmes that have managed to enhance knowledge creation and link it to use. Buni as a networking and knowledge transfer hub has played a key role in promoting business ideas, plans and strengthening knowledge on business discipline, marketing, and support incubation. It has contributed to the introduction of new start-ups and products, strengthening the existing ones which in turn have successfully delivered new products, services, and process. The key area of focus has been on software development although some start-ups have focused on sustainability of relevant business models, for example, recycling plastic material. There is no specific focus on inclusion and sustainability unless it is accompanied by special externally funded projects. The Government of Tanzania through its public funds supports the running of the hub. Strong government control curtails operations of such an entity that is strongly inclined towards private sector-led solutions. There is need for the hub to link with the private sector as the hub activities are directed more towards developing solutions jointly with the private sector. This requires different design models in governance of the hub with a hosting model that reduces bureaucracy to encourage private sector linkages and more collaboration – formally and informally – with the local institutions.

The Vocational Education and Training Authority (VETA) has also managed to develop programmes demanded by communities both in the formal and informal sectors. The organization explicitly focuses on apprenticeship training as a system to foster knowledge acquisition in the informal economy with emphasis on the poor and marginalized communities. There is huge potential for Vocational Education Training (VET) organizations to link the informal KS but need better incentives to advance apprenticeship. This, for example, could be through the introduction of information centres for innovation, technology and entrepreneurship within the VET institutions that help forge knowledge interactions with the informal industry. Other models that could be pursued include establishment of VET centres of excellence to pursue growing areas in Tanzania like the extractive industries, mining, and leather technologies to enhance capacities in these fields. However, these centres need to continue enhancing technical skills development and not end up being knowledge production hubs with university approach unless they remain centres of excellence in TVET and skills.

Key learnings and conclusions

We have sought to apply the KS approach to map national STI systems and understand where interventions could improve outcomes. Review of existing evidence has generated a range of literature and analysis that has helped reveal certain aspects of the KS that address sustainable development outcomes.

We have used the KS perspective to characterize how the different countries in East Africa produce and use knowledge, the key enablers, and barriers to this, and how KS could strengthen their STI systems. Our analysis and stakeholder dialogues around this have indicated the enormous potential for trans disciplinary learning within and across LMICs to help direct STI towards desired outcomes under the SDGs.

Overall, the three countries are characterized by knowledge production, use and policy support systems that seek to promote innovation through support for research, development, and capability building. However, the systems have varying characteristics with different implications in effectiveness of these systems, and their potential to support inclusive innovation and address diverse SDGs.

The Kenyan knowledge system is more open and inclusive, being characterized by a plethora of state and non-state actors producing and using knowledge. However, this KS is relatively strong towards knowledge production but weaker in integration with knowledge use. Our early findings suggest that there have been attempts to strengthen knowledge use through research into use initiatives that coordinate knowledge integration as well as the transition from linear knowledge production to trans-disciplinary knowledge use to meet people's needs and address issues of sustainable and inclusive societies. However, these attempts like *utafiti sera* has only focused in the area of social science with a lot still to be done in other areas.

The Rwandan case presents a state-led type of KS with huge investments in ICT, embracing a particular directionality of objectives. This system also embraces inclusion through state-led initiatives to address informality and especially in key sectors such as health, relevant to its economy. The system has huge potential to achieve structural changes in the KS to accelerate progress towards addressing social and environmental goals but may be impeded with the state-centric approach (exclusion of other valuable actors) making it weaker and less resilient. Inclusion of an array of informal governance actors and effective integration could make its KS transformational.

Most of Tanzania's institutional set-up is still in its infancy, compared with other East African countries (EAC) such as Kenya and Rwanda. The country's KS has largely been supported by foreign institutions contributing to setting up R&D with more orientation towards a sectorally aligned knowledge system. Governance still appears to be relatively weak with alignment towards a state-centric knowledge regime. Donor and foreign support have however made attempts to promote knowledge creation through innovation hubs that support the huge young demographic dividend. Further support has gone into the establishment of research centres such as Sokoine University that links with the end users, the village knowledge centres initiatives that are more inclined towards addressing the socio-economic challenges of the rural poor. Tanzania is therefore uniquely placed to harness its potential by creating an integrated system capable of building inclusive innovations and supporting sustainable development trajectories.

This characterization process using the KS perspective begins to open up the space and broaden out areas of inquiry in the application of STI in each country and how this should shift to bring about inclusion and achievement of SDGs. This does not imply that a more open or consolidated KS is better than the former but gives pointers on how a more open KS could benefit knowledge flows and be more oriented towards transformation.

The case studies looked deeper into novel innovation initiatives in the STI ecosystem. The knowledge into use hubs have attempted to address a key gap in the research-policy conundrum. Although this has succeeded in creating some changes through ensuring research evidence is well synthesized, the normative ways of designing research into use platforms have not succeeded owing to a number of challenges. These challenges may include the hubs turning into usual workshops, ending up reinforcing strong actor networks and closing down the less powerful actors. The outcome is a place where endorsement and validation happen, hence it is important to evaluate these processes to achieve more impact. Similarly, we observe opportunities whereby universities are able to forge new patterns of partnership – addressing some directionality element of their knowledge-related activities interacting with the informal sectors, thus calling for a need to redirect more public investments.

Formal-informal knowledge strengthening is important, and Rwanda's case has been a good example especially in supporting the organization of traditional healers into groups or societies that can be registered. This has brought about dual use of formal and informal health systems by patients. However, there is need for further interrogation on the appropriate models and framework for linking the informal to the formal KS as the process is complex and runs the risk of marginalizing informal processes.

The role of institutional innovations is key, SUA has embraced the idea of "scalable learning" with the goal of partnering with the local communities through the village knowledge centres to disseminate their research. This approach has demonstrated the role different types of actors could play in knowledge co-creation and co-innovation if they are involved in the design of interventions.

The case study analysis revealed the nature of interventions addressing one or two parts of the KS approach that has some directionality and explicit mechanism to focus on SDGs. We see potential in using the KS perspective to begin conversations and guide the design of interventions that will holistically build a transformative STI policy potential.

From our study we observe that using the KS approach, we can guide interventions in STI and put into practice strategic choices and interventions that countries can pursue, or build on, to yield optimal SDG outcomes for their particular contexts.

From our analysis, there is a significant (and very diverse) set of promising knowledge-related activity and initiatives that are often overlooked in mainstream STI planning. There are many examples in the country studies, and these often tap into informal knowledge and innovation processes and are highly relevant to inclusive and sustainable development. Examples include village knowledge centres and novel SDG-facing private sector investments. These types of initiatives hold valuable insights into the way knowledge can be leveraged for local demand-led outcomes and may have innovation models that could disrupt more established modes of leveraging STI outcomes. Investments that bridge these experiences and approaches into mainstream STI planning and investment design could help transform the orientation of the wider STI landscape towards more relevant SDG outcomes.

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[2] We utilize a university-industry example because of the challenge of leveraging the knowledge and expertise of universities in private sector innovation evident in Kenya's knowledge, as it is in most countries. The case study was framed by questions of how effective these linking mechanisms are in supporting innovation in industry in a general sense and the extent to which these developments in the knowledge system are aligned to progressing the SDG agenda and the nature of the institutional arrangements that support or hinder this.

[3] A private university is funded through private resources, mainly students' fees and has offered the opportunity to explore a relatively recent development in the knowledge system whereby private universities are able to forge new patterns of partnership with private industry.

References

Anadon, L. D. , Chan, G., Harley, A. G., Matus, K., Moon, S., Murthy, S. L., and Clark, W. C., 2016. Making technological innovation work for sustainable development. *Proceedings of the National Academy of Sciences of the United States of America*, 113(35), pp.9682–9690. doi: 10.1073/pnas.1525004113.

Asongu, S. A. and Nwachukwu, J. C. 2017. Building knowledge economies in Africa: A survey of policies and strategies. *SSRN Electronic Journal*, pp.1–31. doi: 10.2139/ssrn.2988293.

Chaminade, C. and Padilla-Pérez, R. 2017. The challenge of alignment and barriers for the design and implementation of science, technology and innovation policies for innovation systems in developing countries. in *Research Handbook on Innovation Governance for Emerging Economies. Towards Better Models*, pp.181–204. doi: https://doi.org/10.4337/9781783471911.

Chataway, J., Chux, D., Kanger, L., Ramirez, M., Schot, J. and Steinmueller, E., 2017. Developing and enacting Transformative Innovation Policy: A Comparative Study. in *8th International Sustainability Transitions Conference June 2017 Gothenburg, Sweden.* Sweden, pp.1–28. [Online]. Available at: https://minciencias.gov.co/sites/default/files/developing-and-enacting-transformative-innovation-policy.pdf (Accessed 31 August 2020).

Chataway, J., Dobson, C., Daniels, C., Byrne, R., Hanlin, R. and Tigabu, A. , 2019. Science granting councils in Sub-Saharan Africa: Trends and tensions. *Science and Public Policy*, 46(4), pp.620–631. doi: 10.1093/scipol/scz007.

Cirera, X. and Maloney, W. F. 2017. *The innovation paradox: Developing-country capabilities and the unrealized promise of technological catch-up*. Washington, DC: World Bank. doi: 10.4337/9781786433251.00007.

Cornell, S., Berkhout, F., Tuinstra, W., Tàbara, J. D., Jäger, J., Chabay, I., ... and van Kerkhoff, L., 2013. Opening up knowledge systems for better responses to global environmental change. *Environmental Science and Policy*, 28, pp.60–70. doi: 10.1016/j.envsci.2012.11.008.

Fosci, M., Loffreda, L., Velten, L. and Johnson, R., 2019. *Research capacity strengthening in Low- and Middle-Income countries.* Research Consulting.

Frost, A., Hall, A., Marshall, F., Atela, J., Ndege, N., Ciarli, T., ... and Chataway, J., 2019. *Understanding knowledge systems and what works to promote science technology and innovation in Kenya, Tanzania and Rwanda*. Presentation at Conference 'Global Development Network – Knowledge for Sustainable Development: The research policy nexus'. October 2019. Bonn, Germany.

Fussy, D. S. 2017. Policy directions for promoting university research in Tanzania. *Studies in Higher Education*. 43(9), pp.1573–1585. doi: 10.1080/03075079.2016.1266611.

Hanlin, R. and Khaemba, W. 2017. *The political economy of the Tanzanian science granting council.* Nairobi: SGCI.

ITC. 2019. *Promoting SME competitiveness in Kenya: Targeted solutions for inclusive growth. ITC, Geneva*. p.68. [Online]. Available at: http://www.intracen.org/uploadedFiles/intracenorg/Content/Publications/Kenya_SME_Comp_final_low_res.pdf%0Ahttp://www.intracen.org/publication/SME-competitiveness-Kenya/ (Accessed 31 August 2020).

Khalifa, A. B. 2019. Direct and complementary effects of investment in Knowledge-Based Economy on innovation performance in Tunisian firms. *Journal of the Knowledge Economy*. 10(2), pp.561–589. doi: 10.1007/s13132-017-0481-1.

Kuntosch, A. and König, B. 2018. Linking system perspectives with user perspectives to identify adoption barriers to food security innovations for smallholder farmers – evidence from rural Tanzania. *Food Security*. 10(4), pp.881–896. doi: 10.1007/s12571-018-0821-4.

Mouton, J., Gaillard, J. and Lill, van M. 2014. *Science granting councils in sub-Saharan Africa*. South Africa: Stellenbosch University, Centre for Research on Evaluation, Science, and Technology (CREST), Institute of Research for Development (IRD).

NRF, 2016. General principles for accessing funding from NRF. National Research Fund. Johannesburg: NRF. doi: 10.1017/CBO9781107415324.004.

Ouma, K. F. 2010. *Regularizing the informal sector "jua kali" activities in Nairobi for sustainable development*. Presented at *46th ISOCARP Congress*, pp. 1–13. [Online]. Available at: http://www.isocarp.net/Data/case_studies/1773.pdf (Accessed 31 August 2020).

Padilla-Pérez, R. and Gaudin, Y. 2014. Science, technology and innovation policies in small and developing economies: The case of Central America. *Research Policy*. 43(4), pp.749–759. doi: 10.1016/j.respol.2013.10.011.

Schot, J. and Steinmueller, W. E., 2018. Three frames for innovation policy: R&D, systems of innovation and transformative change. *Research Policy*, 47(9), pp. 1554–1567. doi: 10.1016/j.respol.2018.08.011.

Schrempf, B., Kaplan, D. and Schroeder, D. 2013. National, Regional, and Sectoral Systems of Innovation – An overview. *Report for FP7 Project Progress*. p. 32.

Sutz, J. 2020. Redefining the concept of excellence in research with development in mind. in Kraemer-Mbula, E., Tijssen, R., Wallace, M. L., and McClean, R. (eds) (2019). *Transforming research excellence. New ideas from the Global South*. Cape Town: African Minds, pp.19–38.

The Scinnovent Centre. 2015. The third mission framework: Fostering partnerships between universities/public research institutes with the private sector. Nairobi: Sciennovent Centre. doi: 10.14201/eks2016171718.

Tigabu, A., 2017. Political and economic constraints influencing science granting councils and R&D in Sub-Saharan Africa: the Case of Ethiopia. In: Chataway, J. et al. *Case studies of the political economy of science granting councils*. International Development Research Centre (IDRC). Available at: https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/56811/IDL-56811.pdf?sequence=2&isAllowed=y (Accessed 13 November 2019).

Tijssen, R. and Kraemer-Mbula, E. 2018. Research excellence in Africa: Policies, perceptions, and performance. *Science and Public Policy*. 45(3), pp.392–403. doi: 10.1093/scipol/scx074.

UNCTAD. 2019. *A Framework for Science, Technology and Innovation Policy Reviews: Harnessing Innovation for Sustainable Development.* Geneva: United Nations Conference on Trade and Development. [Online]. Available at: http://unctad.org/en/Docs/dtlstict2011d7_en.pdf (Accessed 31 August 2020).

UNESCO. 2015. Mapping research and innovation in the Republic of Rwanda. In G. A. Lemarchand and A. Tash, (eds.) *Go SPIN Country profiles*. Paris: United Nations Educational, Scientific and Cultural Organization.

PART 2

BUILDING SCIENCE SYSTEMS IN AFRICA: EMPIRICAL CONSIDERATIONS

5

Science Councils and Financing of Research, Development and Innovation in Africa

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Geoffrey Banda

Abstract

The African Union's Agenda 2063, supported by the Science, Technology and Innovation Strategy for Africa (STISA-2024), advocates for economic development that leverages the knowledge-based economy and especially the potential of STI in upgrading industrial activities. It is incontestable that research is fundamental for contextualized generation of new knowledge, adopting and adapting existing innovations and knowledge, and their application to Africa's economic and human developmental needs. African countries' innovation ecosystems that support the aforementioned goals, and the funding of research and STI through science granting councils (SGCs) and other actors, are critical. This chapter discusses three key issues on the funding of STI and research: first – how Africa has historically funded STI and the reasons behind adoption of certain approaches; second, the shortcomings of historical and current funding models; and third, innovative funding models from the continent and elsewhere that can be adopted to accelerate local research and innovation activities.

Adopting a historical and contemporary approach, the chapter explores how private and public actors across Africa can play a significant role and imbue resilience in financing research and innovation. The chapter also explores various strategies and measures research organizations use to align their activities with national development policies.

Introduction

Science, technology and innovation (STI) are undeniably key drivers of change (Cliff, 2010) and have been proffered as a key component of positively impacting African countries' economic growth, national and international competitiveness, as well as accelerating industrial development. The socio-technical imaginaries projected by policymakers revolve around new technology and innovation adoption leading to transitions in: economic and industrial structures; nature and form of employment; impact on people's livelihoods; and food and health security while protecting citizens from current and emerging technology and social risks. We adopt Jasanoff and Kim's (2015) description of socio-technical imaginaries as the notion or conceptualization of collectively held and projected visions of anticipated and wanted futures that are operationalized through STI ventures. Policymakers at national, regional and even continental levels shape these socio-technical imaginaries through policy and practice as well as operationalize them by allocating resources to their realization. Solving the wicked problem of realizing these socio-technical imaginaries hinges upon understanding the complexity of applying context-specific knowledge that applies social, applied and natural sciences, among other fields, to solve the economic and industrial development needs of African countries. We argue that research and innovation in these and other areas is critical in generating Africa-contextualized knowledge that supports evidence-based policy making, generates political legitimacy, acceptance of new technologies and innovations, while at the same time managing new risks that come as societies industrialize. Inevitably, this requires coordination and collaboration of activities by actors in academia, business, government and other sectors. SGCs as boundary-bridgers, boundary-brokers and collaborators (Cash, 2001; Pohl, et al., 2010; Guston, 1999) play a significant role in mediating and extending the research-policy interface and bringing together broader research-stakeholder interface (Schut, et al., 2013). Thus, SGCs do not only function as allocators of scarce resources, but they also have a performativity role which shapes and directs the research trajectory through guided identification of areas that researchers and innovators should focus on. SGCs hence play a role in directing and shaping knowledge and innovation generation and subsequent diffusion. If there are symbiotic and synergistic relationships with other actors and agents which support translational and commercialization activities, it becomes possible to realize the projected socio-technical imaginaries of economic and industrial development. The various interactions, relationships, governance, regulation, support, funding and collaborations of the actors in the value chains and business models constitute the innovation ecosystem.

The developmental challenges for Africa present the typical definition of the wicked problem. The wicked problem has characteristics of such magnitude of complexity – implying a problem that cannot be resolved easily but entails multiple resolutions (Rittel and Webber, 1973; Struik and Kuyper, 2017; Waddock, 2013). We acknowledge that economic and industrial development futures for African countries will face the typical wicked problem. For example, by solving the economic growth challenge through industrialization – which leverages application of new and existing technologies – there is a risk of environmental damage, which raises new risks for citizens. Thus, solving the development problem can create a sustainability, environmental and health challenge for the continent. As one problem is resolved, a new one arises which needs to be resolved, and the sequence is repeated, hence the need for local generation of knowledge, technologies and innovations that address the local issues in a timely manner. We argue that this realization calls for greater emphasis on enhancing local science systems and funding researchers and innovators. The wicked problem is extended to competition for resources for research and innovation against other social and economic development imperatives that need immediate political action. Focusing specifically on research and innovation, there is further intersectoral resource competition across diverse areas such as engineering, social sciences, health, natural sciences and other humanities. We argue that research and innovation require sustainable and innovative funding models and investments by the public, private, public-private-partnerships and charities, as well as other actors.

However, 37 years after adopting the Lagos Plan of Action, and despite consistent acknowledgement of the importance of research and innovation in the continent's economic and industrial development and improved productivity (Mugwagwa et al., 2018), numerous African countries have not met the heads of states' commitment to allocate at least 1 per cent of gross domestic product (GDP) to research and development (R&D). Only Kenya allocated 0.8 per cent and Mali and South Africa – with 0.7 per cent of GDP – have come near the goal (UIS, 2016). Africa's low domestic investments in research and innovation in particular, and in STI broadly worsened after the 2008 global financial crisis and the subsequent 2008–2012 global recession which caused reduced budgetary allocations to R&D globally. The same situation prevailed in developed economies; for example, the EU's target to raise overall R&D investment to 3 per cent of GDP by 2010 was shifted to 2020 after the 2010 deadline was missed (UIS, 2016). The 3 per cent target was an ambitious goal as the UIS data tool shows. To date, only six countries worldwide (three in the EU: Denmark, Finland and Sweden) have managed to surpass the 3 per cent target. The leaders are Japan at 3.6 per cent, Israel at 4.1 per cent, South Korea at 4.3 per cent, while Austria, Germany and Switzerland hover around the 3 per cent target, as does the United States (UIS, 2016). In response to these challenges, countries have experimented with various approaches, institutional reforms, models and mechanisms for funding and financing research and innovation that have delivered good results. For instance, in the USA, the Small Business Innovation Research Program (SBIR) – a pre-commercial procurement scheme – was introduced in 1982 and it mandates the use of 2.5 per cent of the federal R&D budgets from all government departments and agencies with large R&D budgets to contract R&D services from SMEs (SBIR, 2020). Similarly, the Malaysian government established the Cradle Fund, a unit of the Ministry of Finance that supports the creation of an ecosystem to promote a strong and innovative business growth environment for technology entrepreneurs in Malaysia (Cradle, 2020). Africa can learn lessons from some of these programmes.

It is thus imperative that Africa also explores new approaches, sources, tools, and institutional arrangements to improve the funding of research and innovation. Ozor (2015) and World Bank (2008) argue that, to increase funding and financing opportunities for research and innovation under the current global financial crises and national cutbacks in R&D budgets, new approaches and considerations must be made. A key policy hook for increased investment in research and innovation are the Sustainable Development Goals (SDGs), which advocate for promoting research in all fields and full research capacity in all countries by 2030. Our recent work on new approaches for funding research and innovation in Africa (Mugwagwa and Banda, 2019) revealed that countries were deploying specific instruments as tools to translate R&D funding policy formulation into implementation. The possibilities span direct funding by government, of research (whether for government labs, universities, private actors, etc.), or private R&D (through, for example, grants or procurement), to non-financial instruments such as network-based policies, and information brokerage between different actors. Many nations have tried to include a considerable component of tax incentives for private R&D, though this is currently weak in Africa, apart from South Africa.

Undoubtedly, scientific knowledge and technological innovation, among other forms of innovation such as institutional, organizational and social innovation are essential for supporting economic development, fostering social wellbeing while at the same time protecting the environment, and mitigating the effects of anthropogenic climate change. Throughout history, different types of innovations have been important forces behind both positive and negative industrial development trends. As the opportunities ushered in by STI continue to expand – riding on new frontiers in research especially in the life sciences – there is a global shift to clean growth, population mobility and aging society, and a rise in artificial intelligence and data revolution, among others. This entails dynamic changes and complexity in the practice of scientific research, and equally in the funding and governance of research and innovation at different levels. Africans are forced to play in this arena and have to grapple with late comer industrialization where stringent environmental and social standards have been imposed.

These dynamic changes call for new forms of collaboration not only among the key players around STI, namely research funders and research actors such as academia, industry, business, government and private non-profit entities, but also other players outside these sectors. This collaboration will be vital for galvanizing sectors and disciplines across economies, to obtain the best practice of science research ecosystems, funding and governance. Already, increased funding of science, research and innovation by some governments is placing a high premium on increased collaboration. For example, the UK government has committed to increase funding of R&D from roughly £9.5bn in 2016/17 to about £12.5bn in 2021/22, on the back of Grand Challenges which seek collaboration across disciplines; between universities, research and innovation bodies and businesses; and internationally. To foster these collaborations through leveraging and bringing together existing institutional capacities, the UK Research and Innovation (UKRI) was recently established as an organization mandated to spearhead mechanisms to "support the Research Councils to collectively make up more than the sum of their parts," and develop a "smoother pathway to more applied research" (Nurse Review, 2015). Under UKRI, a Strategic Priorities Fund has been established to support multidisciplinary and interdisciplinary programmes, while an Industrial Challenge Fund has been established to bring together the UK's world leading research with business. Enhancement of integrative roles is indeed a core function of key agencies in research and innovation systems worldwide.

Through an ambitious effort ushered in by the African Union's Agenda 2063, African countries have responded to the realization that individually and collectively they will not be able to sustain current levels of economic performance and achieve SDGs without developing and implementing bold policies and programmes for STI (AAS, 2018). The African Union (AU), regional economic communities (RECs) and regional institutions such as the African Development Bank (AfDB), as well as international organizations such as the World Bank and United Nations agencies, have developed strategies and programmes to advance STI for Africa's sustainable development (AAS, 2018). At continental level, the AU launched the STISA 2024 as one of the key strategies supporting Agenda 2063. Specifically focusing on health security, the AU developed the Africa Health Strategy (AHS) 2016–2030 whose focus is developing agile knowledge, technology and innovation systems that are African-driven and address the high disease burden through targeted and systematic health systems strengthening, supported by scaled-up health interventions, inter-sectoral action and empowered communities. A key component of the Health Strategy is strategic investment in research and innovation for improved access to medical health technologies. Consequently, through the African Union Development Agency-New Partnership for Development (AUDA-NEPAD), AU developed the Health Research and Innovation Strategy for Africa 2018–2030 (HRISA 2018–2030) which was recently adopted at the AU Specialized Technical Committee on Health, Population and Drug Control of April, 2015. Aware of the importance of research and innovation funding, HRISA (2018–2030) identified one of the key seven priority interventions as "Promoting Sustained Investments and Financing Mechanisms on Research, Development and Innovation for Health".

At national level, many countries have adopted or are developing policies, strategies and implementation programmes for STI. The scientific community, through institutions such as the African Academy of Sciences (AAS), programmes such as Developing

Excellence in Leadership, Training and Science Initiative for African Scientists (DELTAS) funded by DFID and Wellcome Foundation, national academies and SGCs, have launched various programmes for promoting STI for development (Mugwagwa and Banda, 2018). Against this backdrop of an active and broad agenda for STI in Africa and drawing from recent work of the African Science Granting Council Initiative (SGCI) on new approaches for funding research in Africa, this chapter takes a historical, contemporary and forward-looking approach to explore ways through which African countries can innovatively increase and sustain funding and capabilities for STI. Among the key arguments for this chapter is that there are important lessons to draw from historical and current funding models and approaches to ensure better effectiveness and alignment of STI with national development agendas.

Historical and current funding African research mechanisms

Funding models for research and innovation are largely driven by national competitiveness and hence geared towards economic development and industrial transformation, and these are closely linked to a nation's capacity to educate, innovate, and build (Juma, 2016). In Europe, for example, the innovation principle is argued to be a critical driver of "societal prosperity and… [to be] indispensable for sustainable development and economic growth" (ERF, 2015). With African countries having signed up to SDGs, how innovation is conceptualized and operationalized requires research, especially for localization of industry and economic development strategies that are in line with SDGs.

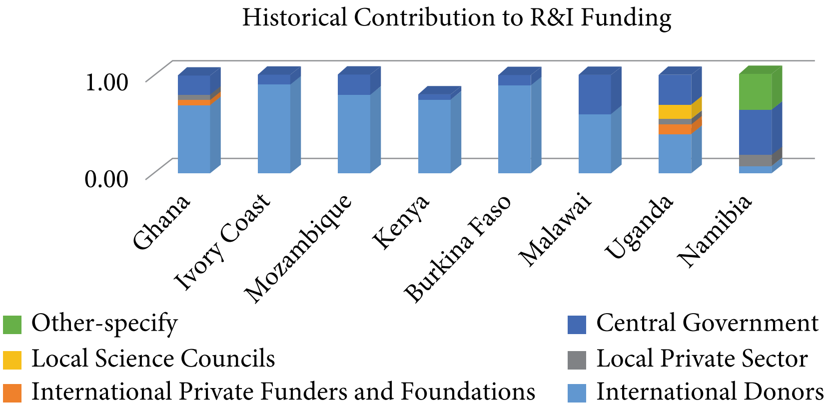
Historical funding mechanisms

Funding research, technology and innovation for many African countries is challenging on many fronts given the impact of colonial history on industry structure, knowledge and innovation generation and appropriation locally. Colonies were set up as the periphery to supply goods to the centre, and the centre generated the innovations and knowledge that were adopted in the periphery; hence the historical low priority and scant allocation of funds to research, technology and innovation. This historical genesis informed strategies for industry structure and development, and as a result there was no purposive effort to promote grassroots technologies and innovations that would be translated locally into commercial goods and services, with the potential for export, except for agriculture.

Agriculture was prioritized for funding compared with engineering and life sciences. Focusing on Zimbabwe, Donovan (1995), for example, highlights that prior to independence, agricultural research was under the responsibility of the Ministry of Agriculture, and in the 1970s the Agricultural Research Council was established to supplement state research. Funding for agricultural research and extension services, a key component of innovation diffusion was availed by the state. With the advent of independence in Zimbabwe, funding for agricultural research fell from 10.8 per cent before 1980 to 7.9 per cent of government expenditure on agriculture in the 1980s (Donovan (1995). However, because of the commercial farming sector, commodity research funded by producer associations increased (Jansen and Rukova, 1992). The story is similar for Malawi and South Africa where funding agricultural research and innovation was the preserve and responsibility of the state. However, in Malawi and Zimbabwe, aid agencies and donor funds played an important role in supporting agricultural research, development and training programmes targeted at small holder farmers (Donovan, 1995). The commercial sector also funded agricultural R&D. For example, commercial farmers formed a Maize Breeders Association in 1919 in modern day Zimbabwe to improve maize varieties grown in the country, building on earlier work to establish research stations in the country (Rusike and Donovan, 1995). Of importance in the funding for agricultural research was how the state linked basic and applied sciences with translational activities, which led to the local development of crop breeds adapted to local climatic conditions.

As argued earlier, colonies were destinations for manufactured goods and consequently other technologies were not prioritized for local development and translation. Data on financing research, technology and innovation in sub-Saharan Africa (SSA) dating back to the 1900s is scant. In a separate project we sought to establish sources of funds for research in the last five years (Mugwagwa and Banda, 2018). We found that historically, international donors provided up to 60 per cent, 70 per cent, 75 per cent, 80 per cent and 90 per cent of research funding in Malawi, Ghana, Kenya, Mozambique and Burkina Faso respectively in the 1990s and 2000s. International and local private sector funding played an insignificant role in funding research, technology and innovation (see Figure 5.1).

Figure 5.1: Historical Sources of Research and Innovation Funding (Beyond 5 Years Ago)



Source: Mugwagwa and Banda (2018)

International donors have historically been the main funders of research (see Figure 5.1) owing to the colonial history described above and the general persuasion that African countries were recipients and consumers of innovation, hence the lack of state and local private investment in research and innovation in areas outside agriculture. Unless there is strategic investment in research and innovation as demonstrated by South Africa and Kenya, which have national research foundations and government departments that support innovation, international donors will continue to play a significant role especially in life sciences. For example, the DELTAS programme underwritten by DFID and Wellcome Foundation supports emerging and senior scientists in African countries in health research, with 40 million pounds availed to support five-year research projects. These funds were used to support, for example, the West African Centre for Cell and Biology of Infectious Pathogens (WACCBIP, 2019) centre for infection and immunology at the University of Ghana where emerging African scientists are working, for example, on identifying candidates for a malaria vaccine. WACCBIP was established in 2013 as one of the centres of excellence funded by the World Bank (with USD8 million), and they have attracted funds from the African Academy of Sciences (AAS), and Alliance for Accelerating Excellence in Science in Africa (AESA) – an initiative in AAS and AUDA, Wellcome Trust and UK aid, among others. In interviews with scientists, they lamented the lack of direct government support for research, technology development and innovation and they reported constant anxiety on the issue of sustainability with international funding especially with the financial crisis that began in 2008 and other economic challenges in the donor countries. It is evident from the foregoing that historically, some dynamic factors and actors have shaped the funding (sources and uses) of research and innovation in African countries.

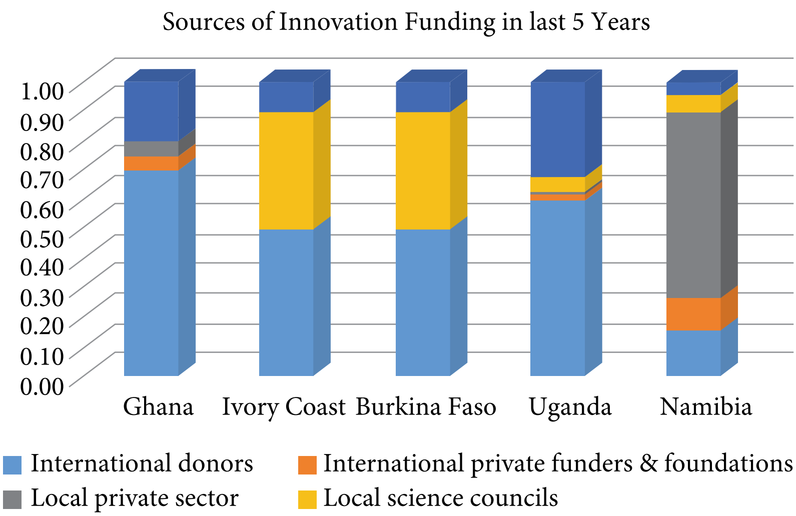
Current funding mechanisms

Over the years, there have been shifts in what donors, central government, science councils and other players will fund. In Ghana, the central government funding budget for research is spread as follows: 80 per cent – salaries, 10 per cent – research and 10 per cent – research infrastructure; whereas international donors support is at 70 per cent for research activities and 30 per cent for research infrastructure. The private sector on the other hand funds research activities at 100 per cent; and international private funders also cover 100 per cent for research activities (Mugwagwa and Banda, 2018). We found that although government funding may not be at the magnitude required to support large scale technology development and innovation, government programmes are an important source of funding by virtue of funding salaries and administrative functions for researchers. The second most important source of funds was multinational and bilateral donors followed by SGCs, local private sector and local NGOs. We found that government and SGCs are assuming a prominent role in funding of research and innovation.

Figure 5.2 representing funding in the last five years, shows remarkable difference from Figure 5.1 on traditional sources of funds. Ivory Coast and Burkina Faso show the significant role played by SGCs while Namibia reported a large role played by the private sector. International donors still play a large role in funding research and innovation in the countries that we surveyed (Mugwagwa and Banda, 2018). Respondents in the study preferred local funding models based on the need to ensure sustainability. However, the different countries reported that research and innovation was ranked low and some of the drivers included inadequacy of funding, difficulties in complying with funding requirements, lack of timely availability of funds, lack of national strategies and governance of research.

Despite the shift in funding sources, the greatest challenge for many SSA countries is supporting translation activities. Funding basic and applied research is a low-hanging fruit; the difficult investment is in supporting translation activities and especially the handover from technology development and proofing to scaling up and commercialization. South Africa has made strides in creating an environment where research and innovation funded by the state in universities is supported by later stage concept proofing by institutions such as the Council for Scientific and Industrial Research (CSIR) – a national research organization established in 1945. The CSIR is funded through the Department of Science and Technology (at 30 per cent) and the balance of funding is generated from contract research activities, royalties, and licenses on intellectual property. The CSIR covers diverse industrial sectors such as Smart Mobility, Next Generation Health, Agriculture and Food, Manufacturing, Chemicals, Defense and Security, Mining, and other sectors relevant to the technological development of the country. The CSIR works closely with universities and local industry, for example, on trialing vaccine candidates. Of importance is the strategic development of an innovation ecosystem that at least spans the value chain of a technology.

Figure 5.2: Sources of Innovation Funding in the Last 5 Years



Source: Mugwagwa and Banda (2018)

Figure 5.3: Diversity of research and innovation funding instruments

Government Role	Exploring	Framing & piloting	Scaling & mainstreaming	Sustaining & nurturing
Visionary	**Foresight & brokerage** Undertake or commission scoping research, host events, broker meetings	**Agenda setting** Develop policy strategy for resource allocation	**Informing and coaching** Providing how-to support via e.g. start-up hubs, innovation district services	**Science diplomacy** Engage within international networks to showcase capacity and attract inward investment
Customer	**Green papers** Commission research on emerging R&D	**Standards** Establish norms that stimulate new use of knowledge	**Procurement (new tech)** Selectively purchase early stage technologies	**Procurement (desired tech)** Support desirable yet mature technology markets
Innovation broker	**Test beds** Provide closed regulatory 'sandboxes' for safe experimentation	**Platforms and clusters** Connect researchers and users in localized networks, with virtual labs, etc.	**Public Private Partnerships** Arrange cooperative agreements with private sector	**Impact rewards** Reward impact toward desired outcomes with savings, capital investment, etc.
Funder	**Direct funding** Funding of primary research	**Direct finance** Stimulate new thinking to drive future opportunities	**Grants and subsidies** Incentivize behaviour change, such as inter-firm R&D collaborations	**Public service investment** Scale up through wider provision of infrastructure and public services
Regulator	**Self-regulation** Encourage voluntary codes	**Governance** Promote ethical standards, transparency and accountability rules	**Value protection** Safeguard intellectual property	**Compliance** Penalize uncooperative practices

Our data suggest that in addition to SGCs the state also has a performativity function that manifests in various roles (see Figure 5.3); with the state as the visionary, customer, provider, funder and regulator. As the key developer of futures and socio-technical imaginaries the state sets the agenda and develops policy and science diplomacy that progresses the realization of the desired futures. In this role, the state can promote foresight and brokerage through undertaking commissioning and scoping of research and this is a function where SGCs collaborate with the state in the identification of the research theme focus for the short, medium and long term. The state, working with SGCs, can act as the consumer of knowledge, technologies and innovations through use of green papers, and commissioning of path-breaking R&D for areas where market failures cause inertia. In addition, the state can use procurement as an active industrial policy tool that forms and shapes markets by promoting state institutions to purchase new technologies from emerging enterprises.

The third function for the state is as an innovation broker, providing institutional and infrastructural frameworks and spaces for testing new technologies and innovations supported in the early stages of development by SGCs. This function as argued earlier calls for collaborative working arrangements between policymakers and SGCs to forecast new technologies in the pipeline and horizon scanning for the challenges of nascent value chains, business models and emerging or non-existent markets. SGCs usually work with industry through industry-academia collaborative grants, with the state providing regulatory and technology sandboxes for safe trial of innovative technologies. Where market failure is a significant impediment, the state can use public-private partnership to avail the material and financial resources to promote a technology or innovation where there is no incentive for the private sector to go it alone. In addition, SGCs in conjunction with the state – based on forecast research and innovation themes – can pull innovations through impact investment.

The fourth function of the state which links directly to the primary remit of SGCs is funding of research and innovation through grants managed by SGCs or an innovation institution usually managed by the state or quasi-state leadership. The state could also use R&D subsidies as market-signalling mechanisms to promote research and innovation. In addition, the state can invest in publicly-funded infrastructure that forms the backbone for basic and applied research, as well as downstream de-risking of proof of concept stage by providing be-spoke infrastructure where innovators can trial their new technologies and innovations. This is attractive for innovators as first, it de-risks the early stages for them and signals to the market and funders the potential of the technology and innovation; and second, the entrepreneurs who are resource-poor can delay investment in infrastructure and allocate scarce resources to progressing commercialization of their technologies and innovations.

The fifth function for the state is that of a regulator, providing governance systems to assure the public of the quality, safety and efficacy of new innovations while mitigating any risks that may arise. A key challenge with especially radical or disruptive innovations is their impact on business models, value chains and markets, and sometimes they need new and unprecedented governance systems. SGCs play a key role in shaping the direction of research themes for emerging technologies, and as argued earlier, if research themes are identified locally and funding to SGCs is also local it becomes easier to align the strategic thrusts of the state, SGCs, researchers, innovators and regulators. The state does not only form and shape markets but through intellectual property protection, also protects the investment of researchers and innovation to allow them to recoup their investments through patents.

Lessons and way forward for effective and efficient science funding in Africa

That the place of STI on the national, regional and continental policy agendas in SSA has become markedly more prominent in recent years is not only reflected through initiatives such as STISA-2024 (AUC, 2014), but also through policy and institutional developments at various levels. It is also increasingly clear that financing research and innovation for sustained economic growth and industrial development in Africa requires a joined-up thinking of the knowledge and innovation generation, translational activities and commercialization continuum. Funding only one aspect of this value chain will not optimize the benefits that innovation gives to economic growth.

Given the pervasive nature of research and innovation, and the potential multiple entry points for funds and impact thereof, good and effective funding approaches are not only those that result in increased capabilities and productivity for the targeted sectors, but also those that demonstrate more encompassing value for money from outputs resulting from deployment of such approaches. Although assessing direct impact is important, so too are the more complex issues such as influence on system-wide decision making, human and institutional capacity, relationships, access to knowledge and the context in which research and innovation outputs can be applied (Mugwagwa et al., 2018). For example, many African countries face immense problems of large numbers of unemployed youths. Young people (15 to 24 years) constitute about 37 per cent of the working age population, but account for more than 60 per cent of all unemployed people in Africa (AfDB et al, 2013). Effective research and innovation funding approaches therefore should result in mutually reinforcing and complementary investments in R&D and innovation by both private and public sectors. This will in turn result in multiple impacts from small entrepreneurial initiatives to growth in high technology industries with the concomitant employment of millions of workers.

As alluded to earlier, the importance of research and innovation is increasing in most African countries, as demonstrated by institutional and policy provisions for STI which have been instituted in the last few years. A key issue for Africa though, is that to a large extent, current understanding of the strengths and weaknesses of different funding arrangements; their relevance and applicability to specific contexts; and of the supporting mechanism needed for them to function are not clearly established. Further, research funding schemes and models differ radically from those for innovation funding even if they are within the same agency. Limited attention is paid to assessing whether the funding vehicle (its structure, governance and support measures or funding models) is optimal for the types of technological and non-technological innovations in the country. Against this backdrop, we highlight the following as key areas for African countries' quests to build research capacity:

Importance of science policy

Science policy provides the mechanisms by which public resources are allocated for the conduct of science. This covers multiple domains and a wide range of activities, including fundamental research (enhancing the understanding of phenomena via breakthroughs), applied research (the application of scientific knowledge to practical advances such as technologies), and their connections into commercialization and marketization. The latter two areas are the focus of innovation policy; science and innovation policy are highly interconnected policy domains through value chains, institutions, and skilled personnel. Within the umbrella of science policy, there will be multiple constitutive areas of policy instruments, such as the management of funding for R&D, human intellectual capital, research infrastructure and facilities, intellectual property laws, and more. A science policy designed to advance social and economic capacities does several things (Steenmans et al., 2019). First, it has to foster R&D and innovation and facilitate the production of high-quality outputs from research activity. Equally, it must explore the diversity of pathways between production and uses of science. For this, it needs to foster broader engagement and intermediary capabilities. The building of scientific capacity therefore spans a range of natural and physical sciences, social science and management skills, responding not only to the needs of individuals, but also of organizations and institutions. The allocation of funding for R&D is a foundational component of science policy. It links the national strategic agenda with the research activities identified as related priorities. It also frames and clarifies the mechanisms by which government targets its support towards the capacities it believes should be developed, with what actors, and within which areas.

Importance of data

In Africa, the African Science Technology and Innovation Indicators Initiative has played an important role in capturing data on research and innovation activities in countries. The extent to which this evidence is used to inform decisions is yet to be confirmed, but it is undoubted that data on the funds being spent, on what activities, and to which recipients, is essential for oversight of the state and health of the performance of the national science system overall, as well as for more granular insight into which areas might benefit more from alternative modes of support. Without a consolidated evidence base of total and disaggregated expenditure, wider mechanisms for transparency and scrutiny are severely restricted.

Conclusions

African countries as late industrializers need to invest in research, innovation and technology development if they are to rapidly industrialize while at the same time protecting the environment through observance of sustainable development goals. However, attaining these economic and industrial development targets requires a shift in strategy from African countries viewing themselves as recipients and consumers of innovation and technologies developed elsewhere. We have argued in this chapter that local funding of research, innovation and technology is important for solving first, the contextualized challenges for African countries, and second, it is important for African countries to play their role as global partners in generating knowledge and innovation. Although at AU level there are pronouncements and declarations to support research and innovation, state funding of research should assume the importance that it requires. This is not new, given the historical role the state played in supporting agricultural research and innovation translation in some African countries.

We have further argued that it is important that African countries explore new and innovative approaches, sources, tools, and institutional arrangements to catalyse industrial and economic development on the back of research and innovation. Foreign funding has dominated funding of research and innovation on the continent. SGCs have not historically played a huge role in funding research and innovation, though in the last five years, the role played by SGCs has significantly improved. To capitalize on this momentum, and if SGCs are to leverage their performativity role, they need to be capacitated by allocation of more resources from government to support the research and innovation community. This will also further strengthen their capacity to act as boundary-bridgers and boundary brokers between government, universities, and the commercial sector. The increased importance of local needs as drivers of research and innovation necessitates a purposive collaborative strategic focus that is driven by the grounded theory approach that uses locally identified research themes driven by these local needs. Systemic collaborations are key among all funders, and recognizing that collaborations take time to build, mechanisms for collaboration must be built into strategies at national and even regional levels. This will be especially important to manage the wicked problem that will persist for some time.

References

African Union. 2015. *Africa Health Strategy 2016–2030*. [Online]. Available at: https://au.int/sites/default/files/documents/24098-au_ahs_strategy_clean.pdf (Accessed 7 April 2020).

African Development Bank, Organization for Economic Cooperation and Development, United Nations Development Program and Economic Commission for Africa. 2013. *African Economic Outlook 2013: Structural Transformation and Natural Resources*, Tunis: AfDB/ Paris: OECD/ New York: UNDP/ Addis Ababa: UNECA.

African Observatory of Science, Technology and Innovation (AOSTI), 2013. Science, technology, innovation and policy-making in Africa: an assessment of capacity needs and priorities. *AOSTI Working Paper No. 2.*

African Technology Policy Studies Network, 2017. *African Technology Policy Studies Network (ATPS), Technopolicy Newsletter*. Issue 011, ATPS Publications.

African Union. 2019. *Health Research and Innovation Strategy for Africa (HRISA) 2018–2030*. Addis Ababa: African Union.

African Union Commission, 2014. *Science, technology and innovation strategy for Africa 2024*. Addis Ababa: African Union Commission

African Union Commission, 2015. *Agenda 2063: The Africa we want. A shared strategic framework for inclusive growth and sustainable development: First ten-year implementation plan 2014–2023*. Addis Ababa: African Union Commission.

Banda, G., 2012. Financing ARV drug manufacture in Zimbabwe: implications for technological capability upgrading and innovation for African local pharmaceutical production. PhD Thesis. UK: The Open University 2012.

Banda, G., 2013. Finance as a 'forgotten technological capability' for promoting African local pharmaceutical manufacture. *International Journal of Technology Management and Sustainable Development.* 12(2),117–35. Available at: http://oro.open.ac.uk/38594/

Banda, G., Tait, J., and Mittra, J., 2018. Evolution of regenerative medicine business models: ecosystem effects on a disruptive innovation. *Clinical Therapeutics*. 40(7), pp.1084–1094. doi.org/10.1016/j.clinthera.2018.06.003

Cash, D.W., 2001. In order to aid in diffusing useful and practical information: agricultural extension and boundary organizations. *Science, Technology, & Human Values*. 26. pp.431–453.

Chataway, J., Banda, G., Cochrane, G. and Manville, C., 2016. Innovative procurement for health and industrial development. In: Mackintosh, Maureen; Banda, Geoffrey; Tibandebage, Paula and Wamae, Watu eds. *Making Medicines in Africa: the Political Economy of Industrializing for Local Health*. Basingstoke: Palgrave Macmillan. UK. pp.243–260.

Cliff, D., 2010. Networked Governance in the Global Financial Markets. [Online]. Available at: http://www.cs.bris.ac.uk/home/dc/Foresight_NetGov_v2a.pdf

Cradle, 2020. Malaysia Early Stage Tech Companies Influencer. [Online]. Available at: https://www.cradle.com.my/about-us/ (Accessed 3 April 2020).

Donovan, P.A., 1995. The management, funding and organizational structure of agriculture R&D in Zimbabwe, Malawi and South Africa. Part I – management and funding. *Agricultural Systems*. 47. pp.259–271.

European Risk Forum, 2015. *The Innovation Principle – Overview*. [Online]. Available at: http://www.riskforum.eu/uploads/2/5/7/1/25710097/innovation_principle_one_pager_5_march_2015.pdf (Accessed 31 August 2020).

Guston, D.H., 1999. Stabilizing the boundary between US politics and science: the role of the office of technology transfer as a boundary organization. *Social Studies of Science*, 29, pp.87–111.

Jansen, D. J. and Rukova, A., 1992. *Agriculture and the policy environment: Zambia and Zimbabwe – political dreams and policy nightmares*. Paris: OECD.

Jasanoff, S. and Kim, S., 2015. *Dreamscapes of modernity. Sociotechnical imaginaries and the fabrication of power*. London: The University of Chicago Press.

Juma, C., 2016. *Gales of creative destruction. In: Innovation and its enemies: why people resist new technologies*. New York: Oxford University Press.

Mugwagwa, J., Banda, G., Bolo, M., Mavhunga, C., Mjimba, V., Muza, O. and Teka, Z., 2018. Unpacking policy gridlocks in Africa's development: an evolving agenda. *International Journal of Technology Management and Sustainable Development.* 17 (2).

Mugwagwa, J., Banda, G., Ozor, N., Bolo, M. and Oriama, R., 2019. New approaches for funding research and innovation in Africa. *African Technology Policy Series (ATPS) Network Working Paper.*

Nurse, P., 2015. *Ensuring a successful UK research endeavour: A Review of the UK Research Councils*, London: Department for Business Innovation and Skills.

Ozor, N., 2015. *Increasing Opportunities for Financing of Research: Lessons for the Demand Side*. Paper presented during an international symposium organized on the theme 'New science, technology and innovation funding mechanisms in Africa', 9–11 December 2015. Dakar, Senegal.

Pohl, C., Rist, S. Zimmermann, A., Fry, P., Gurung, G.S., Schneider, F. … and Wiesmann U., 2010. Researchers' roles in knowledge co-production: experience from sustainability research in Kenya, Switzerland, Bolivia and Nepal. *Science and Public Policy*, 37. pp.267–281.

Rittel, H. and Webber M., 1973. Dilemmas in a general theory of planning. *Policy Science*. 4. pp.155–169.

Rusike, J. and Donovan, P.A., 1995. The maize seed industry in Zimbabwe. *Development Southern Africa*, 12(2). pp.189–196, DOI: 10.1080/03768359508439804

SBIR, 2020. *Small Business Innovation Research: America's Seed Fund*. [Online]. Available at: https://www.sbir.gov/ (Accessed 4 April 2020).

Schut, M., van Paassen, A. and Leeuwis, C., 2013. Beyond the research-policy interface. Boundary arrangements at research-stakeholder interfaces in the policy debate on biofuel sustainability in Mozambique. *Environmental Science and Policy*, 27. pp.91–102.

Steenmans, I., Bevan, L., Tyler, C. and Chataway J., 2019. *C21st Science Policy. Focus on: Human Intellectual Capital*. London: UCL STEaPP.

Struik, P. and Kuyper, T., 2017. Sustainable intensification in agriculture: the richer shade of green. A review. *Official journal of the Institut National de la Recherche Agronomique (INRA)*, 37. pp.1–15.

UIS, 2016. *How much does your country invest in R&D?* [Online]. Available at: https://sdg.uis.unesco.org/2016/09/14/how-much-does-your-country-invest-in-research-and-development-rd/ (Accessed 8 October 2019).

Waddock, S., 2013. The wicked problems of global sustainability need wicked (good) leaders and wicked (good) collaborative solutions. *Journal of Management for Global Sustainability.* 1. pp.91–111.

West African Centre for Cell and Biology of Infectious Pathogens, 2019. [Online]. Available at: http://www.waccbip.org/overview/ (Accessed 3 April 2020).

World Bank Group, 2008. *Finance in Africa: achievements and challenges*. [Online]. Available at: https://siteresources.worldbank.org/EXTAFRSUMAFTPS/Resources/chapter2.pdf (Accessed 3 April 2020)

6

Skills for Science Systems in Africa: The Case of 'Brain Drain'

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Abstract

This chapter discusses key circumstances surrounding skills and opportunities for researchers in science, technology, and innovation (STI), as well as highly trained STI policymakers and research managers, in Africa. So-called 'brain drain' – the phenomenon of massive skilled labour migration from developing countries to developed and industrialized countries – applies continuous pressure on local human resource capacities for development in African countries. Various vital sectors in developing societies are affected by massive outflows of highly skilled labour, hence affecting institutional capacities and knowledge wealth of these societies' science systems. African countries cannot afford to lack strategies that aim to mitigate the negative impacts of 'brain drain' and optimize any positive aspects and opportunities related to it. This chapter presents a comprehensive review of the challenges and opportunities resting on the role of highly skilled African migrants in African science and STI systems. It reviews how science systems are affected by human capital flight and demonstrates the main approaches that respond to it in Africa and beyond. A few policy recommendations are shared at the conclusion of the study.

Introduction

While concerted efforts are continuing to increase human capacities in Africa for industrial, technological and scientific progress, massive skilled labour migration from the continent to other parts of the world – mostly developed industrialized countries – is a major phenomenon that seems to work in the opposite direction to such efforts. It is estimated that about 20,000 highly qualified African researchers have been leaving the continent every year since 1990. There are currently more African PhD holders outside the continent than inside it; a statement that cannot be said about any other continent of the world. Up to one-third of African scientists and research professionals (excluding other professionals) are said to be lost to what is called 'brain drain' – the phenomenon of massive skilled labour migration from developing countries to developed and industrialized countries. Exodus of productive labour from Africa to developed countries is a notably distressing example of the disruptive effect of large-scale migration (Elnur, 2002). It depletes the continent of its talented minds and hinders the building and progress of science systems in general with their various actors in Africa. While such a phenomenon is not unique to Africa, it has a disproportionate effect as compared to other regions. For example, the skilled human capital outflow from Asia is larger in size than from Africa, but not in severity or impact (looking at the entire continent). Emerging and industrialized Asian economies are stronger in human capital than African economies overall. The higher population size and density in Asia account for the larger size of 'brain drain' there but Africa is more affected by the phenomenon than any other continent or region. The overall number of researchers in the region is generally low compared with those of other developing countries.[1]

This chapter discusses key circumstances surrounding skills and opportunities for researchers in science, technology, and innovation (STI), as well as highly trained STI policymakers and research managers in Africa. Various vital sectors in developing societies are affected by massive outflows of highly skilled labour, hence affecting institutional capacities and knowledge wealth of these societies' science systems. Numbers, trends, and observations overall show that the phenomenon must be of serious concern to both developing and developed countries, with overlapping and conflicting interests. This chapter presents a comprehensive review of the challenges and opportunities resting on the role of highly skilled African migrants in African science/STI systems. It reviews how science systems are affected by 'brain drain', with its scope and consequences, and argues for a re-understanding of the role of skilled African migrants. It demonstrates the main approaches, learnt from global and local experiences that respond to skilled labour migration issues with a few cases from around the world, Africa included, presented. Discussion follows, to draw lessons for Africa. To conclude the study, some policy recommendations on responding to African 'brain drain' are shared.

How African science systems are affected by highly skilled labour outflow

By science systems we refer to the entire network formed by institutions, actors, policies, information, and communication channels that together determine the pathways and content of scientific enterprise in any given society. By scientific enterprise we refer to activities that use and produce scientific knowledge (i.e. knowledge based on methodological inquiry and evidence) in various sectors, for example, industry, education, healthcare, infrastructure, communication, and environmental management. For science systems in Africa, addressing 'brain drain' deserves to be on the list of priorities, because it has many strong interactions with those priorities. Various vital sectors in developing economies are affected by the mass migration of highly qualified human resources, hence affecting science systems.

The effects of this migration on science systems in Africa have been briefly addressed by previous authors (see for example, Beaudry, Mouton and Prozesky, 2018; Nunn 2005; Aubert, 2005), but often as a side note – not saying it is a trivial issue but also not dedicating particular attention to it or addressing possible mitigations. In contrast, policymakers, and researchers in emerging and newly industrialized economies in Asia have been vocal and active in dealing with 'brain drain' in their countries and regions (as we shall see later in this chapter). Thorough discussions in Africa are due.

Researchers and policymakers of scientific enterprise play critical roles in any science system (besides those who play roles in the system but not in research or policymaking, such as engineers and technologists in industry, physicians and nurses in health facilities, medium-level public servants, etc.). Between researchers and policymakers also exist research managers – those with the skills and mandate to make sure that research activities are well-organized and research funding well managed to produce the best possible quality and most relevant research outputs and outcomes. These are also highly educated, skilled workers that are important for any country's development, and their area of work can be affected by brain drain.

Science granting councils (SGCs) in several African countries, for example, face challenges of high employee turnover; especially in positions of higher qualifications and influence on institutional strategies and performance (Sheikheldin, 2019). Under the Science Granting Councils Initiative (SGCI), the first author became engaged with SGCs from 15 African countries, as well as with coordinating technical agencies (CTAs). Within a few years, many of these organizations witnessed significant employee turnover in senior positions. In many cases, these employees move to work in other places in the same country, or with international agencies operating in their country or region. Some of them also leave the country, either for employment in other parts of the world or to pursue further academic studies. In general, there is a trend among Africans who leave their countries for high tertiary education – they tend to not return (at least not right after they finish their studies) (Zweig, 2006). And while many return as well, however, some migrate back owing to unconducive environments. The general picture is that there are not enough people capable in research management to go around in a country, so we find many agencies and organizations competing for them, resulting in high employee turnover. On the other hand, high employee turnover in any organization erodes institutional memory, reduces long-term career investment in these organizations, and overall, affects performance in undesirable ways.

Migration in general, in the modern world, often results in some positive correlations, such as increasing the quantity and quality of highly skilled workers in various sectors of human knowledge and economic activity, and financial remittances from migrants back to their countries of origin in ways that contribute to local economies. However, despite positive correlations, many studies agree that the observed and forecasted negative impacts outweigh positive ones, for many developing societies; especially with current trends unchallenged since the 1990s. With ample evidence, 'brain drain' is understood to apply continuous pressure on local human resource capacities for development in African countries, including economic and knowledge capacities. For example, in plain figures, it has been estimated that the full cost of educating a medical doctor in sub-Saharan Africa from primary school to university is about US$66,000, while the corresponding cost of educating a nurse is US$43,000. If this investment is lost to the home country, the opportunity cost could be at least US$364,000 and US$238,000, respectively, for each emigrated professional (Kirigia et al., 2006). These amounts exceed the remittances that these professionals could send home during their working life (UNCTAD, 2012).

Numbers, trends, and observations overall show that the outflow of human capital from less developed countries must be of serious concern to both developing and developed countries, with both overlapping and conflicting interests. It is also not going away any time soon; not without serious intervention. In fact, it is increasing in severity. A 2016 report by the IMF says that "migrants [from sub-Saharan Africa] in OECD countries could increase from about 7 million in 2013 to about 34 million by 2050," confirming that "the migration of young and educated workers takes a large toll on a region whose human capital is already scarce" (IMF, 2016, pp. 197–98). The OECD highlights that "in parts of sub-Saharan Africa and Central America, sometimes more than half of all university graduates migrate to OECD countries, with potentially serious consequences for critical sectors such as education, health and engineering" (OECD, 2015). Even more alarming is that young African scientists and researchers residing in the continent overwhelmingly express that they considered migration as an option. For example, in a study conducted by Beaudry et al. (2018b) in which early career African researchers from around the continent were surveyed, a large proportion (80 per cent) of respondents "indicated that they have considered leaving the African country where they were working or residing at the time of the survey: 20 per cent said that they have 'often' considered doing so, whilst a further 51 per cent indicated that they 'sometimes' think of leaving their home country. For the remaining minority (29 per cent), this has never been a consideration" (p. 115).

Towards a reconceptualization of the highly skilled African migrants: beyond brain drain

For many decades, Africans continued to move in massive numbers both within and beyond the continent. The unifying experience of African peoples dispersed by the trans-Atlantic slave trade marked the colonial era. "The African diaspora, together with the Jewish diaspora – the epistemological source of the term diaspora – enjoys pride of place in the pantheon of diaspora studies" (Zeleza, 2005, p.36). In most related literature, the communities and individuals who were engaged in these early waves of migration are commonly known as the African Diaspora; and their roles in the creation of new cultures, institutions, and ideas outside Africa are well documented. The more recent waves of the "*new diaspora*" or *"the second boat"* are by and large products of a failure of the modernization project in the post-colonial countries and an increasingly globalized world (Elnur, 2002, p. 37).

The trans-Atlantic slave trade targeted mainly young and able-bodied Africans who were forcibly transferred to the *new world* to produce physical labour, disrupting their lives and the historical process. On the contrary, and in comparison with previous epochs, "contemporary African labour migration tends to cream off some of the most skilled and educated parts of the labour force, impoverishing the domestic economy" (Elnur, 2002, p. 38). The effects of recent trends of labour migration flow from Africa, especially to the West, on the sending countries are tackled both in scholarly and policy literature under the term 'Africa's brain drain'. However, the concept of 'brain drain' is arguably inadequate in describing the phenomenon and can be misleading sometimes because it overwhelmingly connotes migration to a merely drastic phenomenon and suggests that it is irreversible. In this chapter, we use other terms, interchangeably with 'brain drain', to reflect our use of the term in context while still being critical of it.

The etymology of the term 'brain drain' emerged in the 1950s and was first used by the British Royal Society to describe a situation in the 1950s, where scientists, doctors, engineers and other skilled individuals were migrating from Europe to the United States and Canada in search of employment. While the term could be quite useful in drawing attention to the adverse impacts of the outflow of skills and talents, it is time to critically question 'brain drain' as a concept and propose that it might be often misleading during our attempts to envision ways in which this flow can be reversed and made to contribute optimally to the progress and prosperity of the migrants' countries of origins. Against this, the valorization of skilled labour as merely 'brain drain' is problematic on a number of accounts including:

- First, it can be perceived to regard the sending country as a geographical, passively static locale, hence deprives this locale from being recognized as a dynamically engaged site in the migration process. Therefore, instead of recognizing migration as a process and skilled migrants as carriers of social capital, brain drain as a notion renders these talents collectively to a permanent loss of resources to the sending countries while also disregarding the role and conditions of the receiving ones, and the agency of the migrant in shaping and being shaped by their diasporic lives[2] (Radwan and Sakr, 2018).

- Second, it tends to point to the movement of skilled migrants as a traditionally major problem for economic development for poorer countries (Docquier, Lohest and Marfouk, 2007). While this argument is partly true, it will be invalid without acknowledging the socioeconomic and political conditions in the countries of origin which represented a prevailing driving force for outmigration and what Elnur describes as a "failed developmental model" (2002, p. 39).
- Third, overall it diminishes human capital loss from the poor countries solely to migrants who fall in the category of tertiary education and above, with little attention paid to younger-age migrants and second generation in the diaspora, many of whom managed to return or contribute to the country of their parents. In studying the effect of 'brain drain' on science systems, which typically focuses on highly skilled migrants, the point may be less concerning, but is worth noting. The uncalculated value of human capital loss is accompanied by an omission of the cost incurred as a result of what is called "brain waste" in the host countries, where qualified migrants find employment only in occupations that do not match their qualification; and
- Fourth, it often appears to underestimate the sought-after ambition or knowledge and expertise acquired by migrants abroad which in some cases might not have been possible without migration to a developed/industrialized country. This somewhat explains why special talents and skilled migrants are overwhelmingly present in the prosperous countries of the global north. In a recent study, Radwan and Sakr (2018, p. 518) contend that the "measures taken to prevent the outflow of scholars might have negative consequences on local development and technological advancements," and that "the mobility of scholars significantly narrows the economic and industrial gap between developed and developing countries."

Many scholars were aware of the dilemma surrounding the terminology of 'brain drain' and its usage, and proposed alternative terms such as brain circulation, brain gain, brain reverse, etc. For example, Adesote and Osunkoya (2018) noted that 'brain drain', otherwise known as human capital flight, has been described as a contentious subject, which has been challenged in recent years, and today some scholars, rather than using the term 'brain drain' prefer more politically neutral terms such as 'brain exchange.'

However, the term ‘brain drain’ still has currency, since even if we talk about ‘brain circulation’ or ‘brain exchange,’ we cannot escape the reality that this ‘circulation’ and ‘exchange’ is still disproportionately costing Africa, and other developing regions of the world, in ways that outweigh the noted benefits, as confirmed by prevalent studies and statistics.

Nevertheless, whatever the terminology may be, the challenges remain. To initiate and strengthen venues of exchange and circulation, enhance the role of the African social capital abroad and allow the transfer of knowledge and technology towards the building of science systems in Africa, it is essential to understand the magnitude of the problem and examine the migration journey including both the pre- and post-departure sites in both the sending and receiving countries respectively.

The scope and consequences of the highly skilled African migrants

The outflow of highly skilled labour is a multifaceted phenomenon, befitting of the age of globalized communication, business, and mobility. Therefore, it has many connections with other phenomena, in various ways. For example, Adesote and Osunkoya (2018) argue that four major factors account for the patterns in modern-day African migration: (i) globalization and integration of the world economy; (ii) economic and political development failures in Africa; (iii) immigration and refugee policies in Europe and the United States; and (iv) colonial background.

In a recent volume, containing a comprehensive study about trends of scientific research in Africa, and particularly the size and productivity of African scientists, a chapter by Mouton (2018) stated that:

> “Arguably, the biggest cause of the decline of African science during the 1980s and 1990s was the devastating effects of the erosion of human capital through the brain drain. Studies sponsored by the Research and Development Forum for Science-Led Development in Africa (RANDFORUM) reveal that up to 30 per cent of African scientists – that is, excluding other professionals – were lost due to the brain drain. According to the Economic Commission for Africa (UNECA) and the International Organization for Migration (IOM), an estimated number of 27,000 skilled Africans left the continent for industrialized countries between 1960 and 1975. Since 1990, at least 20,000 qualified people have left Africa every year. This means Africa has 20,000 fewer people [every year] who can deliver public services and articulate calls for greater democracy and development” (Nunn, 2005, p. 7).

Figure 6.1: Scope and Consequences of the African Highly Skilled Migration

Research and Education	Health	Engineering
• African PhD holders outside Africa outnumber those inside it. • Shortage of teachers and instructors • African researchers are pressured with time in ways that have clear impact on their research productivity. • 80% African researchers indicated that they have considered leaving Africa • Since 1990, at least 20,000 qualified researchers left Africa every year.	• Disparity in the ratio of health professionals: • In Nigeria, 2008, the ratio was 1 to 41,000. • In Liberia, one pharmacist for 85,000 people. • In 2008, Ethiopia had 900 practicing doctors in a country of ~90 millions. • 3,000 Ethiopian doctors work overseas, more Ethiopian-trained doctors practice in Chicago than in Ethiopia	• Significant shortage of engineering skills all over the continent (engineers, technologists, and technicians). • For example, in 2013, it was reported that "in Namibia, Zimbabwe and Tanzania, there is [on average] one qualified engineer for a population of 6,000 people -- compared to one engineer per 200 people in China."

Source: adapted from: Beaudry, et al. 2018; UNCTAD 2012 and UNESCO 2010

While not considered as the only reason for the acute shortages of human capital in critical sectors such as healthcare, education and engineering, in most African countries this outflow of skills occupies a special place among those reasons (see Figure 6.1). Africa is battling with the challenge of having significant shortages of engineering skills (UNESCO, 2010), which are felt continentally while amplified in some countries. In December 2013, UNESCO's Director General, Irina Bokova, relayed that "in Namibia, Zimbabwe and Tanzania, there is one qualified engineer for a population of 6,000 people – compared to one engineer per 200 people in China." The situation in the healthcare sector is not any better (Kinfu et al., 2009). The flight of different categories of skilled health professionals such as consultants, doctors, pharmacists, nurses and social service personnel, led to direct and negative effects on the delivery, effectiveness and quality of services available to the public in both public and private health institutions in home countries. Another major effect of the loss was the disparity in the ratio of health professionals to patients. For example, Sudan lost 90 per cent of its medical doctors to the outside world, while in some parts of Nigeria, the ratio of healthcare professionals to patients in 2008 was as high as 1 to 41,00 (Elnur, 2002). In Liberia, one pharmacist was said to be servicing about 85,000 people. These numbers contrast severely with the minimum health standards recommended by the World Health Organization (WHO) for developing countries, which emphasise that "to ensure basic healthcare services requires 20 physicians per 100,000 people (that is 1 physician to 5,000)". In the African continent, the general ratio of physicians to patients was 1 to 8,000. By comparison, the US has 255 doctors per 100,000 people (WHO, 2014).

Another vivid example of brain drain in the healthcare sector is the case of Ethiopia. It is estimated that more Ethiopian-trained doctors practise in Chicago than in Ethiopia, and while Ethiopia had only 900 doctors in 2008, about 3,000 Ethiopian doctors worked overseas (Shinn, 2008). It has been argued that one of the main reasons why Africa has found it difficult to effectively fight the scourge of HIV/AIDS in the continent was the serious shortage of African health professionals (Adesote and Osunkoya, 2018).

Regarding the education sector, shortages of teachers and instructors are also pronounced (UNESCO, 2016). In African universities, overall, class sizes became bigger owing to the unavailability of resources to have more classes with more manageable sizes for lecturers, partly because the availability of qualified lecturers is a bottleneck (Beaudry et al., 2018a). Additionally, and consequently, African scientists in these universities are pressured with time in ways that have clear impact on their research productivity (Beaudry et al., 2018a). We cannot read these conditions and trends without seeing and acknowledging how the massive outflow of productive labour from the continent has a strong hand in all of it. However, Mouton and Blanckenberg (2018) also found that there has been a recent rise in research-based knowledge production coming from Africa, partly due to some changes in the way African scientists work and collaborate with scientists based outside the continent.

And while the situation on quantity is problematic enough, quality is not spared, with possible connections. For example, many foreign companies and organizations that are technology and science based, operating in African countries, continuously cited problems of competency in explaining why they do not hire more local engineering

Box 6.1: Ethiopia's academic diaspora: a case study

There is a dearth of people with doctorate-level degrees in Ethiopia, and this is especially true where they are most needed – in higher education. Among the 15,192 teachers and researchers working in the country's 25 universities, only 979 (6.4 per cent) hold a doctoral degree. Moreover, PhD holders are very unevenly distributed, since half of them work at the University of Addis Ababa. The bulk of the country's university teachers and researchers have a master's degree (43.4 per cent) or a bachelor's degree (42.6 per cent). The number of PhD-holding teachers and researchers active in the country's universities is much lower than the members of the Ethiopian diaspora just in the United States and Canada who have that level of education: 1,600, according to conservative estimates. A study on the Ethiopian academic diaspora that was prepared in 2012 for an UNCTAD report identified 200 Ethiopian professors working in foreign universities, of whom 148 were active in the United States. Among these, 72 were full professors. In Ethiopia, by contrast, only 65 persons at the time held an equivalent position. In other words, there are more Ethiopian full professors working in the United States than in Ethiopia itself, despite the strong need of Ethiopian universities for highly skilled scholars and teachers.

Source: UNCTAD, 2012

graduates; a problem that can be connected to the pressure on African academic staff to teach and train more students while their numbers – the academic staff – may not be sufficient in colleges and universities. When many such foreign companies and agencies do not absorb enough local engineers and technicians, that eventually impacts technology transfer negatively. A study on local technological capabilities and foreign direct investment in Tanzania, by the Science, Technology and Innovation Policy Research Organization, in 2011, found that in manufacturing, agriculture and mining, weak linkages between local and foreign investments partly arose from concerns among foreign firms about capacities of local labour and firms, which in turn resulted in very limited transfer of technological know-how to local talents.

Another impact of 'brain drain' that is not often addressed is the substantial decrease of purchasing power in local economies. Highly educated workers in modern societies often fill a large slot of the middle-income bracket of the local population, who often account for a larger share of consumption of goods and services in local economies. When a local economy has less middle-income workers, the purchasing power within that economy is generally negatively affected. In the same vein:

> "Endogenous growth theory…typically predicts that high skilled emigration reduces economic growth rates. Indeed, research finds that the average level of human capital in a society has positive effects on productivity and growth. One study of 111 countries from 1960 to 1990 found that a one-year increase in the average education of a nation's workforce increases the output per worker by between 5 and 15 per cent. Conversely, low average levels of education can slow economic growth, damage the earnings of low-skilled workers, and increase poverty" (Lowell and Findlay, 2001, p. 6).

Nonetheless, the picture is not complete without having an idea of what happens to those highly skilled Africans who migrate to other parts of the world. By far, most of them end up in OECD countries, primarily North America and Europe. In Canada, the USA and Europe, immigrants represented 31 per cent, 21 per cent, and 14 per cent, respectively, of the increase of highly educated labour force. Such labour force comes from all over the world and not just Africa, but we can take a closer look at African migrants. For instance, in the USA, a study by the Census Bureau, between the years 2008 and 2012, found that "compared with the overall foreign-born population, the foreign-born from Africa had higher levels of educational attainment" (Gambino, et al. 2014, p. 9), meaning that, if considered as one group, African immigrants – first generation immigrants – are shown to be the most formally educated of all immigrants in the USA. The situation may not be the same in Canada and Europe, but given that the majority of highly educated African migrants go to North America, with the USA receiving more of them than Canada (for reasons that seem to be generally related to differences in the sizes of the job market and population between the two North American countries), the statistics from the USA carry a strong impression.[3] There are, however, studies that speak specifically to African migration of the highly skilled in some European countries (e.g. Nunn, 2005) and their results seem to echo the situation in the USA.[4] Overall, various studies have established that immigrants contribute significantly to technological progress and innovation in the OECD, whether in industrial R&D or scholarly and academic R&D, especially in Science, Technology, Engineering and Mathematics (STEM) (Hunt, 2010; Ruiz, 2014) or overall improvements in products and services provided by innovative companies (Hewlett, Marshall and Sherbin, 2013). In direct economic contribution, immigrants overall contribute to public budgets of OECD countries, in the form of taxes (income, property and business taxes) annually more than they receive from states in the form of social services (Greenstone and Looney, 2010; Liebig and Mo, 2013; Chiswick, 2011).

The former president of the USA, Barack Obama, once said, "We can never say it often or loudly enough: immigrants and refugees revitalize and renew America".[5] If African immigrants can generally have this overall positive impact in their newly-adopted countries, and if the impact on the other side (in Africa) is almost opposite to that, we can begin to see why African 'brain drain' is a significant, longstanding challenge.

However, it would indeed be unrealistic and untrue to say that skilled labour migration, in the modern world, has no positive aspects, or that things would be better if it did not exist at all. The movement of educated minds and exceptional talents across borders, since the last century, has contributed to realizing breakthroughs, enhancements and transformations in theories and applications in science, technology, communication, ideas, trade, social systems and knowledge paradigms, and even before that, all over the globe. In recent trends, many skilled migrants from developing countries to OECD countries gain advanced knowledge and techniques in research and technological specialties. In several cases, such gains were shown to find a way to contribute to science systems back in their first home countries, in various ways. For example, a significant number of skilled migrants tend to stay connected with their first homes and become actively involved in relevant research, teaching and consultancies in their scientific and technical fields in their first homes.

Additionally, skilled migrants who begin to earn higher incomes in their newly-adopted countries tend to contribute to the economies of their first homes by sending remittances, and sometimes investing there (Lowell and de la Garza, 2000; World Bank, 2011); even some second generation immigrants with high skills and high earnings seem to do the same actions as their parents. In some cases, immigrants return to their first homes, bringing back with them added knowledge and skills (Lowell and Findlay, 2001; OECD, 2014). Africa has its share of these cases (Haque and Khan, 1997; Haque and Kim, 1995). Nonetheless, it is noted that no studies so far could say that the economic benefits from migrant remittances to their first home outweigh, or even balance out, significant losses caused by massive outflows of skilled labour.

Additionally, several studies have shown that some of the highly skilled migrants do not send remittances, especially if they remained for prolonged periods outside their first homes, while those who return to their first homes often return as retirees, no longer active in their skilled professions.

What could be said, to understand the big picture, is that skilled labour migration is not necessarily always a problem or a negative thing in itself; but it becomes a serious problem when it becomes 'brain drain', that is when it becomes massive, continuous and disproportionately disadvantaging to one side – the fragile countries; that is when it becomes unsustainable. Currently, in the case of Africa, it is unsustainable.

How the world responds to 'brain drain'

Although the challenge is as big as it appears by now, lessons from around the world show that there are approaches that can work in mitigating the loss of a country's highly qualified citizens. For instance:

> "The migration of skills can be slowed through the return of expatriates to their country of origin, as demonstrated by the examples of Israel… China, and more recently India and Mexico, whose diaspora communities have been mobilized to transfer, teach, and upgrade the vital technical and managerial skills needed in their countries" (Aubert, 2005, p.27).

Countries around the world have been addressing this phenomenon with various strategies; particularly in Asia's emerging and newly industrialized economies, but also other countries such as Mexico.

Policies of addressing mass exodus of knowledge and skills have been summarized by what is called 'the six Rs' as a list of main approaches all starting with R: Return, Restriction, Recruitment, Reparation, Resourcing, and Retention (see Fig 6.2):

> "The choice of "Rs" is simply expository; there is no agreed-upon terminology for the policies used to respond to the brain drain. Thus, return, restriction, and recruitment are policies directly affecting the movement of people (e.g., migration policies). Reparation refers to schemes to create monetary compensation to source countries for brain drain. The resourcing option includes a variety of approaches that might be grouped under what are variously known as diaspora options, e.g., ways to benefit from expatriates. Retention includes policies that focus on improving domestic opportunities in the educational sector, as well as those that target domestic economic growth and lessen the incentive to emigrate" (Lowel, 2001, p. 3).

Depending on the country, a mix of the above approaches have been used or explored. 'Return' is perhaps the most direct and rewarding approach, but also perhaps the most challenging. A mix of incentives, opportunities, and perhaps consequences, may make return a viable option for a good number of skilled migrants (including those who received foreign education). For example, economic growth in China, along with political stability, improved housing and the opportunities opened with growth, made tens of thousands of Chinese migrants consider returning (Démurger and Xu, 2011), but also government policies made it encouraging for foreign-educated managers, academics and scholars to take the return option seriously.[6] The size of the phenomenon of returnees, and the preferential treatment many of them receive ('recruitment'), became worthy of its own name in China since the last decade: sea turtles. But while economic growth made sea turtles return to China, their return itself propagates that growth by increasing the pool of skilled human capabilities and middle-income consumers in the country. Policies of 'recruitment' have also been tried, with relative success, in India and Thailand (Kale, Wield and Chataway, 2008; NSTDA, 2015). As Kale et al. (2008) put it: "Over the years, [regions of India and China] typically have been treated as low-cost production sites for multinational companies, but the 'reverse brain drain' of engineers or scientists educated and trained in the US or Europe can accelerate technological upgrading of these regional economies" (p. 417).

The 'restriction' approach exists in many developing countries, where there are some policies and regulations that make travel abroad for work not easily accessible to all skilled workers. Although the restriction approach can keep some people from migrating (or going abroad for work for some years), its sustainability is questionable as globalization takes hold all over the world. However, when used in calculated, flexible doses, and combined with other policies of incentives, restriction may be prudent. Restriction policies, if necessary, must be carefully introduced, because if not taken voluntarily they might create a tension between the country's "public good" and citizens' human rights in freedom of travel and movement, as per – for example – the 1948 Universal Declaration of Human Rights.

'Reparation' was, and continues to be, an approach that still invites strong opinions and sentiments, although it has not been broadly implemented. It is the idea that loss of human capital deserves compensation for countries that bear the consequences of that loss, paid either by the recipient countries or by the migrants themselves (in the form of 'brain drain taxes'). Lowell (2001) reports that the idea was quite popular in the 1970s, despite never being realized. Could it still hold ground today, now that many studies have cumulated evidence for the benefits of receiving countries from brain drain and the losses borne by 'sending countries'?

'Resourcing' and 'retention' policies are perhaps the least controversial in the era of globalization, in both theory and practice. India, Mexico, Thailand, Bangladesh, China, and South Africa are some of the countries that use policies of resourcing and retention (Bangladesh Employers' Federation, 2015; Zweig, 2006; Aubert, 2005; Lowell, 2001; NSTDA, 2015). For example, leading collaborative research and co-publishing have been a noticeable trend between home-based and migrant Chinese scholars (Wang, et al., 2013). This can be compared to the level of collaboration among African scholars, inside and outside Africa, which is limited and disparate (Mouton, Prozesky, and Lutomiah, 2018).

Figure 6.2: How the World Responds to 'Brain Drain': The Six Rs

Return of migrants to their source country Permanent return focus of most policies
Recruitment of international migrants Improved regulatory and other incentives
Restriction of international mobility Restrictive exit/travel policies
Reparation for loss of human capital Compensation for skilled migrants' opportunity cost in the country of origin, through tax paid wither by host states or migrants themselves
Resourcing expatriates Establish links and networks with the diaspora in order to facilitate STI transfer and remittances
Retention of local skills Creating national robust institutions to encourage skills to stay and retain work ties with those who have left

Source: Adapted from Lindsay, Lowell B., 2001, P.4

These experiences and others, broadly reviewed, bring perspective into the African situation: massive outflows of highly skilled Africans are problematic but relative mitigation is possible, if we learn from such experiences and adapt to our contexts.

Case studies from Africa: current approaches

Rwanda has been successful in adopting internationally accepted best practices for ICT, and in so doing, becoming a hub for technology innovation in sub-Saharan Africa (Chand, 2018). One of the key findings of the World Investment Report was that countries that ranked high in nepotism and corruption in the labour market were also ranked high in 'brain drain'. By improving its anti-corruption apparatus, coupled with investment in the ICT field, Rwanda reaped the fruit of reducing push factors for 'brain drain' by attracting talents from other parts of Africa (UNCTAD, 2012).

This points to the importance of African countries investing in the fields of science and technology if they want to reverse their 'brain drain'. Rwanda is now a leader in sub-Saharan Africa in attracting talent from other countries, followed by Seychelles, Morocco, and Ivory Coast (Chand, 2018). A large part of Rwanda's success could be attributed to its working with different internal stakeholders to design its Technical and Vocational Education and Training (TVET) programme to help meet the demands of the labour market. The programme was launched in 2008 and has resulted in more workers with technical skills who can be employed by industries. This went hand in hand with its "One laptop per child" policy in educating children in schools. Additionally, Rwanda has benefited from a relatively open visa policy in attracting international and African talents (UNCTAD, 2012).

Ethiopia, on the other hand, has extended to its diaspora members the same benefits and rights as domestic investors through the issuance of yellow cards and introduced investment incentives for diaspora members. These practices can be studied and adapted by different African countries as they design their own programmes to connect with their knowledge diaspora in the US (UNCTAD, 2012).

Nigeria, as well, has well-developed diaspora professional associations in the US and returnee diaspora organizations (UNCTAD, 2012). In 2017, Malawi launched a national diaspora engagement policy which "seeks to establish a mutually beneficial relationship between Malawi and her diaspora, with the underlying goal of mainstreaming and empowering Malawians abroad to effectively make significant and effective contribution to the development of the country" (Republic of Malawi, 2017). On February 18th, 2019, Malawi's first diaspora portal was launched – a platform that aims to provide an interactive platform for continuous engagement with highly skilled Malawians abroad and connect them with stakeholders at home.

At the continental level, one example of short-term diaspora engagement projects is the Carnegie African Diaspora Fellowship Program (CADFP), a scholarly fellowship programme for educational projects at African higher education institutions. It is offered by the Institute of International Education (IIE) in collaboration with the United States International University-Africa (USIU-Africa) and funded by a grant from Carnegie Corporation of New York (CCNY). In the pilot of the programme (2013–2015), the CADFP supported 110 short-term fellowships for African-born academics (UNCTAD, 2012). An ongoing initiative is for instance, a collaboration between the African Academies Diaspora Fellows Program (AADFP) in Senegal and the Inter-Academy Partnership Carnegie Project (IAP-NASAC project Academies). The Academy started to create a diaspora database to establish a strong cooperation link between the Senegalese scientific diaspora and their home country. It also helps to develop a national strategy for Senegalese skills residing abroad, to enable them to contribute to Senegal's economic, social, and cultural development efforts in training, research, expertise, consultancy and specific initiatives that enhance research results.

The African Union has a Citizens & Diaspora Directorate (CIDO), "the department responsible for leading the AU's engagement with non-state actors through Diaspora & Civil Society Engagement."[7] According to CIDO, it works to engage the African diaspora and civil society to work closely with the AU's Economic, Social and Cultural Council. It could perhaps be utilized more to coordinate approaches such as the aforementioned ones. On the other hand, in September 2018, Ghana declared 2019 as the 'Year of Return', commemorating the 400th anniversary of the arrival of enslaved Africans in the Americas. The call was made to people of African descent to return to their home continent.[8] While too early to assess, and while meant to be inclusive, it could be another window of attracting highly skilled professionals, entrepreneurs and others who could contribute to Ghana's STI system; and could lead other African countries to observe and learn from Ghana.

Another example of such an approach would be the services provided by the African Partners Medical Group, a group of African doctors and nurses in North America and Europe who sponsor annual educational workshops around Africa. These workshops through teaching, seminars, and hands-on experiences, help local physicians, nurses, and other supporting staff with opportunities to acquire new skills in a small group setting.

Discussion

Two things can be learnt from literature and reality: that the African massive outflow of skilled labour overall works against the development agenda of the continent, including the agenda of advancing STI, and that measures can be taken to address it. As shown from records, highly skilled labour migration is not likely to resolve itself (rather, it is more likely to exacerbate) but the experiences of other countries show that it is possible to steer trends towards more favourable outcomes, that is, from 'brain drain' to 'brain circulation'. Although conditions in African countries in general tell a different story from South Asia, China or Mexico, lessons could still be learnt from their experiences and modified to look towards Africa. State policies play a sure role in the picture (De Haas and Rodríguez, 2010).

The 'Six Rs' approaches provide a variety of possibilities and policy mixes. Resourcing and recruitment, for example, can work together through various policies to make Africans abroad more engaged and interested in African science systems, whether they remain physically in their newly-adopted countries and find opportunities of being involved in work in Africa while not necessarily 'moving back' completely, or they decide to return (partially or fully). Research projects, on topics of scientific and technological frontiers or relevance, can draw talents and skills from a larger pool than those already residing in Africa, and can intentionally make research and R&D collaborations between 'diaspora' and 'homeland' Africans more frequent and significant than they are now. Retention policies, on the other hand, could purpose to value the African talents that are already residing in the continent, by ensuring an enabling and conducive environment for researchers, technologists and innovators to build their careers. Absorbing local talents, in productive and fulfilling career paths, is a priority.

Windows of 'return' are not far-fetched either. African migrants always express nostalgic sentiments of home and some of them do return; this reverse mobility presents "a major advantage of mobility for home institutions, in the case of returning researchers, is gained through the resultant brain gain" (Beaudry et al., 2018b, p.114). As put by a young African scientist: "Actually it's not leaving for good but leaving only for opportunity and then coming back because this is my homeland, it's where my family is … [The reason I am going is] to expand the scope of my work and also to be able to practise what I have, if I had the opportunity" (Beaudry et al., 2018b, p.114).

Despite massive outflows, there have been noticeable inflows recently of returning Africans to the continent – skilled workers and entrepreneurs who took recent economic growth records in African countries as windows of opportunity (see for example, Sinatti, 2018; Black and Castaldo, 2009). Overall, the number of expatriate workers and migrants in Africa has been steadily increasing since the beginning of the millennium. According to the International Migration Report of 2017, by the United Nations, 25 million documented international migrants were residing in Africa in 2017, accounting for about 2 per cent of the total population in the continent. Between 2000 and 2017, migration to Africa increased by an average of 3 per cent per annum. This evokes lines of thinking that, if this number is increasing, to meet increasing demands from growing local economies in African countries, it should be intuitive that many of those incoming expatriates could be and should be returning skilled Africans. As we saw earlier (in the previous section), that is what happened in China, India, Thailand, Mexico and other countries.

While 'restriction' measures already exist in many African countries, they alone do not seem to work properly. Rather, they are seen as problematic in the era of globalization and mobility of labour, goods and finance. On the other hand, some countries already have some 'reparation' policies in place, although they are not called that. In countries like Sudan, for instance, Sudanese expatriates have been contributing more to the state budget, through different payments for public services and taxes, than their local counterparts. Eritrea has a similar system. Such measures are not necessarily problematic or unpopular by themselves but can be viewed as ineffective when managed poorly, for example, when expatriates still receive little-to-no recognition for their contribution and when the general public service and taxation systems fail to meet basic standards of good governance.

We would also do good to touch on whether levels of respect for human rights can be influential in determining trends of 'brain drain' besides economic development and political stability; sometimes comparably. Admittedly, most of the literature on migration and brain drain has focused on the subject from a development perspective; particularly economic opportunities and general conditions that count as political stability. Yet, addressing human rights' deficits as one of the elements affecting migration in general, and highly skilled labour migration in particular, is a legitimate angle of inquiry. As explained in a paper by the Office of UN's High Commissioner for Human Rights, "where poverty and lack of opportunity is a major cause of migration, human rights can contribute to remedying these factors such as gender discrimination and lack of equal access to education, health and housing" (p. 5). For a long time, research on the area did not quite pick-up on the connection between socioeconomic opportunities and human rights, but such oversight is difficult to excuse under some influential discourses on development, such as the 'development as freedom' discourse, pioneered globally in the last two decades (Sen, 1999).

Conclusions and recommendations

A well-educated and skilled labour force is a key resource that every country in the world seeks to have enough of. The global phenomenon of human mobility across borders and seas, for visiting, working and learning, is overall an impressive feature of modernity, allowing humanity, its creativity and productivity, and the fruits of such creativity and productivity, to be more global and less territorial. For science systems, and for STI and R&D, this feature does wonders when different minds from around the world have access to each other's wealth of knowledge and skills. The big picture of that phenomenon however still has negative aspects to deal with. The phenomenon of massive outflows of highly skilled labour from developing to developed and industrialized countries, often referred to as 'brain drain', is one of these aspects. For Africa, it is a significant problem.

As African scientists, engineers, managers and innovators leave the continent at a rate higher than what the continent can relatively balance through local opportunities of higher education, career and research support, African science systems are left continuously disadvantaged by brain drain. The disadvantage also affects the economy and overall development agenda. To build more sustainable and productive science systems and STI environments, brain drain needs to be addressed at national and regional levels. It would be advisable to do this through evidence-informed policies that rely on accurate description of the phenomenon, accurate relevant data, and a reliable study of possible remedies. There is need to increase studies on African 'brain drain', but with what we already have as data and case studies of practices from around the world, we can build informed opinions and suggest initial policy directions.

African national and regional institutions that deal with STI and science systems should take highly skilled labour migration seriously. For example, events that address the problem as a main issue, instead of a side topic, should be organized, for example, national and regional fora and conferences, focused meetings of governments, industries and academia (triple helix), and related initiatives. Previous experiences on international and national levels in other parts of the world exist, and conventions, conferences, and policy roundtables, as well as policy papers, are common practices that precede policy agenda setting and formulation.

National policies that are directly related to 'brain drain' should explore the 'six Rs' approaches, to come up with suitable policy mixes and use various policy instruments (including regulations, incentives, targeted programmes, and soft instruments such as information dissemination and awareness campaigns). There is also a need to facilitate and encourage collaboration between scientists, engineers, and administrators of the African diaspora and those in the home continent, on various projects and programmes. This approach has a record of making a difference, as witnessed in the Chinese and Indian experiences. In addition to all the above, strengthening and promoting research and R&D establishments in Africa is a must, by all means possible and sustainable. Researchers and developers are more inclined to stay and build careers at home when a conducive research environment that allows them career growth exists, while in return they enrich the entire science system.

There are also other regulatory aspects that may not be directly related to 'brain drain' but they influence national environments and how they fare in comparison with other countries. For example, dual-citizens are nowadays, generally, an advantage to their first homes (countries of origin/birth), in the era of globalized knowledge and business; thus policies that reduce the ability of migrants who attain new citizenships to contribute to technological and economic progress in their first homes should be reconsidered. Currently there are African countries that keep national policies and criteria, from decades ago (when they perhaps made more sense than nowadays), that are unfriendly to multiple citizenships. Such policies are increasingly disappearing from the rest of the world, for the reasons mentioned above.

Overall, there is a problem that needs to be acknowledged, and there are possible remedies or solutions to investigate. African countries, individually and collectively, cannot afford to lack a strategy of mitigating the challenges of 'brain drain' and optimizing any relatively positive aspects and opportunities related to it.

Notes

[1] Although, on the other hand, some trends are encouraging in some respects, such as that 'the proportion of female to male researchers [in the Southern African region] is better than in many countries outside the [southern Africa].' (taken from the first regional report on investments in R&D for STI, by Southern African Development Community (SADC); not made public yet).

[2] Contrary to this, in many cases, emigration cannot be considered as a permanent decision, and skilled migration is characterized by its temporary nature. Moreover, empirical evidence has identified a correlation between migration flows to the host country and knowledge flows to the source country (Radwan and Sakr 2018).

[3] There are other strong impacts of migrants on industrialized countries, that may not be directly related to highly educated labour force but still related to semi-skilled labour force that is crucial for industrialized economies. For instance, in addition to the above, "immigrants represented about a quarter of entries into the most strongly declining occupations in Europe (24%) and the United States (28%). In Europe, these occupations include craft and related trades workers as well as machine operators and assemblers; in the United States, they concern mostly jobs in production, installation, maintenance, and repair. In all these areas, immigrants are filling labour needs by taking up jobs regarded by domestic workers as unattractive or lacking career prospects." (OECD, 2014, p. 2)

[4] Mary Kent. 'More US Scientists and Engineers are Foreign-born.' January 11, 2011: https://www.prb.org/usforeignbornstem/

[5] Barack Obama, from a speech on December 15th, 2015 at the National Archives Museum, where immigrants from over 25 countries were sworn in as U.S. citizens.

[6] ILO. "International Migrants Day (18 December 2006). Reversing the brain drain in China: the return of the 'sea turtles'". Article, 11 December 2006: https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_080665/lang--en/index.htm

[7] African Union. The Citizens & Diaspora Directorate (CIDO). Viewed on March 27, 2020 on: https://au.int/en/directorates/citizens-diaspora-directorate-cido. Further information could not be found about the activities and projects of CIDO to date.

[8] Benjamin Tetteh. "2019: Year of return for African Diaspora". *Africa Renewal,* December 2018–March 2019: https://www.un.org/africarenewal/magazine/december-2018-march-2019/2019-year-return-african-diaspora

References

Adesote, S. A. and Osunkoya, O. A. 2018. *The brain drain, skilled labor migration and its impact on Africa's development, 1990s-2000s. Journal of Pan African Studies*, 12(1). pp.395.

Aubert, J-E., 2005. Promoting innovation in developing countries: a conceptual framework. *Policy Research Working Paper, No. 3554*. Washington, DC: World Bank.

Bangladesh Employers' Federation. 2015. *Preliminary assessment of impact of labor migration from South Asia on the South Asian employers*. Supported by ILO Country Office of Bangladesh and SIDA, Sweden.

Beaudry, C., Mouton, J. and Prozesky, H., 2018a. The young scientist: a profile. In: C. Beaudry, J. Mouton and H. Prozesky, (eds.) *The next generation of scientists in Africa.* Cape Town: African Minds Publishers. Ch. 4, pp. 45–70.

Beaudry, C., Mouton, J. and Prozesky, H. 2018b. Mobility and the careers of young scientists. In: C. Beaudry, J. Mouton and H. Prozesky, (eds.) T*he next generation of scientists in Africa.* Cape Town: African Minds Publishers. Ch. 7, pp.103–21.

Black, R. and Castaldo, A., 2009. Return migration and entrepreneurship in Ghana and Côte d'Ivoire: the role of capital transfers. *Tijdschrift voor economische en sociale geografie* 100(1). pp.44–58. doi: 10.1111/j.1467-9663.2009.00504.x

Chand, M., 2018. Brain drain, brain circulation, and the African diaspora in the United States. *Journal of African Business,* 20(2), pp.1–14.

Chiswick, B. R., 2011. Immigration: high-skilled versus low-skilled Labor? *IZA Policy Paper No. 28.* [Online]. Available at: http://ftp.iza.org/pp28.pdf (Accessed 31 August 2020).

Démurger, S. and Xu, S., 2011. Return migrants: the rise of new entrepreneurs in rural China. *World Development*, 39(10). pp.1847–61. doi: 10.1016/j.worlddev.2011.04.027

Elnur, I., 2002. The second boat of Africa's new diaspora: looking at the other side of the global divide with an emphasis on Sudan. *African Issues*, 30(1): 37-41.

Gambino, C. P., Trevelyan, E. N. and Fitzwater, J. T., 2014. The foreign-born population from Africa: 2008–2012. *American Community Survey Briefs.* US Census Bureau: ACSBR/12–16.

Greenstone, M. and Looney, A. 2010. Ten economic facts about immigration. Report by the Hamilton Project, Brookings Institution, USA. [Online]. Available at: http://www.brookings.edu/~/media/research/files/reports/2010/9/immigration-greenstone-looney/09_immigration.pdf (Accessed November 2015).

De Haas, H. and Rodríguez, F. 2010. Mobility and human development: Introduction. *Journal of Human Development and Capabilities*, 11(2), pp.177–84. doi: 10.1080/19452821003696798

Démurger, Sylvie & Xu, Hui, 2011. Return Migrants: The Rise of New Entrepreneurs in Rural China. *World Development*. 39(10), pp.1847–1861.

Docquier, F., Lohest, O. and Marfouk, A., 2007. Brain Drain in Developing Countries. *The World Bank Economic Review*. 21(2), pp.193–218.

Haque, N. Ul and Se-Jik, Kim. 1995. Human capital flight: impact of migration on income and growth. *IMF Staff Papers*. 42(3), pp.577–607.

Haque, N.Ul and Khan, M. A., 1997. *Institutional development: skill transference through a reversal of 'human capital flight' or technical assistance*. Working Paper of the International Monetary Fund, Washington, D.C.

Hewlett, S.A., Marshall, M. and Sherbin, L., 2013. How diversity can drive innovation. *Harvard Business Review,* December Issue. [Online]. Available at: https://hbr.org/2013/12/how-diversity-can-drive-innovation (Accessed 31 August 2020).

Hunt, J., 2010. Skilled immigrants' contribution to innovation and entrepreneurship in the US *Open for Business: migrant entrepreneurship in OECD countries*. Paris: OECD Publishing. doi.org/10.1787/9789264095830-en

International Monetary Fund, 2016. *World Economic Outlook, October 2016: Subdued Demand – Symptoms and Remedies*. Washington DC: IMF.

Kale, D., Wield, D. and Chataway, J., 2008. Diffusion of knowledge through migration of scientific labour in India. *Science and Public Policy*. 35(6), pp.417–430.

Kinfu, Y., Dal Poz, M., R., Mercer, H. and Evans, D. B., 2009. The health worker shortage in Africa: are enough physicians and nurses being trained? *Bulletin of the World Health Organization,* Issue 87, pp.225–230. doi:10.2471/BLT.08.051599

Kirigia, J.M., Gbary, A.R., Muthuri, L.K., Nyoni, J. and Seddoh, A. 2006. The Cost of Health Professionals' Brain Drain in Kenya. *BMC Health Services Research*. 6(1), p.89. London: the UK.

Liebig, T. and Mo, J., 2013. The fiscal impact of immigration in OECD countries. *International Migration Outlook 2013*. Paris: OECD Publishing.

Lowell, B. L. and de la Garza, R. 2000. *The developmental role of remittances in US. Latino communities and in Latin American countries*. Report of the Tomás Rivera Policy Institute and the Inter-American Dialogue. [Online]. Available at: http://www.thedialogue.org (Accessed 31 August 2020).

Lowell, B. L., 2001. Policy responses to the international mobility of skilled Labor. International Migration Papers, paper No. 45, Series by the International labour Office, Geneva, under the DFID-sponsored project on *"Skilled labour migration (the 'brain drain') from developing countries: analysis of impact and policy issues."*

Lowell, B. L. and Findlay, A., 2001. Migration of highly skilled persons from developing countries: impact and policy responses. International Migration Papers, paper No. 44: Synthesis Report. Series by the International Labour Office, Geneva, under the DFID-sponsored project on *"Skilled Labour migration (the 'brain drain') from developing countries: analysis of impact and policy issues."*

Mouton, J., 2018. African science: a diagnosis. In: C. Beaudry, J. Mouton and H. Prozesky, (eds.) *The next generation of scientists in Africa.* Cape Town: African Minds Publishers. Ch. 1, pp.3–12.

Mouton, J. and Blanckenberg, J., 2018. African science: a bibliometric analysis. In: C. Beaudry, J. Mouton and H. Prozesky, (eds.) *The next generation of scientists in Africa.* Cape Town: African Minds Publishers. Ch. 2, pp.13–25.

Mouton, J., Prozesky, H. and Lutomiah, A., 2018. Collaboration. In: C. Beaudry, J. Mouton and H. Prozesky, (eds.) *The next generation of scientists in Africa.* Cape Town: African Minds Publishers. Ch. 9, pp.147–74.

National Science and Technology Development Agency, Ministry of Science, Technology and Environment, 2015. *The Reverse Brain Drain Project, Thailand*. [Online]. Available at: https://www.ilo.org/dyn/migpractice/migmain.showPractice?p_lang=en&p_practice_id=43 (Accessed 31 August 2020).

Nganga, G., 2014. Survey finds most East Africa graduates 'half-baked'. *University World News, Global Edition.*, issue 321. [Online]. Available at: https://www.universityworldnews.com/post.php?story=20140523130246934 (Accessed 31 August 2020).

Ngwé, L., 2016. African brain drain: is there an alternative? *The UNESCO Courier. [Online].* Available at: UNESCO's website: https://en.unesco.org/courier/january-march-2018/african-brain-drain-there-alternative (Accessed 28 June 2019).

Nunn, A., 2005. *The 'brain drain': Academic and skilled migration to the UK and its impacts on Africa*. Report to the AUT and NATFHE. [Online]. Available at: https://www.ilo.org/dyn/migpractice/migmain.showPractice?p_lang=en&p_practice_id=43 (Accessed 27 June 2019).

Office of United Nations' High Commissioner for Human Rights, 2013. *Migration and development: a human rights approach.* Geneva: Switzerland.

OECD. 2012. Renewing the skills of ageing workforces: the role of migration. *International Migration Outlook 2012*, Paris: OECD Publishing.

OECD. 2014. *Migration policy debates: is migration good for the economy?* [Online]. Available at: www.oecd.org/migration (Accessed 31 August 2020).

OECD, 2015. *Migration and the brain drain phenomenon*. [Online]. Available at: http://www.oecd.org/dev/poverty/migrationandthebraindrainphenomenon.htm (Accessed 3 November 2015).

Radwan, A. and Sakr, M., 2018. Exploring 'brain circulation' as a concept to mitigate brain drain in Africa and improve EU-Africa cooperation in the field of science and technology. *South African Journal of International Affairs*, 25(4), pp.517–529.

Royal Academy of Engineering. 2012. *Engineers for Africa: Identifying Engineering Capacity Needs in Sub-Saharan Africa*. London: RAE.

Republic of Malawi. 2017. Malawi Diaspora Engagement Policy, August 2017. [Online]. Available at: https://www.malawiembassy.de/National-Diaspora-Engagement-Policy-Final.pdf (Accessed at 31 August 2020).

Ruiz, N. G., 2014. *The geography of foreign students in US higher education: origins and destinations*. Brookings Institution. [Online]. Available at: http://www.brookings.edu/research/interactives/2014/geography-of-foreign-students#/M10420 (Accessed 8 November 2015).

Sen, A., 1999. *Development as Freedom.* Toronto: Random House.

Sheikheldin, G., 2019. *Inviting innovation for industrialization: Public technology intermediaries*. Presentation at 4th AfricaLics International Conference, October 22-24 2019. Dar es Salaam, Tanzania.

Sinatti. G., 2018. Return migration, entrepreneurship and development: contrasting the economic growth perspective of Senegal's diaspora policy through a migrant-centred approach. *African Studies*. 78(4), pp.609–623. DOI: 10.1080/00020184.2018.1555310

United Nations, 2017. *International Migration Report 2017*. Report ST/ESA/SER.A/404, by the Department of Economic and Social Affairs.

United Nations Conference on Trade and Development, 2012. The Least Developed Countries Report 2012: Harnessing remittances and diaspora knowledge to build productive capacities. *Mobilizing the diaspora: from brain drain to brain gain*. New York and Geneva: UNCTAD.

United Nations Educational, Scientific and Cultural Organization, 2010. *Engineering: issues, challenges and opportunities for development*. Paris: UNESCO.

United Nations Educational, Scientific and Cultural Organization, 2016. *The world needs almost 69 million new teachers to reach the 2030 Education goals*. Paris: UNESCO.

Wang, X., Xu, S., Wang, Z., Peng, L., and Wang, C., 2013. International scientific collaboration of China: collaborating countries, institutions and individuals. *Scientometrics,* 95(3), pp.885–894. doi: 10.1007/s11192-012-0877-4

World Bank, 2011. *Migration And Remittances Factbook 2011*. [Online]. Available at: https://datacatalog.worldbank.org/dataset/migration-and-remittances-factbook-2011 (Accessed 31 August 2020).

World Health Organization. 2014. *Density of physicians*. [Online]. Available at: https://www.who.int/gho/health_workforce/physicians_density/en/ (Accessed 31 August 2020).

Zeleza, P. T., 2005. Rewriting the African diaspora: beyond the black Atlantic. *African Affairs*, 104(414), pp.35–68.

Zweig, D., 2006. Competing for talent: China's strategies to reverse the brain drain. *International Labour Review*, 145(1-2), pp.65–90.

7

Public-Private Partnerships in Research and Innovation

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Abstract

In the transition to knowledge-based economies, the role of knowledge is at the pinnacle of trade, investments, manufacturing and socio-economic development. Public-private partnerships (PPPs) in research and innovation present an opportunity for co-creation and exchange of knowledge and associated products with the private sector. In the context of the Science Granting Councils Initiative (SGCI), PPPs refer to the linkages between the publicly funded research entities on the one hand, and industry, particularly the manufacturing sector, on the other hand. To promote the co-creation and exchange of knowledge and associated products between the public and private sectors, the SGCI and the science granting councils (SGCs) in sub-Saharan Africa (SSA) instituted a Public and Private Partnership Research and Innovation Grant Scheme. This chapter looks at the activities of these schemes in Malawi and Uganda using a case study approach of five projects funded across the two countries. The analyses of the cases are presented alongside four over-arching sub-themes: (i) stakeholder engagement; (ii) institutional strengthening; (iii) contribution to policy processes;

and (iv) organizational culture and practices. A final concluding section looks at the lessons and prospects for the future as the emerging findings on new technologies and products; new business opportunities; and the diversified use of locally available raw materials.

Introduction

The demand on universities and public research institutes to become more entrepreneurial and build linkages with private sector has been on the increase since the early 1990s (Caulfield, et al., 2012). This has been attributed to the decreasing support for universities from government as well as the transition to knowledge-based economies (Downie, 2006). This demand behoves universities and public research institutes to produce research with commercial potential and interact more closely with the intended beneficiaries of their research (Goransson and Brundenius, 2011). Opinion is divided on whether this emphasis on commercialization of university research is good, with protagonists arguing that it will: (i) allow universities to have more direct impact on the lives of its beneficiaries; (ii) increase the researchers' income and prestige; and (iii) allow exchange of knowledge with industrial actors. The antagonists have pointed out that: (i) close associations with industry will erode the universities' focus on broader social goals; and (ii) this entrepreneurial culture may dictate the exact nature of research done in universities with a potential over-emphasis on research that lends itself to commercially viable innovations in the short to medium term, a situation that may disadvantage basic research (Kumar, 2010).

The public-private partnership (PPP) arrangements have immediate influence on the conduct of scientific research and how the findings of such research are made available to stakeholders, particularly the private sector and other beneficiaries. Of immediate interest to this chapter is the commercialization and related impact pathways to technology development and knowledge exchange. The commercialization debate dates back to the post second world war period with the publication of the Vannevar Bush report *"Science: the endless frontier"* (Bush, 1945), in which he argued for steady federal funding for basic research *"so that university researchers could engage in research free from the adverse pressure of convention, prejudice or commercial necessity"*. The publication of the Bayh-Dole Act in 1980 in the USA is considered a turning point in the appropriation of academic research, produced through government funding. It permitted universities to obtain patents on research done with federal funding and exploit such patents for commercial use.

In many African countries, the emphasis towards commercialization of research has resulted in a number of institutional and organizational realignments in the universities and public research institutes. For example: (i) new structures in the form of technology transfer offices (TTOs) or intellectual property management offices (IPMOs) have been created; (ii) new offices and titles have been introduced into the university management structures, for example, the office of Deputy Vice Chancellor (Research and Innovation); (iii) new companies attached to or owned by universities; and (iv) science and technology parks and incubation centres.

At the national level, there's renewed emphasis on innovation (application of knowledge) both in national policies[1] as well as in government funding instruments.[2] Outside government, new intermediary organizations dedicated to enhancing academia-industry linkages have emerged.[3] Similarly, donor-supported interventions such as the knowledge transfer partnerships (KTP) in Kenya and Rwanda supported through DFID/UK have resulted in technologies and innovations licensed to the private sector. These developments at the national (policy), organizational (institutional) and partnership (operational) levels have effects on the opportunities for follow-on innovation and participation in new collaborations.

In the context of the foregoing, this chapter: (i) examines the conditions under which public-private partnerships lead to development of new innovations and technology transfer; and (ii) presents evidence to inform the practice of establishing and governing effective PPPs geared towards addressing innovation and commercialization. The chapter is based on practical experiences and case studies of contemporary public-private partnerships in Uganda and Malawi, and highlights experiences and good practices which can strengthen the intermediary role of councils in fostering PPPs to enhance commercialization of research findings. The key questions being answered by this chapter are:

(a) How have PPPs in research and innovation contributed to the development of new products and services?

(b) What are the existing good practices of effective PPPs in research and innovation in Africa?

(c) How have the PPPs enhanced the capacity of councils in catalysing, facilitating and mediating PPPs for research and innovation?

Research methods and approach

Contemporary case studies of PPPs in research and innovation

The concept of PPPs in research and innovation (R&I) as implemented under the SGCI-1 projects emphasizes the principles of *co-investments* (of financial and non-financial resources), *co-creation* of knowledge and *co-application* (through commercialization and other uptake pathways). As such, building PPPs has been hailed as effective in combining skills, competencies and expertise to overcome their individual actor limitations (Kania and Kolk, 2013). PPPs fulfil several other sustainable development functions including knowledge production, information and innovation; dissemination of knowledge and good practices; technical implementation; institutional capacity building; standard setting and certification; lobbying and advocacy; and technology transfer, among others (Pattberg et al., 2012).

There are various motivations for actors entering into PPPs as a commercialization pathway including: (i) access to knowledge, expertise, skills, networks and contacts; (ii) access to funding; (iii) improved stakeholder relations; (iv) improved reputation and credibility; (v) increased operational efficiencies and effectiveness; (vi) creation of more appropriate services and products; (viii) access to and knowledge of new (future) markets; (viii) access to and more insight into business operations, current markets and supply chains; and (ix) increased leverage/impact (Rondinelli and London, 2003).

Such motivations often (but not always) result in: (i) joint programming; (ii) knowledge transfer; (iii) research commercialization; and (iv) collaboration between universities, national research institutes and business communities which can encourage stronger and productive partnerships between the public and private sector. Effective PPPs have the potential to increase public sectors' responsiveness to the transformation of innovation processes and associated private sector needs and strategies, as well as to enhance the translation of research outputs into innovative products.

To interrogate these issues, the chapter adopts a case study approach (Yin, 1994; Thomas, 1998) and uses contemporary case studies.[4] The cases to be studied have been selected to reflect: (i) different commercialization and uptake pathways; (ii) different economic sectors or themes; and (iii) geography and location (East Africa, Southern Africa).

Consistent with the case study approach, the chapter follows a largely qualitative design involving a systematic collection, organization and interpretation of material derived from document reviews, interviews, and monitoring and evaluation (M&E) reports.

Our study design triangulated a number of methods involving: (i) document reviews in which a number of key policy and strategy documents were consulted; and (ii) issues emanating from initial documentary review (mainly of policies and strategies) were put to selected practitioners and policymakers through short, exploratory key informant interviews (KIIs): the key informants comprised the project coordinators (PIs in the selected PPP projects; SGCI coordinators in the selected countries; and other identified experts in the areas under investigation). The KIIs were conducted through a short questionnaire administered through a survey monkey. The KIIs were a precursor to more in-depth focused interviews with representatives and coordinators of the science granting councils (SGCs).

The use of in-depth interviews allowed the research team to obtain tacit knowledge including how decisions were made in the partnerships and the influence and details of the application of the rules and policy guidelines; it also helped to elicit the perception of individuals and groups on the institutional context, role of different actors, coordination and role of government agencies, governance and decision-making. The in-depth interviews focused primarily on the councils – their mandate and role in collaborative research especially in the context of the contemporary PPP projects; their constraints and capacity strengthening requirements; and their policy advisory role and the support required to enhance partnerships and collaborations.

For analysis, we define the outcomes from the projects at three different levels: (i) internally, on the work and capacity of the implementing organization; (ii) externally, on the attitude, behaviour and practices of the partners and community; and (iii) contribution to project objectives. On the first level – institutional strengthening – we describe how the projects have added value to the institution through positioning for future work (in similar and related areas); and human skills development as well as infrastructural enhancement. At the second level, we detail whether the project findings had any policy implications. If so, what policy processes did the project engage with and what approaches were used to engage policymakers and policy contribution to processes. We also interrogated whether new partnerships and collaborations arose from the projects.

Flowing from the above, four sub-themes present themselves for the analysis of our case studies:

- Stakeholder engagement (especially the private sector)
- Contribution to policy debates and processes
- Community building including new networks, partners and consortia
- Changes in organizational culture and practices – attitudes,, knowledge, skills and motivations of project partners and stakeholders.

Case study summaries

The first case study, *"High fibre bakery and confectionery products from maize germ and bran"* focuses on the utilization of abundant maize bran and germ generated by the different millers in product development for bakery and confectionery enterprises. The commercial potential of the project is based on the ever-increasing demand for maize, hence resulting in bran and germ availability. The production of baked and confectionery products in Uganda is currently dominated by the use of refined flours with low fibre content and are highly priced. The project aimed to incorporate bran and germ into various baked and confectionery products such as muffins, bread and cookies. These products are differentiated from the existing products owing to their high fibre content and associated health benefits.

The project is led by Makerere University's Department of Food Technology and Nutrition and targets maize millers who produce bran and germ as by-products. In particular, the project's private partners include: (i) Maganjo Grain Millers – producing a range of milled cereal flours, extruded breakfast and snack food; (ii) Agro ways (U) Limited – producing maize grit; and (iii) JOVAY School of Cookery – producing a variety of bakery and confectionery products. The major beneficiaries of this project are the millers who generate bran and germ; the bakery and confectionery enterprises; and the consumers who enjoy high fibre foods. The consumer demand for health products provide the springboard for uptake and utilization of knowledge generated by the project.

In the second case study, the project *"Commercial exploitation of propolis and bee venom in Uganda"* aims at developing propolis and bee venom-based products including: propolis powder supplement, bee venom powder supplement, a syrup drink and a ready-to-drink beverage. The School of Veterinary Medicine and Animal Resource-

Research Center for Tropical Diseases and Vector Control (SVAR-RTC) at the College of Veterinary Medicine, Animal Resources and Biosecurity (COVAB)-Makerere University, have partnered with private sector players such as the Uganda National Apiculture Development Organization (TUNADO) which has a network of 9,000 beekeepers and Aryodi bee farm with a network of 500 producers, an already running business with between 10,000 kg and 15,000 kg of honey per season.

In the third case study, the project *"Cocoa waste to wealth using yeast strains from Ugandan box fermentation"*, aimed to develop a single cocoa fermentation box to help small-scale farmers who cannot generate large quantities of cocoa beans required in storey box fermentation. The single fermentation box requires less capital and is gender inclusive. The project also proposed the use of yeast starter with pectin hydrolysing properties to aid extraction of cocoa juice from cocoa pulp using a stainless-steel tank with a hydraulic press. The development of value-added products such as ethanol and wine from cocoa pulp juice and sweating is expected to reduce Uganda's ethanol importation costs which stood at US$500,000 in the year 2015. Additionally, the project was expected to boost income generating capacity of participating cocoa farmers in varying agro-ecological zones of Uganda by up to 25 per cent through sale of value-added products to laboratories and well fermented cocoa beans to cocoa buyers, thus fetching better prices. This project was led by the National Coffee Research Institute (NACORI) in collaboration with the private actors in the cocoa industry namely ICAM Chocolate and Lwanga enterprises.

In the fourth case study, Tsangano market in Malawi is associated with huge quantities of vegetable waste which most of the time is dumped in open space. This has adverse effects on the environment, climate and human health. However, vegetable waste is a valuable resource for biogas production. The project is premised on the fact that production of biogas at the market would help to provide an alternative source of energy for cooking to restaurants, chips making businesses and households. Additionally, use of biogas will help to reduce deforestation, and promote sanitation at the market and in the surrounding communities.

In the fifth case study, the innovative solar-powered milking machine technology was not available to smallholder dairy farmers in Malawi. This necessitated research intervention to assess the feasibility of incorporating renewable energy in milking dairy cattle. The design of the solar energy powered systems was done, and solar-powered milking machines and solar-powered water pumps were installed and operated.

Case studies of agro-processing in Uganda

Case study 1: High fibre bakery and confectionery products from maize germ and bran[5]

Maize is the most important cereal food crop supporting about 86 per cent of the 4.2 million agricultural households in Uganda. Processing maize into refined flours results in large amounts of bran and germ as by-products. These are widely used as animal feed but are not yet considered as human food. Maize bran remains the richest source of additional fibre and contains various minerals which are vital for the proper functioning of the body and in the prevention of constipation. Maize germ, on the other hand, is highly nutritious with essential oils, vitamins and proteins. Maize bran and germ, when used in product development can impart a number of health benefits.

At the moment, the two by-products of industrial maize milling – maize germ and maize bran – are considered of low economic value and have dominated the animal feed production sector, hence not been considered as human food. In this project, different ratios of bran and germ have been used to produce bread, cookies and cakes. These products have been tested for both sensory and chemical properties. Wheat flour was replaced by maize bran, maize germ and soy flour at different levels of 0 per cent, 10 per cent, 20 per cent, 30 per cent and 40 per cent to produce enriched balanced bread. Preliminary results indicate that mixing bran, germ, soy and wheat can produce an acceptable product. At 30 per cent substitution, the bread had the highest loaf weight and crumb hardness. At 20 per cent substitution, the bread produced had the overall good general appearance and acceptability. With respect to aflatoxin content, all bread tested had less than 0.005 ppm. As the project progresses, further formulation experiments are being conducted to produce more bread, cookies and cakes.

Case study 2: Commercial exploitation of propolis and bee venom[6]

In Uganda, the proportion of people that are immune-compromised owing to factors such as malnutrition, communicable diseases and stress are rising. Bee products such as propolis and venom are known to be medicinal. In Asia, Europe and USA, propolis and venom have been processed and commercialized as medicine and food supplements. In Uganda, only 1 per cent of propolis is crudely harnessed by cottage enterprises that have ventured into production of supplements and beverages enriched with propolis or bee venom. However, the production (extraction) processes and quality of the products not only vary but are also not known. Thus, the need to standardize and optimize the processes, and develop prototype products for the growing Ugandan market.

This project aimed at contributing towards income and food security through diversification into high value products of honeybees such as propolis and bee venom. The household income contribution of beekeeping is limited at only 7 per cent (Amulen et al., 2017). Yet bees offer numerous products that are of high medicinal and commercial value such as propolis and bee venom. However, with all the numerous benefits of the high value products, their exploitation within Uganda remained low. To significantly improve the contribution of beekeeping to rural household incomes there is need to improve production and extraction of non-honey products such as propolis and bee venom, and create high value ingredients out of them for food supplements, beverages, cosmetics and pharmaceutical products. In addition, the available cottage industries that had ventured into production of propolis and bee venom had limitations in their production (extraction) process and quality of the products. These products greatly varied, and most times had unknown composition. Based on the foregoing, this project aimed at standardizing and optimizing the processes, and developing prototype products for the nascent Ugandan market. The project works with existing private enterprises to develop and promote supplement and beverage product prototypes for improved commercial exploitation of propolis and bee venom in Uganda.

Case study 3: Cocoa waste to wealth using yeast strains from Ugandan box fermentation[7]

Cocoa ranks fourth in foreign revenue contributions and supports over 10,000 households in Uganda. Cocoa is harvested as pods, broken open to remove the white mucilaginous pulp which consists of water, sugars, pectin and organic acids that act as the fermentation media. In Uganda, cocoa fermentation is carried out spontaneously by unidentified microorganisms using either storey boxes or heaps; this leads to product and price variability. NACORI has isolated pure yeast strains from Bundibugyo and Kayunga districts that could be used to generate controlled fermentation to attain better quality beans. In Uganda, the storey box method of cocoa fermentation is mostly afforded by commercial exporters since it requires huge capital investments and large volumes of beans (over 100 kg) to attain quality results. This forces small-scale farmers to sell fresh beans with no value added. This is the gap that this project aims to fill.

Fermentation is one of the vital steps that ensure the development of chocolate flavour precursors and thus determines not only the quality of resultant chocolate and prices offered to farmers. The fermentation methods that are currently used require huge volumes of cocoa pulp (over 400 kg) to achieve the desired quality, leaving small-scale farmers with no option but to sell their cocoa fresh at a low price. During cocoa fermentation, a lot of waste is generated as sweating from fermentable juices that can be detrimental to the environment by affecting soil pH. The project is tackling the above challenges by designing a single cocoa fermentation box that handles smaller volumes (40 kg and more) and a stainless-steel press for extraction of juice from cocoa pulp that can be fermented to generate value-added products such as wines and ethanol. This is expected to boost income generating capacity of cocoa farmers and lessen the negative impact on the environment.

The first prototype of the single fermentation box has been developed and efficiency studies are being conducted in Kasawo alongside a storey box fermentation method. A temperature profile for both methods has been obtained. Full fermentation of cocoa beans was achieved after 144 hours in both methods. Preliminary results have shown that the single fermentation box will be a better alternative cocoa fermentation method for small-scale farmers. Similarly, a cocoa juice extraction press with a capacity of 15 kg has been designed and fabricated, and production of value-added products from cocoa juice has commenced.

Case studies of renewable energy in Malawi

Case study 4: Piloting biogas as a social enterprise at Tsangano vegetable market, in Ntcheu District

Tsangano market located in Ntcheu District is one of the largest vegetable markets in Malawi. The market supports both Malawian and Mozambican vegetable farmers. However, the market is associated with huge quantities of vegetable waste. The market lacks proper infrastructure and facilities for waste management, and as a result waste is dumped in open space. This has adverse impacts on the environment, climate and public health. However, biodegradable materials such as vegetable waste are a valuable resource that can be used to produce biogas for cooking. At the market, the demand for heat energy by chips makers and restaurants is very high. Therefore, biogas produced will be supplied to such users at a fee. The use of biogas will also help to reduce deforestation at Tsangano and the surrounding areas. Organic fertilizer is a by-product of the biogas production process, which will also be made available to vegetable farmers. Organic fertilizer will be packed and sold to smallholder vegetable farmers. The market potential for organic fertilizer is high as the price of inorganic fertilizer keeps on increasing in Malawi. The use of waste as a raw material for biogas and organic fertilizer production will also help to solve waste challenges at Tsangano market. In the long run, it is expected that biodegradable waste will become valuable raw material that can be traded.

The overall goal of the research project is to promote biogas development for socio-economic development and environmental sustainability in Malawi. The project seeks to pilot "Fee-For-Service Social Enterprise Business Model" in biogas. The entrepreneurship component of the project will help to generate funds for operation and maintenance of the biogas plants. It is expected that this approach will help to address the problem of project failure, which mostly happens with energy projects given as a gift to communities in Malawi. The expected outcomes of the project are: (i) increased knowledge on biogas as a social enterprise; (ii) biogas as a clean and alternative source of energy promoted; (iii) increased use of organic fertilizer at Tsangano; and (iv) improved sanitation at the market and surrounding areas.

Malawi University of Science and Technology (MUST) implemented this project in partnership with a local energy company, Green Impact Technologies (GIT). The project also engaged the Malawi Government and other stakeholders such as non-government organizations in order to influence a change in policy.

Case study 5: Solar powered technologies for smallholder dairy industry[8]

Malawi's dairy industry is dominated by smallholder farmers estimated at a population of 7,000 who produce the bulk of milk that is available for processing. However, the farmers do not have access to electricity, reliable power or energy sources to modernize their farming activities such as milking and water supply. Milking is done using hands and most of the farmers do not have a reliable supply of safe water for watering cows and for maintaining adequate levels of hygiene and sanitation. Consequently, the smallholder dairy industry is characterized by low milk production and poor milk quality resulting in huge actual and potential financial losses.

Machines can safely be used for milking cows if proper hygiene is maintained. Thus, a steady supply of clean water is mandatory for proper utilization of milking machines and hence the need for water pumps. The operation of milking machines and water pumps requires energy which is generally inaccessible to Malawian smallholder dairy farmers. As of 2014, access levels to grid electricity in the country were lower than 2 per cent in rural areas where smallholder dairy farming is done. Nonetheless, Malawi has a high solar energy potential which can be introduced into the country's smallholder dairy industry.

The overall objective of this project was to contribute towards improved milk production among smallholder dairy farmers in Malawi through the introduction of two innovative solar-powered dairy production technologies: (i) solar powered milking machines which are neither available at the local market nor utilized in smallholder dairy production systems; and (ii) solar-powered water supply systems which are currently not used in the smallholder dairy production systems. The project was piloted in Lilongwe and Dedza districts and targeted smallholder farmers, solar energy technology dealers and local milk processors. The project was jointly implemented by LUANAR and a Malawian registered private company – Orifice Irrigation and Water Supply (OIWS) Limited – which specializes in supply and installation of solar energy technologies and water supply systems.

Opportunities, approaches and outcomes

Opportunities for innovation and intervention

Maize germ is highly nutritious with essential oils and proteins that are necessary for the human body. When plain maize bran is added to a recipe, it greatly increases the fibre content. It can be used in products like cereals, chips, or snack bars, to increase the fibre. It has a minimal impact on calorie count, so foods designed for dieters can be made with bran to keep the calories low and give the food a filling notion. Fibre contains various minerals which are vital for the proper functioning of the body and prevention of constipation. In view of these facts, value addition to maize germ and bran becomes a key area of nutritional intervention leading to the utilization of the large amounts of bran and germ generated during production of maize flour.

One of the key challenges in the bee project was low supplies of propolis in the dry season from the Lango sub-region. However, using the TUNADO broad network, the project team opted to expand the geographical collection of propolis for product development. A key opportunity from this project concerns the need to develop specialized propolis collection equipment for Ugandan beehives such as log hives. This will increase yields per hive. Another specialized equipment needed is a mechanical churning machine to accelerate the time of powder extraction and increase yield. Currently, the churning is by hand and produces only 7 per cent yield per kg. Lastly, one of the exciting findings of the project is that for the first time, the project has documented the presence of black and red propolis in Uganda, which provides a basis for further assessment and analysis, especially with respect to determining if there are variations in their antibacterial properties. This project is the first to launch the propolis powder and juices in the Ugandan market.

Cocoa is harvested as pods, broken open to remove the white mucilaginous pulp which consists of water, sugars, pectin and organic acids that act as the fermentation media. In Uganda, cocoa fermentation is carried out spontaneously by unidentified microorganisms using either storey boxes or heaps; this leads to product and price variability. The storey box method of cocoa fermentation is mostly afforded by commercial exporters since it requires huge capital investments and large volumes of beans (over 400 kg) to attain quality results. This forces small-scale farmers to sell fresh beans with no value added. This is the gap that this project aimed to fill.

In Malawi, the private sector has not been actively involved in biogas development. Biogas is mostly given for free to communities as a way to address energy, deforestation and environmental challenges. The approach is not sustainable, so as a result, some biogas projects have failed to achieve the intended results. The biogas project piloted a Fee-For-Service Social Enterprise Business Model which involves commercialization of social services. Under this model, services are sold directly to the target populations, individuals or communities. Based on the project pilot results, the partner company, GIT will replicate the enterprise to other potential areas. This will help to promote biogas development and increase access to clean energy.

Approaches to innovation and technology uptake

The maize germ and bran project utilize locally available raw materials that have been considered to be of low human value and dominate the animal feed sector. The raw materials used to make bread were wheat flour, maize bran, maize germ, soy flour, fat, sugar, yeast, salt and water. Soybean grain was purchased from Soybean Africa Ltd., a local soybean company along Gayaza-Zirobwe Road, the grain was thoroughly sorted, and extraneous materials removed, roasted and milled by Kayebe Grain Millers, another local milling company in Kasangati. Maize bran and maize germ were obtained from Maganjo Grain Millers Ltd., a local grain milling company in Kawempe, while wheat flour, yeast, fat, sugar and salt were obtained from Kikuubo Market in Kampala. Wheat flour was replaced by maize bran, maize germ and soy flour at different levels of 0 per cent, 10 per cent, 20 per cent, 30 per cent and 40 per cent to produce enriched balanced bread. Maize germ was substituted in the range of 4 to 15 per cent and maize bran in the range of 1 to 10 per cent. All formulated breads were baked in an oven set at 200°C for 30 minutes.

To obtain the above results the *bee venom project* baseline surveys were conducted to capture current practices, product profiles, economic viability and opportunities for improvement of the product. Further, 140 samples of propolis and venom were collected from four regions for laboratory analysis to determine composition and safety. Two product prototypes (drink infusion of propolis powder and beverage drink) have been formulated to be up scaled by the private sector partner (Aryodi Farm). Finally, the project trained 20 trainers under the Uganda National Beekeepers on hygienic handling of the new products.

A total of 140 propolis samples for laboratory analysis were collected, 450 kgs of propolis for product development procured, 140 survey questionnaires administered, and all entered in a database. A Masters student supported through research has completed presenting her proposal to the higher degrees committee at the School of Veterinary Medicine and Animal Resources and has been cleared to proceed and collect data. The Masters student conducted safety analysis for the propolis samples that were collected from beekeepers and apiaries to check for mycotoxins and also assess antibacterial properties. Two press releases in the Daily Monitor and New Vision newspapers were published.

The first prototype of the fermentation box was designed basing on the principle of the engine crank shaft. The first prototype was developed, and field tested to determine its fermentation efficiency alongside the tower fermentation method. Both single and tower fermentation boxes were loaded to capacity with cocoa pulp (50 kgs and 700 kgs respectively) and the initial temperature and pH recorded at 12-hour intervals. Temperature and pH were recorded at 12-hour intervals at three points of the box and mean obtained. A total of 200 g samples were taken every 24 hours and kept in the refrigerator. The cocoa in both boxes was turned after every 48 hours: in the single fermentation box, the beans were turned by rotating the hand crank clockwise 360 degrees; while for the storey fermentation box, turning was done using a wooden stick to transfer it to the lower box. The beans were removed from both boxes on the sixth day (144 hours) and sun dried separately on a raised tray. These fermentation processes were done in according to the local practices. In addition, samples collected during the fermentation process were sun dried to a moisture content of 7 per cent for subsequent analyses. All the trials were conducted at the premises of one of the private sector project partners.

The biogas social enterprise is expected to contribute to the local economy in a number of ways. For example, what would have been waste will become a valuable resource which can be marketed, thus converting waste streams to income streams; community members will have an opportunity to collect, sort and sell waste for biogas production thus providing an alternative source of livelihood; biogas as an alternative source of energy will drive local business activities such as restaurants and chips-making business at Tsangano; organic fertilizer, a by-product of biogas production will boost agriculture and conserve the soil at Tsangano where agriculture is the main source of livelihood; and GIT will employ local people in biogas and organic fertilizer production and marketing.

Outcomes and key lessons

From the maize germ and bran project, the immediate outcome was the enhanced collaboration between the university and the private sector. This project fostered the collaboration between the miller (Maganjo Grain Millers Ltd.), the baker of confectionery products (JOVAY School of Cookery) and the university (Makerere University, Department of Food Nutrition and Technology). Further, both the university and the baking partner have purchased equipment that will strengthen both their research and innovation infrastructure, while two students will graduate from the project (one at Bachelor's level – completed and defended his research project; and another at Master's level – has collected data and is currently conducting analysis). It is anticipated that the work on the use of bran and germ may open up new policy discussions on their use in human food, especially the provision of high fibre products.

In the bee venom project, the team expected crushing and churning of propolis to be much easier and as such, simple kitchen aids like a blender would work. However, it did not turn out as expected. Propolis is a sticky, hard substance that is harder to crush in large volumes. So, the team took time to crush some of the samples and this led to the recommendation for a mechanized churning machine for accelerated extraction of propolis powder.

The preliminary baseline survey results indicated that 90 per cent of the beekeepers were not harvesting propolis for sale and did not even know how to harvest or store the product. The few processors who bought propolis were poorly handling the raw materials by leaving it in open air instead of storing it in a dark dry place. All these confirmed the initial hypothesis that there was limited knowledge on handling of propolis and these bee farmers need to be trained, and awareness created about the opportunities the product can offer if harvested and handled properly.

The project found – for the first time – that there are two colours of Ugandan propolis powder (black and brown) even though it is yet to be determined, through further analysis, whether these two types differ in content of active ingredients. This new finding remains largely unknown and unexplored owing to the limited study of the product properties. Crushing and churning propolis gum is difficult and needs a mechanized crushing machine for quick industrial crushing; however, the project devised a means of freezing the product to remove the gummy and sticky nature before crushing. This was not earlier on hypothesized, so it is an emerging outcome from the project implementation.

From the cocoa project, a single fermentation box prototype was developed. For its operation, cocoa pulp is loaded into the box to capacity, door closed and top covered with a jute or sisal bag to avoid any external temperature influence. After 48 hours of fermentation, the hand crank is rotated clockwise (360 degrees) to turn the beans upside down. This helps to aerate the beans for growth of acetic acid bacteria. The commercial potential of the box will be determined after full evaluation in the different agro-ecological zones. Through the project, a student pursuing Bachelor of Science degree in agricultural sciences and entrepreneurship at Uganda Christian University was facilitated to carry out his special project research: *Evaluating Small Scale Cocoa Farmers' Fermentation Processes in Bundibugyo District.* The student has finished the research work and defended his dissertation, is awaiting graduation and is currently attached to NaCORI as a trainee.

Smallholder farmers in rural areas of Malawi have limited available energy to boost production of agricultural products for economic development, yet Malawi's economy is agro-based and agriculture accounts for 36 per cent of the country's Gross Domestic Product (GDP), 90 per cent of Malawi's export earnings, and employs 70 per cent of the active labour force. The dairy industry in Malawi plays a significant role in providing employment and contribution to the GDP. Currently, Malawi's dairy industry is dominated by smallholder farmers who have no access to electricity to modernize their dairy farm activities such as milking. The smallholder sector has a total of about 7,000 dairy farmers with technical support from government and some NGOs.

Discussion and analysis

Stakeholder engagement: new and emerging networks and collaborations

From case study 1, two private sector partners have been fully engaged in the project. Makerere University as a public research institution is collaborating with Maganjo Grain Millers Ltd., producing large amounts of maize germ and bran, and Jovay School of Cookery, a small-scale bakery where formulation and product development activities are being undertaken. The two private sector partners have provided their premises for conducting the research. Maganjo Grain Millers are providing the maize bran and germ which they process to the specification of the project. Further engagement of the different stakeholders is planned during sensory evaluation of re-developed products, and when developing strategies for strengthening local capacity of local bakery and confectionery industries to use maize germ and bran as ingredients in product development.

In case study 2, new partnerships are emerging in the implementation process. The project has strengthened its networks with industry in areas such as branding and marketing to support Aryodi Bee Farm (the private sector partner) in proper packaging of the end product. The project team is also in discussions with metal fabricators to explore means of having a mechanized churning machine for accelerated extraction of propolis powder, reducing time from four weeks to three days and increasing yield from 7 per cent to 9 per cent per kg.

Makerere University as a public academic institution appreciates that better innovations are built together with communities and as one of the project team members notes: *"because under this project, we have been able to share ideas on how to improvise a local hive or specialized equipment for propolis production that beekeepers intending to become commercial propolis producers can adopt."*

In case study 4, the biogas project was implemented as a partnership between Malawi University of Science and Technology (MUST) and Green Impact Technologies (GIT) – a private sector company. The company was involved from the inception meetings, community mobilization, awareness, sensitization and actual construction of the plant. The involvement of the company in the project design ensured that after commissioning, it would take over, expand, sustain and replicate the technology to other areas where there are similar challenges of wastes problems, addressing deforestation and providing alternative energy for cooking.

In case study 5, the solar powered milking machines in Malawi project was led by the Agricultural Engineering Department (AGE) of LUANAR under a PPP arrangement with a private company, Orifice Irrigation and Water Supply Limited (OIWS). The two parties signed a Memorandum of Understanding (MoU) for the working partnership of the project. Under the partnership, responsibilities of each party and other logistical and management issues between the two parties were agreed upon. The PPP arrangement ensured that sustainability of the innovation was enhanced upon project completion.

Institutional strengthening

The projects have contributed to institutional strengthening through provision of equipment, thus improving the research and innovation infrastructure; increasing the visibility of researchers; training of students and providing opportunities to leverage more funding. The quotes below from project team members in case study 2 provide some insights:

> "*This project has improved our research capacity in the subject area. It has enabled us to acquire new equipment, mentor a student whom we hope to grow into a scientist in the field through her PhD work in the future. It has also placed SVAR-RTC at the fore front of high value product development as evidenced by the numerous calls from other private sector actors who need help on how to convert their propolis into powder.*"
>
> "*The administration is also considering adding us more workspace due to the visibility that this project has created.*"
>
> "*We have been able to mentor students and laboratory technicians. As scientists, our understanding of these products has also improved. Through the upcoming scientific meetings, we as scientists shall gain publicity. But it has also built a network between the university, communities (beekeepers) and private processors (Aryodi) including governing NGOs like TUNADO.*"

Furthermore, from case study 2 the team has reported that: *"as a result of the project initiatives, the PI was funded by US professional fellows to lobby for new funding in how to develop insect- propolis-honey based herb for child nutrition in agro-pastoral areas*". The project has also opened new funding opportunities within the university structures. Notably, as the team confirm: *"we now have an opportunity to apply to the university innovation fund because we have a pilot of our idea."*

The maize germ project has also reported that two students were recruited to undertake their Bachelor and Masters studies under the project. The Bachelor's student has completed and defended his dissertation while the Masters student is due to complete studies this academic year.

In case study 3, NACORI has been able to leverage additional funding and projects as a result of their PPP project. As they note: "*the work on fermentation box has attracted attention of MARK UP (an EU project) and NACORI has been given activity under the project to expand the scope of training farmers for improved cocoa fermentation*". This activity will focus on developing technologies for reduced pest and disease incidence, developing new cocoa varieties and designing appropriate technologies for improved post-harvest handling of cocoa. Furthermore, funds have been obtained through their Competitive Grant Scheme (CGS) at a tune of USh 100 million. This funding is focused at developing manuals to rehabilitate old cocoa fields and develop value-added products from cocoa.

In case study 5, one of the machines was installed at Bunda College Animal Science Students' farm and apart from being used for drawing lessons, it is being used for teaching animal science students in use of solar-powered milking machines. This will ensure sustainability of the technology because some of the students will work with dairy farmers when they graduate, while others may be in policy making positions. Sustainability of the innovations will also be ensured through the linkages made by the project team. The project team linked up farmers with agents providing back-up services to ensure after-project services for the innovation. The project team also provided training to the farmers both during and after implementation of the solar powered equipment project to ensure sustainability of the innovation. The involvement of the PPP partner (OIWS) is also very key in ensuring that the technologies are sustainable. OIWS will continue to market the technologies as a business entity, thereby also providing additional backup services to farmers with the technology.

Contribution to national policy processes

> *"We have contributed to developing standards in handling propolis and will still add more information that is currently lacking once our composition results are due. During the technical committee meeting, it was evident that data on composition of our local propolis was limited and even setting limits was difficult because of unknown levels of contamination. The findings of laboratory analyses from this project will be able to give a Ugandan position on the standards."*

The above quotation from a project participant highlights the type of impact research can have on policy processes.

A policy brief has been drafted to support TUNADO (the governing body for beekeepers) to lobby how issues raised in the exploitation of these new products shall be handled. Findings of composition analyses once ready shall be submitted to the Uganda National Bureau of Statistics (UNBS) to support standards development.

> *"The training manual for propolis and bee venom handling under the African context being developed will be the first in East Africa that may be also adopted by neighbouring countries."*

In case study 4, the project team in the course of the project implementation made a presentation at a Cleaner Cooking Camp through the National Cook Stove Steering Committee which is chaired by the Department of Energy Affairs. The policy brief has been developed and shared with the parliamentary committee on environment, department of forestry, department of energy, department of environment and the overall Ministry of Energy, Natural Resources and Mining. The policy brief has also been shared with the Malawi Energy Regulatory Authority (MERA) to inform the development of a regulatory framework for biogas systems in Malawi.

Organizational culture and practices

Private and public-sector organizations have cultures and practices that are at times conflicting and this sometimes becomes a challenge. For example, the private sector expects to be paid immediately upon supplying an item; however, in a public institution these items need to be verified by the auditor before payments are approved. Sometimes private actors share information without team approval thereby jeopardizing the privacy and procedures of the project, and in some cases threatening the intellectual property protection of the products.

For monitoring and traceability, record keeping has improved and institutions such as SVAR-RTC has a registry (book) where all new persons contacting the project for help in propolis product development are registered. For example, available records show that since the press release, three persons have called for help. One wanted to add propolis to cosmetics, another farmer wanted to see how to add propolis into his ice cream and there was someone who just wanted supply of bee venom.

On governance, the projects have adopted attendance forms that are signed to capture details of the engagement. Some of the projects have also signed agreements for engagement, and each stakeholder assigned activities to implement and budget, and resources accordingly allocated. These are important in reducing conflicts and managing any such conflicts wherever they occur.

> In case study 4, the system was designed by Intrinsic Biogas Company and the bill of quantities shared with the project team. The model is that GIT will take over the plant once all is done to operate it for sustainability. The technology being used on this project is a patented design by the contractor – Intrinsic Biogas Company. This is a cross flow biogas system with up to three stages digestion system within one digester. The design was selected based on the time needed for the substrate to be digested and the retention period. The design also incorporates the greenhouse system which will increase heat as the selected area has low temperatures during the winter. The project is being implemented in an area where agri-business is increasing, hence an inclusion of liquid and granule bio-fertilizer to assist farmers to increase the crop yield and improve soil fertility.

Lessons and prospects for the future

New products and technologies

The new technologies and products developed under the PPP projects are a testimony of the viability of this approach in facilitating and fostering technology transfer and knowledge exchange between different actors within the national innovation ecosystem. All the five projects in Malawi and Uganda have resulted in some novel products that have been prototyped and tested. Some of these, such as the propolis powder have not been exploited as a commercial product in Uganda and the idea of incorporating the propolis powder into juice is new in the Ugandan market. These products are anticipated to grow commercially.

The confectionary products under the maize germ and bran products have not only introduced more nutritious products in the market but also expanded the product portfolio at the private sector partner business lines. This increases revenue and conversion of what would have been waste products into new income streams.

In Malawi's renewable energy sector, the introduction of the biogas system to deal with health and sanitation at the Tsangano market under the fee-for-service model offers opportunities for an academia-private sector-community partnership that is likely to offer long-term solutions to deforestation, soil degradation and sanitation.

New business opportunities

The private sector is getting excited about the business prospects of the new products and processes such as propolis, maize germ and bran in human food and the fermentation box. For example, when private actors read in the papers that the bee propolis project was buying propolis to make powder, this resulted in increased competition for the raw material; consequently prices rose from Ush 15,000 per kg of raw material to Ush 30,000 per kg.

The biogas project is the first of its kind in Malawi and it is being piloted when the country is facing massive deforestation owing to high demand for firewood and charcoal for cooking. The project positions MUST as a leader in research on renewable energy and agricultural activities. At the policy level, the project has attracted interest from the Department of Energy Affairs and Malawi Energy Regulatory Authority who are keen to learn from and design future projects adapting the concept piloted at Tsangano market.

Similarly, the solar-powered milking machines in Malawi's dairy industry have attracted the interest of the cooperatives who have committed to collect funds and upscale the uptake and use of such machines among their members. This has already expanded business opportunities for the private sector partner – OIWS – in selling and maintaining these machines.

New uses for locally available raw materials

In all the cases, the use of what would have been considered waste products or by-products have now been put to productive and beneficial use through the projects. In some cases, such as the maize germ and bran, customer perception and attitudes will require further sensitization or careful product labelling to change people's mindset regarding maize bran and germ as animal feed.

In the biogas case in Malawi, the incorporation of a public toilet facility and an abattoir into the raw materials for the project after an agreement with the municipal council is a pointer to the usefulness of what would have been abandoned projects. In the dairy project, farmers have donated their facilities and resources including land, labour and other inputs in the spirit of partnerships and collaboration. For sustainability, they have committed their own financial contributions from their cooperative savings besides other in-kind contributions.

Notes

[1] Most countries have forward-looking development blueprints, e.g. the Vision 2030 in Kenya. Almost all of these are anchored on science, technology and innovation (STI).

[2] That now place emphasis on multi-disciplinary, multi-institutional collaborations and demonstrated partnerships with the private sector (STI grants scheme).

[3] Examples such as LIWA (Linking Industry with Academia) in Kenya could be found elsewhere in the study countries.

[4] These case studies are derived from (i) public-private partnership (PPP) projects under Phase 1 of the Science Granting Councils Initiative (SGCI) in Uganda and Malawi.

[5] For details on this project, see policy brief: "*Maize germ and bran for value addition: high fiber bakery and confectionery products*" available at: https://scinnovent.org/wp-content/uploads/2020/02/Policy-Brief-08-for-print.pdf

[6] For details on this project, see policy brief: *"Strategies for increased utilisation of new propolis products in Uganda*" available at: https://scinnovent.org/wp-content/uploads/2020/02/Policy-Brief-11-for-print.pdf

[7] For details on this project, see Policy brief, *"Building the capacity of small-scale cocoa farmers to conduct on-farm fermentation* available at: https://scinnovent.org/wp-content/uploads/2020/02/Policy-Brief-04-for-print.pdf

[8] For details on this project, see policy brief, *"solar powered technologies for the smallholder dairy industry in Malawi*" available at: https://scinnovent.org/wp-content/uploads/2020/02/Policy-Brief-06-for-print.pdf

References

Amulen, D. R., D'Haese, M., Ahikiriza, E., Agea, J. G., Jacobs, F. J., de Graaf, D. C., Cross, P., 2017. The buzz about bees and poverty alleviation: Identifying drivers and barriers of beekeeping in sub-Saharan Africa. *PLoS ONE*, 12(2), p. e0172820.

Bush, V., 1945. *Science: the endless frontier*. Washington DC: Government Printing Office.

Caulfield, T., Harmon, S. H. and Joly, Y., 2012. Open science versus commercialization: a modern research conflict? *Caulfield, et al. Genome Medicine*. pp.1–11.

Downie, J., 2006. The power of money: commercialization of research conducted in public institutions. *Otago Law review*. pp.305–326.

Goransson, B. R. and Brundenius, C., 2011, eds. 2011. *Universities in transition: the changing role and challenges of academic institutions*. Ottawa: IDRC.

Kania, J. and Kolk, A., 2013. Partnerships as panacea for addressing global problems? On rationale, context, actors, impact and limitations. In: M. Seitanidi and A. Crane, eds. 2013. *Social partnerships and responsible business: a research handbook.* Routledge.

Kumar, M. N., 2010. Ethical conflicts in commercialization of university research in the post-Bayh-Dole era. *Ethics and Behaviour.* 20(5), pp.324–351. DOI: 10.1080/10508422.2010.491759.

Pattberg, P., Biermann, F., Chan, S. and Mert, A., 2012. *Public-private partnerships for sustainable development. Emergence, influence and legitimacy*. Cheltenham: Edward Elgar.

Rondinelli, D.A. and London, T., 2003. How corporations and environmental groups collaborate: assessing cross-sector alliances and collaborations. *Academy of Management Executive*, 17(1), pp.61–76.

Thomas, A., 1998. Challenging cases. In: A. Thomas, J. Chataway and M. Wuyts, eds. 1998. *Finding out fast: investigative skills for policy and development*. The Open University, UK.

Yin, R. K., 1994. *Case study research*: *design and methods*. London: Sage.

8

An Analysis of Experiences with PPPs in Africa

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Abstract

This chapter reviews public-private partnerships experiences in Africa, identifying the challenges and barriers to their implementation. The analysis is based on a systematic literature review and supplemented by interviews with representatives of 12 African science granting councils, allowing for a discussion of the role they should play in facilitating partnerships that help drive science-based innovation in African businesses and industries. The chapter seeks to improve our understanding of the realities involved in implementing PPPs in Africa.

Introduction

Public-private partnerships (PPPs) are a policy instrument embracing a wide range of collaboration and institutional arrangements and allowing for the joint development of products and services by the public and the private sectors (Klijn and Teisman, 2003). Their adoption is more prevalent in infrastructure projects and can be traced back as far as the 18th century (Nirupama, 2009). Their implementation increased in popularity due to the economic crisis in the late 1970s. By the late 1980s, PPPs were a popular policy instrument used to leverage the experience and funds of the private sector to implement projects at a reduced cost, while also creating jobs, upgrading skills, improving delivery, and increasing the quality of performance (Dykes and Jones, 2016; Grimsey and Lewis, 2007; International Monetary Fund, 2004). Formally, PPPs are understood as those alliances in which the public and private sector enter into long-term collaboration to produce better quality products and services at a lower cost (Roehrich, et al., 2014).

Although PPPs are mostly linked to the development of infrastructure, their cross-sectoral and multidisciplinary nature makes them an excellent instrument for promoting linkages and knowledge flows among stakeholders with different competencies (Lember, et al., 2019). Early in the 2000s, their adoption expanded to many other economic sectors, such as the health and water sector (i.e., supply partnerships). They were also adopted as an instrument to facilitate investment in science, technology, and innovation (STI) to develop industrial processes, products, and services in ways that would not have been possible without the involvement of both the public and the private sector (OECD, 2004). These PPPs in research and innovation (RI) are defined as modes of cooperation between publicly-funded research organizations and private firms, characterized by long-term institutional and formal strategic arrangements in order to achieve complementary goals by jointly operating research activities (Buckland, 2009), sharing financial risk, and exploiting research results (Becker and Dietz, 2004).

PPPs in RI are instruments commonly adopted in the innovation policy in Europe and the United States, particularly in addressing societal challenges or the UN Sustainable Development Goals. In developing countries, particularly in sub-Saharan Africa (referred to as Africa from here on), the adoption of PPPs is still in its early stages. Nevertheless, there are notable cases of PPPs in RI on the continent, as well as explicit efforts by African STI actors to promote the engagement of the private sector in research and the incubation of research to support viable businesses, particularly in terms of solar energy and pharmaceuticals, among other things (Ahmed, 2017; Dorothal, 2019; European Commission, 2015). Although these experiences are recorded in case studies, there are not yet sufficient lessons and insights on how to adapt PPPs for use in building technology and innovation capabilities. In the case of Africa, one of the biggest challenges in the implementation of PPPs is their adaptation to the African landscape, including the underdeveloped institutional setting, a private sector with high levels of informality, and large rural populations (Adekenle et al., 2016; Akampurira et al., 2009; Kajimo-Shakantu et al., 2014; Rana and Izuwah, 2018).

This study situates itself within broader debates on long-term research and innovation initiatives for sustainable development. It identifies barriers and bottlenecks in the implementation of different types of PPPs (i.e., for infrastructure, health, water, clean energies, tourismto provide useful lessons and insights for those interested in promoting PPPs in RI in the African context. Barriers and bottlenecks arise at different levels of the innovation system, preventing organizations from implementing solutions (or implementing them inefficiently). A difference between barriers and bottlenecks is that the former refers mostly to the enabling environment, while the latter to factors internal to the organizations engaged in the PPP (Wehn et al., 2018). Therefore, barriers to innovation can emerge from various elements in the system, such as the presence or absence of learning opportunities between actors, contextual factors such as informal and formal institutions, the nature of decision-making processes, and policy frameworks, among other things (Vallejo and Wehn, 2016).

Among African STI actors, the African science granting councils (SGCs) are "crucial intermediaries in the flow of international funding and technical support to research and development (RD) performing institutions in a country" (Mouton et al., 2014, p. 16). However, their way of operating and interacting with other actors in the system, particularly with the private sector, remains full of challenges and can be described as 'patchy' (Chataway et al., 2017).

The research contributes to an understanding of the types of capabilities needed to overcome these barriers and facilitate the adoption of PPPs in RI as an innovation policy instrument in Africa by identifying barriers and bottlenecks to the adoption of PPPs from a systematic revision of the empirical literature. It recognizes the need to understand the role and practice of PPPs in Africa and why strengthening them is critical. It aims to identify the governance gaps between the academic community and policymakers regarding PPPs in the context of Africa. The analysis is complemented by the perceptions of African SGC representatives (gathered in interviews) on the main challenges preventing them from promoting PPPs as an innovation policy instrument. By adopting this mixed approach, the research compares and benchmarks both the evidence reported in the empirical literature and the perceptions of policymakers to identify not only the overlaps and gaps in the two perspectives but also the relationships between the challenges identified.

The following section presents the methodology adopted in this study. Section 3 describes the patterns of publication of the literature analysed. Section 4 presents the results of the analysis. Section 5 discusses the main findings. Section 6 presents the conclusions of the chapter.

Methodology

The analysis was undertaken in two steps. The first consisted of a systematic review of the literature addressing challenges or barriers to the implementation of PPPs, predominately from the perspective of infrastructure and public sector projects in housing, education, water, and health. The second step consisted of interviews conducted with directors and representatives of 12 African SGCs.

A systematic review of the literature

The first part of the analysis is based on a systematic review of the literature, including only academic articles addressing barriers or challenges to the implementation of PPPs. A systematic review allows for a replicable, scientific, and transparent process, as it uses a systematic and explicit method to identify, select, and critically appraise relevant research.

Database, search terms and, article selection process

The search was limited to peer-reviewed journal articles written in English from January 2000 to August 2019 to control the quality of the results. It was limited to the last 20 years to narrow the focus to current – more recent – issues. The analysis is based on articles published in peer-reviewed journals, as this type of academic output is considered validated knowledge (Podsakoff et al., 2005), as it has undergone assurance for academic quality and rigour by at least two knowledgeable reviewers (Lockett et al., 2006). Other authors adopting this rationale include Osei-Kyei and Chan (2015), Roehrich, et al. (2014) and Torchia, et al. (2015).[1]

A comprehensive search was carried out using the same search terms in Google Scholar, Web of Science Core Collection, and ScienceDirect. This search was narrowed by searching for a combination of keywords in the 'title/abstract/keyword' field of the search engines, combining either public private partnerships, 'Public-Private Partnership', or PPPs WITH challenges, barriers, or bottlenecks, which produced a large number of results. Figure 8.1 presents the combinations of keywords used in the search. These results were further restricted by applying the filter of keywords to only the title of the article. The last search resulted in 148 academic references in Google Scholar, 37 in Web of Science, and 8 in ScienceDirect, totalling 193 academic references.

Figure 8.1: Boolean Operators Used in the Search

Google Scholar	Web of Science	ScienceDirect
All in title: (public private partnerships OR "Public-Private Partnership" OR PPP) (barriers OR challenges OR bottlenecks)	TI = (public private partnership* OR PPP* OR "Public-Private Partnership") AND (barrier* OR bottleneck* OR challenge*)	In title: (public private partnerships OR "Public-Private Partnership" OR PPP) AND (barriers OR challenges OR bottlenecks)
Results: 148	Results: 36	Results: 8

Source: Authors

A further revision of the academic references resulting from the search was conducted. This was particularly relevant in the case of those references identified by Google Scholar, as this search engine does not allow for the selection of journal articles only. In this step, 92 articles were eliminated, as they were not journal articles, but working papers, discussion papers, theses, policy briefs, books, or book chapters. Additionally, four references were removed from the sample, as they were outside the scope of the current research.

After the elimination of these academic references, 97 research articles were left in the sample. EndNote X8 software was used to manage the selected articles electronically. In the following step, duplicated (repeated) articles were identified across the three databases, and 12 articles were eliminated for this reason, leaving 85 articles. A final step in the selection of the journal articles was to retrieve the articles – when checking for accessibility, 19 of the journal articles were not accessible to the researchers. One more article was dismissed because it was written in French, although the abstract was presented in English, leaving the sample at 65.

Reading and classification of journal articles

The 65 available articles were skimmed (i.e., the abstract, conclusions, and selected parts of the articles were read). To be retained, an article needed to satisfy two criteria. First, it should be a case study or a revision of empirical literature. Under this criterion, four articles were excluded, as they were opinion or editorial articles. Second, they needed to be published in a peer-reviewed journal with at least two reviewers involved in the process. Peer-reviewed articles have gone through a standard practice of research validation and quality improvement before publication. The homepages of each of the journals in which the articles were published were revised to identify the 'peer-review policy' of the journal. The following dummy variables were given to each category: (i) journals with a peer-review process (as a minimum requirement) were coded with a dummy value of 1, and (ii) journals without a peer-review process (as a minimum requirement) were coded with a dummy value of 0. Under these criteria, seven articles were excluded, as the peer-review policy did not indicate mandatory reviewing from anyone other than the journal editor, bringing the total number of articles excluded to 11. Figure 8.2 illustrates the process from database selection up to the final selection of articles to analyse.

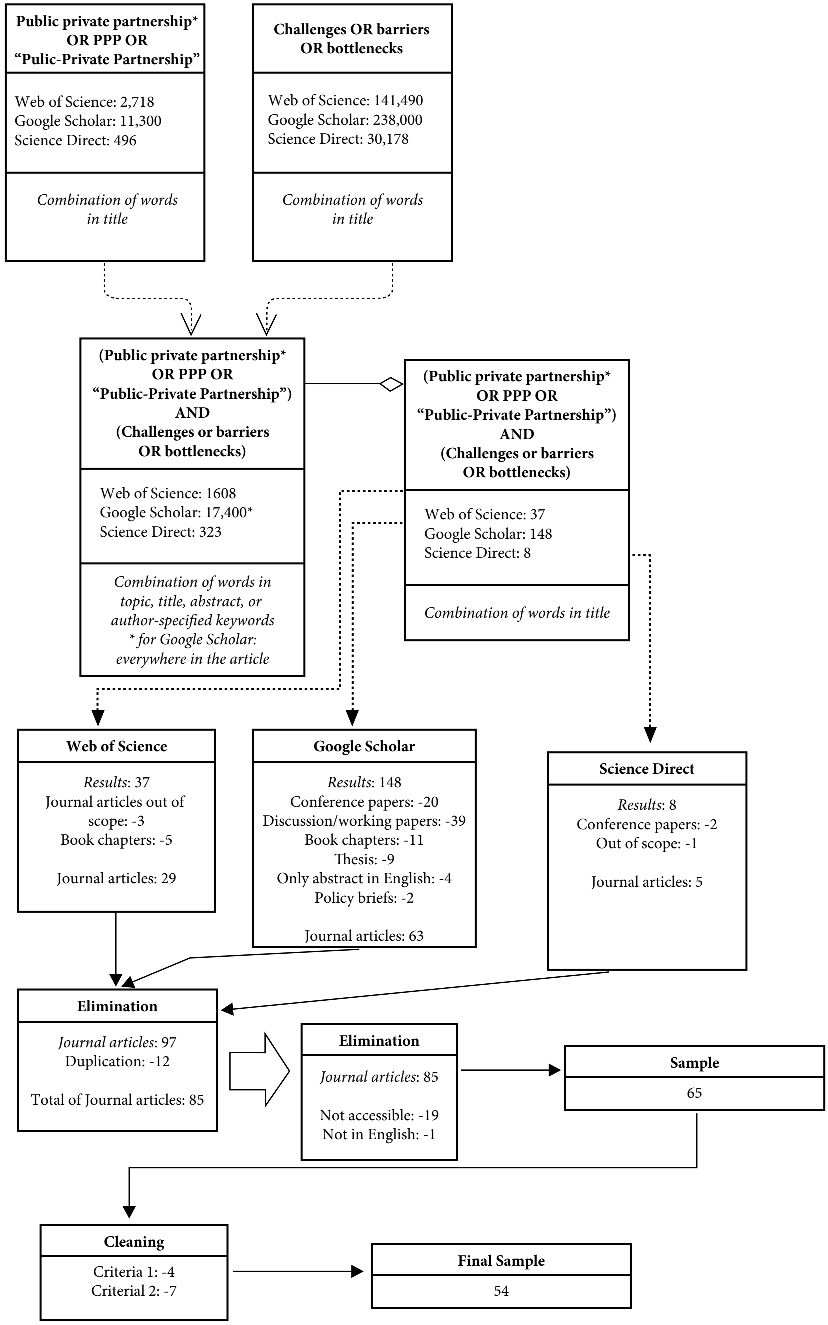
The remaining 54 research articles were categorized by year of publication, type of article (i.e., case study, questionnaire survey/interviews/mix-method, or literature review), sector of analysis, and region of analysis using EndNote X8 software. This initial classification allowed us to gain a perspective on the distribution of the articles.

In the first round, the articles were read in their totality, and PDF-Xchange editor was used to colour-mark the: (i) paper objective and research question; (ii) sector of analysis; (iii) country or region of analysis; (iv) method of analysis; (v) barriers or challenges to PPPs identified by the article; (vi) key themes identified; (vii) cross-references; and (viii) relevant quotes. An adaptation of the Conceptual Synthesis Excel Dump (CSED) research tool developed by Pacheco Vega (2016) was used for this compilation, as well as research memorandum notes for each journal article. During the second round, the articles were uploaded and read once again in their totality using Atlas Ti (Version 8). The articles were coded while reading using the same logic as the CSED but focusing in more detail on the barriers or challenges mentioned in the article.

Interviews

Semi-structured interviews were prepared in English and administrated to 12 representatives of research councils and SGCs coordinators in Botswana, Burkina-Faso, Cote d'Ivoire, Cameroon, Ethiopia, Ghana,

Figure 8.2: Systematic Review Flow Diagram



Source: Authors

Malawi, Senegal, Tanzania, Uganda, Zambia, and Zimbabwe. The interviews were conducted at the Annual High-Level Meeting of Science Granting Councils in Livingstone, Zambia, on November 22–23, 2017. All the interviews were voice recorded after obtaining the informed consent of the SGC representative. Each interview lasted about 25 minutes. Each representative was interviewed separately in a private location, away from the conference group.

Two open-ended questions were asked of the interviewees, focusing on the barriers or bottlenecks to the implementation of PPPs in each of the interviewees' countries and on the type of private sector actors targeted by the SGCs. The audios of the recorded interviews were coded using Atlas Ti (Version 8). The results of the interviews are presented, taking care to protect the anonymity of the interviewees.

Code analysis

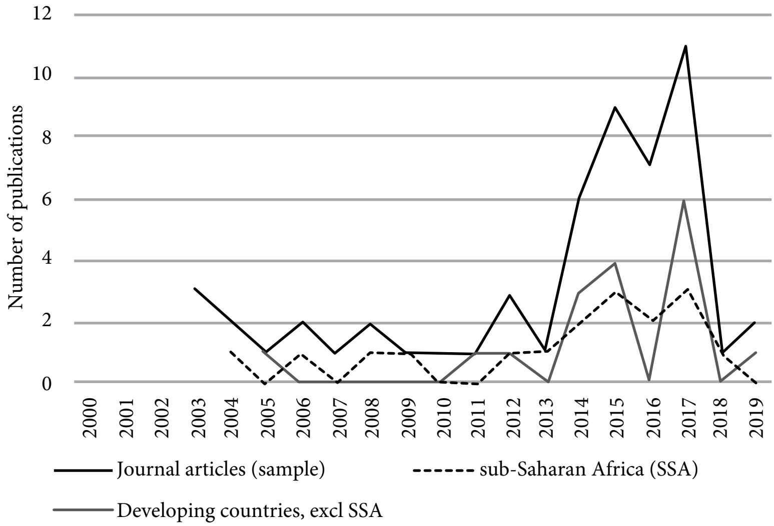
The documents (printed and audios) were uploaded to Atlas Ti and coded. The codes were grouped into families according to the following attributes: economic and financial constraints, stakeholder constraints and limitations; environmental and institutional barriers; and technological barriers. The literature and interviews were coded using deductive, inductive, and auto-coding; additionally, word cruncher was used to obtain the frequency of the keywords in the text. Document groups were created to distinguish those papers presenting cases in Africa, from those on cases in developing countries in other places (excluding Africa), and those based on cases in developed countries.

Systematic literature review: patterns of publication

Evolution of publication over time

In line with the increase in publications on PPPs over the last two decades, as reported by Cui et al. (2018), Osei-Kyei and Chan (2015), and Roehrich et al. (2014), the number of journal articles on challenges or barriers to PPPs published between 2000 and 2019 has also increased, as presented in Figure 8.3. As identified by Osei-Kyei and Chan (2015), our findings showed a major peak in publications on PPPs after 2013. This indicates a gradual rise in interest by scholars in identifying the challenges and barriers to the adoption of PPPs, particularly in developing countries. About 63 per cent of the articles analysed focus on developing countries, with about 50 per cent of them focusing on Africa.

Figure 8.3: Number of Publications on Challenges or Barriers to PPPs (2000–2019)

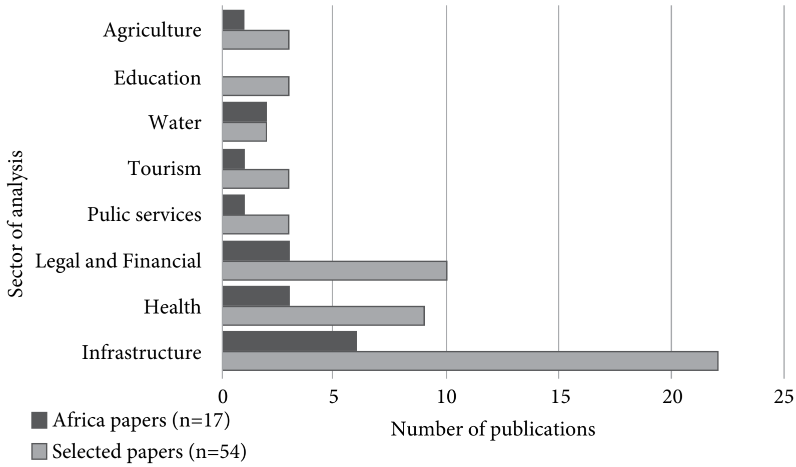


Source: Authors

Sectors of analysis

Most of the selected papers (i.e., 69 per cent) focus mainly on two categories: infrastructure and public services, as illustrated in Figure 8.4. Under this classification, *infrastructure* refers to those articles dealing with issues related to infrastructure, construction, transport and transportation, housing, real estate, and building (about 41 per cent of the sample). Although *water* (4 per cent of the sample), *education* (4 per cent of the sample), and *health* (17 per cent of the sample) are public services, they are presented as separate sectors to be more illustrative for the reader. *Public services* refer to energy, waste management, security, and other services (excluding water, education, and health) and account for about 4 per cent of the sample. Legal and contractual aspects, accounting and fiscal issues, and governance represent about 19 per cent of the sample and are grouped under *legal and financial*. Other categories are *agriculture* and *tourism*.

Figure 8.4: Number of Journal Articles Classified by Sector of Analysis



Source: Authors

Emerging barriers and bottlenecks for PPPs in Africa identified in the analysis

Inadequate access to financial resources

Chalons-Browne (2005) highlights a lack of access to sustainable funding as a major barrier to PPPs in low- and middle-income countries. PPP consortiums rely on loans (equity) to operate; therefore, local banks and financial institutions are needed to provide private companies with financial loans. Studies on PPPs for infrastructure in Malawi (Sukasuka and Manase, 2016), the road sector in Zambia (Chilala and Mulenga, 2017), the water sector in Botswana (Molokwane and Tshombe, 2017), and the housing sector in Nigeria (Muhammad and Johar, 2018) point to the difficulties experienced by local firms when accessing local loans (or equity), and the very high-interest rates of the loans available, as important barriers to local private participation in PPPs.

Competition between programmes for funding is identified by Otairu et al. (2012), in their survey of public sector officials, as a barrier to the implementation of PPPs in infrastructure in Nigeria. The authors mention the political interest of local governments in awarding road or civil engineering works as a way to siphon funds from the public treasury with little accountability. This deprives private companies involved in PPP projects from guarantees of repayment within an agreed period, as low-cost (or free) alternatives are provided to the public by local governments. Kostyak et al. (2017) and Njau, et al. (2009) also identify competition for funding with other programmes as a source of inefficiency and waste of resources.

A challenge identified for PPPs in RI in both the interviews and journal articles is insufficiency in the allocation of public funds. Three of the interviews revealed that when involving the local private sector, it is the government that, through pre-designed calls, specifies the value of the grant and the goals to be targeted (Interviewee 6, 2017; Interviewee 7, 2017; Interviewee 8, 2017; Interviewee 11, 2017). Some of the respondents indicated that the allocation of funds is always insufficient and does not necessarily correspond with what is reported on paper (Interviewee 8, 2017). The Organization for Economic Co-operation and Development (OECD, 2014) indicates that public financing rarely meets crucial expenditure requirements. This is also indicated by Molokwane and Tshombe (2017) in their study on PPPs for water utilities in Botswana, where the insufficiency of public funds has resulted in the deterioration of existing infrastructure and lack of improvements, resulting in a call for the participation of the private sector through PPPs to fill the gap. In addition, the interviews revealed that public funds are frequently allocated to projects seeking commercialization and up scaling, rather than to investments in science, technology, and innovation, which receives a low contribution of public funds (Interviewee 1, 2017; Interviewee 2, 2017; Interviewee 3, 2017; Interviewee 6, 2017; Interviewee 7, 2017; Interviewee 8, 2017; Interviewee 11, 2017).

In the absence of accessible financial loans, PPPs rely on foreign financial institutions (or donors) to finance projects (Otairu et al., 2012). Our interviews with SGCs representatives identified the reliance on international donors to finance projects as a challenge to the sustainability of PPPs. The increasing participation of foreign-financed PPPs, with the consequent demand for short-term results, has, in some cases, reduced national ownership and interaction with programmes (Kostyak et al., 2017; Interviewee 8, 2017). There are concerns that internationally funded PPPs may divert national priorities and increase the inequality of vulnerable groups, as priorities are set according to donors' interests (Kostyak et al., 2017; Interviewee 8, 2017).[2]

Inability or inexperience in managing PPPs

Lack of relevant experience of the public sector in the management of PPPs is identified as a bottleneck that inhibits and complicates the implementation of PPPs, demotivating private sector participation and, in some cases, contributing to the failure of the partnership (Babatunde et al., 2014; Babatunde et al., 2015; Chilala and Mulenga, 2017; Hall, 2006; Interviewee 7, 2017). This includes public sector inability or inexperience in managing consultants (Babatunde et al., 2015; Chilala and Mulenga, 2017; Otairu et al., 2012), and limited capacity to make choices that improve the outcomes of the PPP (Kamugumya and Olivier, 2016) and steer it towards the agreed objectives (Muhammad and Johar, 2018). The appropriate selection of private partners is critical to the success of a PPP (Muhammad and Johar, 2018). Therefore, the lack of technical expertise in the public sector (Chilala and Mulenga, 2017; Desta et al., 2014; Hall, 2006; Muhammad and Johar, 2018; Otairu et al., 2012), as well as lack of time and resources (Chilala and Mulenga, 2017), often mean that the public sector is unable to engage with technically competent and financially capable firms (Muhammad and Johar, 2018). Inadequate assessment tools to determine the feasibility and affordability of partners, as well as lack of clarity about the assessment process, has been identified as a bottleneck in the implementation of PPPs, as it discourages the participation of private partners (Molokwane and Tshombe, 2017; Nkrumah, 2004; Sukasuka and Manase, 2016). Failing to monitor the performance and proper implementation of the PPP is also seen as a barrier, as it discourages the public sector from engaging in this type of activity (Fombad, 2013).

Shortage of skilled workforce and inefficient local industry

Inefficient local industry and a shortage of capable local contractors has resulted in a large number of PPPs being handled by foreign firms that have the financial strength and competence required for these projects (Otairu et al., 2012). Babatunde et al. (2014) and Otairu et al. (2012) identify the inexperience of local firms in Africa, low level of skills among the local workforce, and scarcity of materials as significant bottlenecks in the implementation of PPPs in Nigeria. This is supported by Molokwane and Tshombe (2017) in their study of water management PPPs in Botswana, in which the authors identify the shortage of expertise among the technical staff as a factor underpinning PPP performance. In the case of African PPPs in RI between international partners and local public research partners, the outcomes are often not useful, as no local private sector actor is usually able to join the partnership (Hall, 2006).

Poor interaction between stakeholders and information asymmetry

Inadequate inclusion or consultation of stakeholders is identified in the interviews and literature as a barrier to the success of PPPs in Africa (Babatunde et al., 2015; Interviewee 2, 2017; Interviewee 3, 2017; Interviewee 6, 2017; Interviewee 8, 2017; Interviewee 11, 2017). In their study on PPPs in the provision of health services in Tanzania, Kamugumya and Olivier (2016) state that the private sector and non-public actors are not always adequately represented in strategic and planning decisions and, on many occasions, are severely marginalized. This is supported by the findings of Desta et al. (2014), Kamugumya and Olivier (2016), and Molokwane and Tshombe (2017). This exclusion not only means that all potential service providers are excluded, but also that many of the people whose names appear in the PPP contract are not part of the planning and strategic decision sessions (Kamugumya and Olivier, 2016). Civil society is weakly, or not at all, represented in discussions with public actors, even though, in some cases, their centrality is key to the PPP's institutionalization and arrangements (Lo, 2008). Fombad (2013) and Nkrumah (2004) report the exclusion of citizens and civil society organizations from the negotiations between public and private partners, which, on many occasions, are conducted in secrecy. In the case of partnerships with influential international donors or multi-national corporations, local governments in many developing countries have expressed their concern about not being fully involved in decision-making for projects (Kostyak et al., 2017).

Lack of transparency and information asymmetry between stakeholders, which includes unclear information on the project, is a recurring theme identified in the performance accountability of PPPs (Chilala and Mulenga, 2017; Fombad, 2013; Lo, 2008). Babatunde et al. (2015) and Kamugumya and Olivier (2016) mention the lack of understanding and inadequate information available prior to the project as relevant barriers to the success of PPPs. The poor quality of information and data prevents stakeholders from adequately assessing risk. Substantial gaps in the information shared between the public and private sectors increase mistrust and decrease potential value creation outcomes (Kamugumya and Olivier, 2016; Molokwane and Tshombe, 2017). Hall (2006) identifies weak communication between the different ministries, as well as the fragmentation of available scientific resources among them, as examples of information asymmetry in PPPs in RI.

Technological path dependency and entry costs of new technologies

A relevant barrier to PPPs identified in the interviews is the cost of new technologies. Interviewees 3, 6, and 8 (2017) all pointed out that importing technology is cheaper and more comfortable than investing in local STI (Interviewee 3, 2017), which discourages local STI efforts. Other barriers identified in the interviews are lack of communication and cooperation between the private sector and local universities (Interviewee 2, 2017; Interviewee 3, 2017), lack of interest by the private sector in academic output (Interviewee 3, 2017; Interviewee 6, 2017), and poor leadership by SGCs and related agencies in the national policy-making arena (Interviewee 1, 2017; Interviewee 6, 2017; Interviewee 8, 2017; Interviewee 11, 2017).

Irregular procurement process

In most African countries, PPPs are the result of tenders based on predetermined goals and designed by the government (Interviewee 6, 2017; Interviewee 7, 2017). However, most of the interviewees do not consider this to be the most efficient way to construct partnerships. A partnership involves elements of collaboration contracted through a written agreement. The kind of arrangement adopted depends on the type of project, the needs addressed, and the sector of implementation (European Commission, 2003). An important bottleneck to the implementation and performance of PPPs in Africa is ineffective contractual arrangements.

Kamugumya and Olivier (2016) report that, in the case of health PPPs in Tanzania, most PPPs are informal, except those funded by international donors, for which, usually, only a memorandum of understanding (MoU) is in place. The lack of written formal legal agreements allows for misunderstandings between parties and limits progress towards the goals of the PPP (Molokwane and Tshombe, 2017). Muhammad and Johar (2018) indicate that contract complexity is a significant bottleneck for PPPs. A complex contract requires a higher level of management and steering capacity on the part of the public sector, which is often non-existent (Muhammad and Johar, 2018). Otairu et al. (2012) and Fombad (2013) identify inadequate project preparation and poor specification of the desired output as bottlenecks in the operational phase of PPPs in South Africa and Nigeria. Therefore, a properly formulated contract is needed to specify the distribution of risks, prevent the private sector from changing prices, and prevent the government from imposing changing political exigencies on the PPP (Mustafa, 2015; Otairu et al., 2012). Miranda Sarmento and Renneboog (2017) present evidence of opportunistic bidding for PPP contracts, which, once acquired – and the competition eliminated – lead to renegotiation to increase revenue. Their analysis shows that incomplete legal arrangements (due to contract complexity, size, and length) favour renegotiation at the operational stage. Election years (the year leading up to an election) are positively correlated with the renegotiation of large PPPs, either by governments or the private sector (Miranda Sarmento and Renneboog, 2017).

Another identified barrier is contract secrecy. In most cases, PPP arrangements are kept confidential, preventing public access to partner selection, targets, and goal setting, as well as the formulation of guidelines (Kostyak et al., 2017). Fombad (2013) identifies the non-disclosure of PPP contracts as a source of accountability issues, particularly regarding public perceptions of government transparency in public procurement in South Africa. Muhammad and Johar (2018) report how in the case of housing delivery in Nigeria, the lack of transparency in the procurement process was linked to corruption and political influence, due to a lack of clarity in the guidelines.

Absent or weak competition and lack of incentives

The absence of competition is identified in the literature as an essential barrier to the performance of PPPs (Babatunde et al., 2015; Sai et al., 2015). The scarcity of bidders for PPP projects is a barrier, particularly in environments where the local private sector is mostly formed by small and medium-sized companies unable to compete with large or international companies (Chilala and Mulenga, 2017; Fombad, 2013). Authors like Fombad (2013) mention that in the absence of competition, successful bidders for PPPs become monopolistic suppliers to the public sector. Firms tendering on a PPP should be not only able to understand the procurement process and have knowledge of the sector but also be able to cover the costs of preparing their proposal and have access to finance before the conclusion of the bidding process (Chilala and Mulenga, 2017; Fombad, 2013; Muhammad and Johar, 2018; Otairu et al., 2012).

Lack of incentives for PPPs was identified as a barrier to their implementation in both the interviews and literature (Interviewee 2, 2017; Sai et al., 2015). Taxation is a severe barrier to the implementation of PPPs, as identified by stakeholders in the various African countries studied (Interviewee 2, 2017; Kostyak et al., 2017; Molokwane and Tshombe, 2017; Njau et al., 2009; Otairu et al., 2012; Sai et al., 2015). Customs duties, as well as complicated taxation systems, have been reported by some authors as barriers to PPPs, mainly when international partners are involved (Kostyak et al., 2017; Njau et al., 2009). Njau et al. (2009) identified import difficulties, taxation problems, and the lobbying of influential individuals, as important barriers for PPPs and a waste of resources.

Conflicting values and norms

A significant barrier to the success of PPPs is the conflict of interest among stakeholders (Babatunde et al., 2015; Interviewee 2, 2017; Interviewee 8, 2017; Kamugumya and Olivier, 2016). Self-interest driven behaviour by local government officials is not uncommon in PPPs in Africa and other developing countries (Kamugumya and Olivier, 2016). In their case study on health service provision in Tanzania, Kamugumya and Olivier (2016) report how the District Council Team influences decisions based on politically motivated interests, rather than value distribution, thwarting private actors' engagement in the partnership. Sukasuka and Manase (2016) relate how the involvement of a cabinet minister in the decision committee of the private company involved in infrastructure PPP in Malawi led to conflict, promoted corruption, and prevented the participation of potential investors. Similar experiences were reported in the interviews with SGCs representatives, which described how the personal interests of influential policymakers determined the direction and coverage of the PPPs in RI (Interviewee 8, 2017).

Corruption is frequently identified in the literature as a barrier to the design, implementation, execution, and performance of PPPs in Africa (Kostyak et al., 2017; Mustafa, 2015; Otairu et al., 2012; Sukasuka and Manase, 2016). Examples of corruption range from bribery, which is endemic in Africa, including under-the-table payments (involving not only local actors but also international firms), to issues such as political influence and interference, such as the personal interests of policymakers in specific private counterparts (Muhammad and Johar, 2018; Sukasuka and Manase, 2016). Reliance on foreign donors is sometimes associated with corruption and moral hazard. Hilmarsson (2017) in his analysis of PPPs for clean energy (i.e., geothermal energy) presents a case where a government ended up paying the cost of disputes with foreign private partners, as these private partners had a close relationship with the World Bank and leveraged this relationship in the dispute.

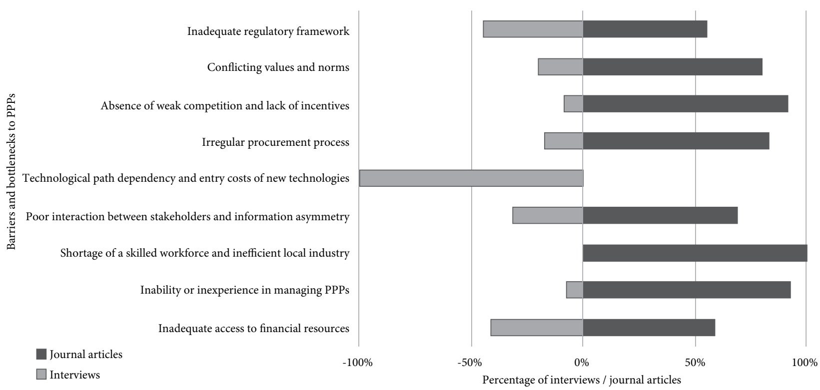
Inadequate regulatory framework

The use of public funds to finance large infrastructure projects as a way to drain off such funds with low levels of accountability is also a barrier to PPPs (Otairu et al., 2012). The phenomenon of 'tenderpreneurship'[3] is also commonly referred to as a form of corruption facing PPPs in the region (Fombad, 2013; Otairu et al., 2012). A weak or poor regulatory framework has been identified as an important barrier to PPP implementation by Hall (2006), Njau et al. (2009), Nkrumah (2004), Otairu et al. (2012), and Interviewees 2 and 3 (2017). Another barrier identified in both the interviews and articles is bureaucracy (Hall, 2006; Interviewee 2, 2017; Interviewee 6, 2017; Interviewee 11, 2017; Njau et al., 2009; Nkrumah, 2004; Otairu et al., 2012).

Discussion

This study takes a dual approach consisting of desk and empirical research. The desk research identified barriers and bottlenecks in the implementation of several types of PPPs in Africa. The empirical research, consisting of interviews with representatives of African SCGs, identified specific local barriers, which in the perspective of the SGCs should be addressed to create an enabling environment for the successful adoption of PPPs in RI. The combination of both approaches provides insights and lessons from the implementation of PPPs in several sectors that should be considered when designing and adopting PPPs in RI in the African context. Figure 8.5 presents the recurrent barriers and bottlenecks mentioned in the literature and identified in the interviews.

Figure 8.5: Challenges and Barriers to PPPs



Source: Authors

The analysis included at least three barriers and bottlenecks to the adoption and adaptation of PPPs (including PPPs in RI) affecting the involved organization's ability to engage in innovation and learning activities. These barriers are: (i) *inadequate access to financial resources* (60 per cent of the papers and about 90 per cent of the interviews); (ii) *technological path dependency and entry costs of new technologies* (75 per cent of the interviews); and (iii) *irregular procurement process* (59 per cent of papers and 25 per cent of interviews). These are barriers and bottlenecks that require a reconfiguration of the existing decision-making arrangements and governance structures and the capacity strengthening of organizational resources, as well as leadership and management.

An innovation system is an institutional concept. In terms of formal institutions, the analysis shows that *an inadequate regulatory framework* is also a barrier to innovation through PPPs (29 per cent of papers and 50 per cent of the interviews). *Lack of trust between stakeholders* (71 per cent of papers and 25 per cent of interviews) is another barrier to PPPs identified in both the literature and the interviews. The role that informal institutions play in innovation is recognized in the capacity-building literature, mainly through commonly shared social and cultural values. The analysis identifies *conflicting values and norms* (47 per cent of papers and 25 per cent of interviews) as a barrier to PPPs.

Interactive learning among actors in the system enables change and innovation. About 65 per cent of the papers and 63 per cent of the interviews identified *poor interaction between stakeholders and information asymmetry* as an important barrier to PPPs (including PPPs in RI). In the interviews, SGCs' representatives highlighted the need to include partners such as ministries of agriculture and civil society.

Capacity development is needed to address the public sector's *inability or inexperience in managing PPPs* (76 per cent of papers and 13 per cent of interviews), the *shortage of a skilled workforce* and an *inefficient local industry* (24 per cent of papers), as well as the *lack of incentives and weak competition* (47 per cent of papers and 25 per cent of interviews).

Conclusions

The identification of barriers and bottlenecks in the implementation of PPPs provides an overview of what needs to be addressed by SGCs in the adoption of PPPs in RI. In general terms, the barriers and bottlenecks identified by the papers addressing multisectoral cases of PPPs are in line with the perception of SGCs' representatives of the barriers to PPPs in

RI. The nature of the barriers reveals weaknesses in several components of the African innovation system. This focuses attention on the need to integrate private, political, technological, and social perspectives in the adoption of PPPs in RI as a development tool.

Limitations of the study

As in any other systematic review of the literature, some important articles that address relevant aspects were missed. Owing to the combination of keywords used, all those addressing barriers to PPPs, but not using the words 'challenges, barriers, or bottlenecks' in the title are not included in this review. However, the results presented here are a robust first step towards the recognition of those challenges and barriers to the design and implementation of PPPs in Africa. These results open the door to future research on the causes of these challenges and the extent to which they could be addressed. There is no doubt that there is a need for more academic empirical evidence in Africa, through lessons learned and best practices, as input for policymakers.

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Disclaimer: The results and conclusions drawn from this study do not necessarily reflect the views of the organizations to which the authors are affiliated. The usual caveats apply.

Notes

[1] The authors acknowledge that there is a significant amount of material on PPPs in RI in Africa that has not been published in academic journals.

[2] Foreign funding in health has been linked to increased opportunities for corruption and the leakage of funds to other sectors (Kostyak et al., 2017).

[3] 'Tenderpreneurship' is where a person uses his/her political contacts to secure public procurement contracts (Piper and Charman, 2019).

References

Adekenle, A., Osazuwa, P., and Raghavan, V., 2016. Socio-economic determinants of agricultural mechanisation in Africa: a research note based on cassava cultivation mechanisation.' *Technology Forecasting & Social Change,* 112, pp.313–319. http://dx.doi.org/10.1016/j.techfore.2016.09.003

Ahmed, A. ed., 2017. *Managing knowledge and innovation for business sustainability in Africa.* Brighton: Palgrave MacMillan.

Akampurira, E., Root, D., and Shakantu, W., 2009. Stakeholder perceptions in the factors constraining the development and implementation of public-private partnerships in the Ugandan electricity Sector. *Journal of Energy in Southern Africa,* 20(2), pp.2–9. https://doi.org/10.17159/2413-3051/2010/v20i2a3300

Babatunde, S.O., Perera, S., Udeaja, C., and Zhou, L., 2014. Challenges of implementing infrastructure megaprojects through public-private partnerships in Nigeria: a case study of road infrastructure.' *International Journal of Architecture, Engineering and Construction,* 3(2), pp. 142–154. https://doi.org//10.7492/IJAEC.2014.012

Babatunde, S.O., Perera, S., Zhou, L., and Udeaja, C., 2015. Barriers to public-private partnership projects in developing countries: a case of Nigeria. *Engineering Construction and Architectural Management,* 22(6), pp.669–691. https://doi.org/10.1108/ECAM-12-2014-0159

Becker, W. and Dietz, J., 2004. R&D cooperation and innovation activities of firms – evidence for the German manufacturing industry. *Research Policy,* 33(2), pp.209–223. https://doi.org/10.1016/j.respol.2003.07.003

Buckland, R., 2009. Private and public sector models for strategies in universities. *British Journal of Management,* 20(4), pp.524–536. 10.1111/j.1467-8551. 2008.00593.x

Chalons-Browne, R., 2005. *Development-driven public-private partnerships in health, emerging priorities from roundtable discussions of work* [Online] Available at: https://www.weforum.org/agenda/2015/04/can-public-private-partnerships-strengthen-global-healthcare/ (Accessed 10 December 2019).

Chataway, J., Ochieng, C., Byrne, R., Daniels, C., Dobson, C., Hanlin, R., and Hopkins, M., 2017. Case studies of the political economy of science granting councils in sub-Saharan Africa. [Report] Nairobi: Science Policy Research Unit (SPRU) and African Centre for Technology Studies (ACTS).

Chilala, R.N. and Mulenga, M., 2017. Challenges in implementing public-private partnerships (Ppps) projects in the road sector in Zambia. *Global Journal of Researches in Engineering,* 17(3), pp.55–60.

Cui, C., Liu, Y., Hope, A., and Wang, J., 2018. Review of studies on the public-private partnerships (PPP) for infrastructure projects. *International Journal of Project Management,* 36(5), pp.773–794. https://doi.org/10.1016/j.ijproman.2018.03.004

Desta, T.S., Gebreselassie, A.G., and Gebreegziabher, A.H., 2014. Assessing the status, challenges, and opportunities of public-private partnership (PPP) in solid waste management (SWM) in Ethiopia: a case study on Mekelle City, Tigray. *International Journal of Research in Commerce & Management,* 5(6), pp.29–36.

Dorothal, M., 2019., *Eastern Africa regional solar report. Ethiopia-Kenya-Uganda-Tanzania.* [Report] Dakar: SolarPlaza.

Dykes, B.J. and Jones, C.D., 2016. Public-private partnerships in Africa: challenges and opportunities for future management research. *Africa Journal of Management,* 2(3), pp.381–393. https://doi.org/10.1080/23322373.2016.1206806

European Commission., 2003. *Guidelines for successful public-private partnerships*. [Report] Brussels, BE: European Commission.

European Commission., 2015. *EU–Africa cooperation in science, technology, and innovation*. [Report] Luxemburg: European Union.

Fombad, M.C., 2013. Accountability challenges in public-private partnerships from a South African Perspective. *African Journal of Business Ethics,* 7(1), pp.11–25. https://doi.org//10.4103/1817-7417.119954

Grimsey, D. and Lewis, M. 2007. Public Private Partnerships and Public Procurement. *Agenda: A Journal of Policy Analysis and Reform,* 14(2), pp.171–188. https://doi.org/10.22459/AG.14.02.2007.06

Hall, A., 2006. Public-private sector partnerships in an agricultural system of innovation: concepts and challenges. *International Journal of Technology Management & Sustainable Development,* 5(1), pp.3–20. https://doi.org/10.1386/ijtm.5.1.3/1

Hilmarsson, H.P., 2017. Capital intensive clean energy projects: some costs, benefits and challenges of using public-private-partnerships. *Regional Formation and Development Studies,* 22(2), pp.58–66. https://doi.org/10.15181/rfds.v22i2.1477

International Monetary Fund., 2004. *Public-private partnerships*. Washington, DC: IMF.

Kajimo-Shakantu, K., Kavela, L., and Shakantu, W., 2014. Applicability and constraints of delivering water infrastructure via public-private-partnership. *Social and Behavioral Sciences,* 119, pp.867–876.

Kamugumya, D. and Olivier, J., 2016. Health system's barriers hindering implementation of public-private partnership at the district level: a case study of partnership for improved reproductive and child health services provision in Tanzania. *BMC Health Services Research,* 16(596), pp.1–13. https://doi.org/10.1186/s12913-016-1831-6

Klijn, E.H. and Teisman, G.R., 2003. Institutional and strategic barriers to public-private partnership: an analysis of Dutch cases. *Public Money & Management,* 23(3), pp.137–146. https://doi.org/10.1111/1467-9302.00361

Kostyak, L., Shaw, D.M., Elger, B., and Annaheim, B., 2017. A means of improving public health in low- and middle-income countries? Benefits and challenges of international public-private partnerships. *Public Health,* 149, pp.120–129. https://doi.org/10.1016/j.puhe.2017.03.005

Lember, V., Petersen, O.H., and Scherrer, W., 2019. Understanding the relationship between infrastructure public-private partnerships and innovation. *Annals of Public and Cooperative Economics,* 60(2), pp.371–391. https://doi.org/10.1111/apce.12232

Lo, M., 2008. Public-private-partnerships for maternal health in Africa: challenges and Prospects, *Marriage & Family Review,* 44(2–3), pp.214–237. https://doi.org/10.1080/01494920802177444

Lockett, A., Moon, J. and Visser, W., 2006. Corporate social responsibility in management research: focus, nature, salience and sources of influence. *Journal of Management Studies,* 43(1), pp.115–136. https://doi.org/10.1111/j.1467-6486.2006.00585.x

Miranda Sarmento, J. and Renneboog, L., 2017. *Renegotiating public-private partnerships*. Tilburg University, Center for Economic Research, 2017–014, Tilburg.

Molokwane, T. and Tshombe, L.M., 2017. Key challenges to public-private partnerships in Botswana. The case of Water Utilities Corporation – Lobatse Management Centre. *African Journal of Public Affairs,* 9(9), pp.157–182.

Mouton, J., Gaillard, J., and van Lill, M., 2014. *Science granting councils in sub-Saharan Africa.* [Report] South Africa: Stellenbosch University, Centre for Research on Evaluation, Science, and Technology (CREST), Institute of Research for Development (IRD).

Muhammad, Z. and Johar, F., 2018. Coping with challenges of public-private partnership (PPP) for housing delivery in Nigeria. *International Journal of Engineering & Technology,* 7(2), pp.1097–1101.

Mustafa, A., 2015. Public-private partnerships in sub-Saharan Africa: challenges and opportunities. *The Journal of Structured Finance,* 21(2), pp.55–59. https://doi.org/10.3905/jsf.2015.21.2.055

Nirupama, K., 2009. *A survey of payment mechanisms for public-private partnership transportation projects: comparisons of the US, India and Mexico*. The Leonard N. Stern School of Business. Glucksman Institute for Research in Securities Markets, New York.

Njau, R.J.A., de Savigny, D., Gilson, L., Mwageni, E., and Mosha, FW, 2009. Implementation of an insecticide-treated net subsidy scheme under a public-private partnership for malaria control in Tanzania – challenges in implementation. *Malaria Journal,* 8(201), pp.1–27. https://doi.org/10.1186/1475-2875-8-201

Nkrumah, M.K., 2004. Challenges to urban water management in Ghana: making public-private partnerships work. *Ghana Journal of Development Studies,* 1(2), pp.85–100. http://dx.doi.org/10.4314/gjds.v1i2.35008

Organisation for Economic Co-operation and Development, 2004. *Public-private partnerships for research and innovation: an evaluation of the Dutch experience*. [Report] Paris: Organisation for Economic Co-operation and Development.

Organisation for Economic Co-operation and Development, 2014. *Pooling of institutional investors capital – selected case studies in unlisted equity infrastructure*. [Report] Paris: Organisation for Economic Co-operation and Development.

Osei-Kyei, R. and Chan, A.P.C., 2015. Review of studies on the critical success factors for public-private partnership (PPP) projects from 1990 to 2013. *International Journal of Project Management,* 33(6), pp.1335–1346. https://doi.org/10.1016/j.ijproman.2015.02.008

Otairu, A., Umar, A.A., Zawawi, N.A., and Pakir, A.H., 2012. Public sector perception of barriers to the use of public-private partnerships (PPP) in Nigeria – findings from a Questionnaire Survey, *Research Journal of Applied Sciences, Engineering and Technology,* 5(9), pp.2809–2820.

Pacheco Vega, R., 2016. Synthesizing different bodies of work in your literature review: the Conceptual Synthesis Excel Dump (CSED) Technique. [Blog] Available at: http://www.raulpacheco.org/2016/06/synthesizing-different-bodies-of-work-in-your-literature-review-the-conceptual-synthesis-excel-dump-technique/ (Accessed 3 December 2019).

Piper, L. and Charman, A., 2019. Tenderpreneur (also tenderpreneurship and tenderpreneurism). In: Ledeneva, A. (ed.). *Global Informality Project.* [Online]. Available at: http://www.in-formality.com/wiki/index.php?title=Tenderpreneur_(South_Africa) (Accessed 31 August 2020).

Podsakoff, P.M., MacKenzie, S.B., Bachrach, D.G., and Podsakoff, N.P., 2005. The influence of management journals in the 1980s and 1990s. *Strategic Management Journal,* 26(5), pp.473–488. https://doi.org/10.1002/smj.454

Rana, F. and Izuwah, C., 2018. Infrastructure & Africa's development – the PPP imperative. [Blog] *World Bank Blogs*. Available at: https://blogs.worldbank.org/ppps/infrastructure-africa-s-development-ppp-imperative (Accessed 9 September 2019).

Roehrich, J.K., Lewis, M.A., and George, G., 2014. Are public-private partnerships a healthy option? A systematic literature review. *Social Science & Medicine,* 113, pp.110–119. https://doi.org/10.1016/j.socscimed.2014.03.037

Sai, J.P., Muzondo, N., and Marunda, E., 2015. Challenges affecting establishment and sustainability of tourism public-private partnerships in Zimbabwe. *Asian Social Science,* 11(23), pp.35–50. https://doi.org//10.5539/ass.v11n23p35

Sukasuka, G.N. and Manase, D., 2016. Best practice guide to procurement challenges of public-private partnerships in infrastructure development in Malawi. *Journal of Construction Project Management and Innovation,* 6, pp.1503–1518.

Torchia, M.T., Calabro, A., and Morner, M., 2015. Public-private partnerships in the health sector. A systematic review of literature. *Public Management Review,* 17(2), pp.236–261. http://dx.doi.org/10.1080/14719037.2013.792380

Vallejo, B. and Wehn, U., 2016. Capacity development evaluation: the challenge of the results agenda and measuring return on investment in the

Global South. *World Development,* 79, pp.1–13. https://doi.org/10.1016/j.worlddev.2015.10.044

Wehn, U., Mendoza-Sammet, A., and Amorsi, N., 2018. *Deliverable D2.2 Initial demand-driven research & innovation outlook*. [Report] Delft: IHE

9

Building Sustainable Research Management Capacity in Sub-Saharan Africa

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Abstract

The growing importance of research and innovation, and the increased levels of regulation and oversight have led to the development of the research management field. Creation of new knowledge and innovation are the driving forces for countries advancing into knowledge economies. Although the capacity to innovate remains low in most African countries, deliberate efforts by governments to increase investments in human capital, research and infrastructure through science granting councils (SGCs) has the potential to strengthen their innovation capacity. The SGCs have been recognized as critical to science, technology and innovation (STI) systems in Africa; however, they face constraints that impact on their status, influence and functioning. As part of the Science Granting Council Initiative (SGCI), a comprehensive capacity-building programme in research management was established to address some

of these systemic challenges. This chapter presents the elements of the programme as well as the challenges, successes and lessons learnt.

Research management and capacity-building concepts

Research management and its professionalization

Two main drivers have reportedly caused the development of research management: the growth in the importance of research and related activities, and the increased levels of legislation, regulation, oversight and exhortation that are associated with the area (Carter and Langley, 2009; Kirkland, 2009). Several authors have reported on the practice of research management in higher education (Carter and Langley, 2009; Kirkland, 2009). Their reports suggest that research management has developed considerably to become an activity that encompasses elements of institutional strategy, policy, governance, profile, finance, people management, postgraduate research, assessment, systems and so on. What used to be a strand of generalist administration is now a profession with various areas of specialization and with many people of different types involved either fully or to some extent (Carter and Langley, 2009; Kirkland, 2009). Research management is not limited to higher education and has also emerged as a specialized area for other research institutions and in government and funding agencies (Olsson and Meek, 2013). Olsson and Meek (2013) argue that growth – for countries and their institutions – depends on adequate policies (including governance and management); sufficient resources and investment; and highly trained human capital.

Globally, research management is evolving as a profession with on-going efforts to bind research managers together through a common understanding of the environment they operate in and through shared practices and values. Professionalization opportunities are usually available in the form of masters-level qualifications offered by universities, for example the online Master in Research Administration offered by the University of Central Florida[1] and other institutions in the United States; professional certificate programmes, for example those offered by the Association of Research Managers and Administrators, UK[2] and the Australasian Research Management Society[3]; and professional recognition, for example, recognition through the Research Administrators Certification Council in the United States[4].

The professionalization of research management in Africa was recently reported by Dyason, et al. (2017) and Williamson, Dyason and

Jackson (2020) and demonstrated the competencies that were deemed necessary for research managers and the routes that research managers could follow to become professionally recognized.[5] Since then, a Postgraduate Diploma in Research Management and Administration has been developed[6] and the Research Management in Africa Programme (ReMPro Africa) aims to fill critical gaps in research management to ensure a strong research ecosystem to maximize the quality and output of research by focusing on institutional leadership, sustainability, standards and individual capacity strengthening.[7]

Science granting councils and the knowledge economy

Governments globally are placing unprecedented emphasis on research and innovation as a key mechanism for driving the knowledge society and knowledge economy, as research and innovation have long been associated with strong economic activity and social health and well-being (Houghton and Sheehan, 2000; World Bank, 2007; Weber, 2011; OECD, 2010; The Royal Society, 2011).

The African continent is lagging behind the rest of the world concerning STI, with most sub-Saharan countries spending less than 0.5 per cent of their gross domestic expenditure on research and development (GERD) (Asongu and Nwachukwu, 2017). African governments are increasingly recognizing and embracing the development of STI capacity and its role in the knowledge economy (Mouton, Gaillard and van Lill, 2015). According to the African Union Development Agency's African Innovation Outlook III survey of 2019, African leaders are gaining a deeper understanding of the link between STI and poverty reduction and job creation, on the one hand, and sustainable economic growth on the other (African Union Development Agency, 2019). This is reflected by the 10-year Science, Technology and Innovation Strategy for Africa (STISA-2024) and the long-term people-centred AU Agenda 2063, which were approved in 2014, during the 23rd Ordinary Session of the African Union Heads of State and Government Summit (AU, 2014).

SGCs play a critical role – they are normally unbiased and neutral agents of government, while at the same time representing the interests of the scientific community nationally as well as regionally and internationally (Mouton, Gaillard and van Lill, 2015). As a result of the broad range of systemic challenges surrounding SGCs, Mouton, et al. (2015) recommended a comprehensive institutional capacity-building programme to address the constraints of the SGCs so that the goal of becoming competitive knowledge economies could be achieved. The recommendation resulted in the Science Granting Councils Initiative (SGCI),[8] a multi-funder partnership to build capacity in 15 African SGCs that focuses on four main themes including: the strengthening of research management practices; designing and monitoring research programmes based on the use of robust STI indicators; strengthening the ability to support knowledge exchange with the private sector; and strengthening partnerships among SGCs. This chapter focuses on the strengthening of research management practices of the participating SGCs.

Conceptualizing capacity-building in research management

According to Linnell (2003), capacity is an organization's ability to achieve its mission effectively and sustain itself in the long term. Capacity also refers to the skills and capabilities of individuals. Organizations have 'capacity' in relation to every part of the organizational work: governance, leadership, mission and strategy; administration (including human resources, financial management and legal matters); programme development and implementation; fundraising and income generation; diversity, partnerships and collaboration; evaluation, advocacy and policy change; marketing, positioning, and planning. For individuals, capacity may relate to leadership, advocacy skills, training and speaking abilities, technical skills, organizing skills, and other areas of personal and professional effectiveness (Linnell, 2003).

Other scholars have defined capacity-building as a process for strengthening the management and governance of an organization so that it can effectively achieve its objectives and fulfil its mission (Beesley and Shebby, 2010; Connolly and York, 2002). Within the grant making sector in the United States, what has been adopted in terms of the definition of capacity-building by grantees and federal, state, or local governments is the ability of an organization to fulfil its mission through a blend of sound management, strong governance, and a persistent rededication to achieving results (Grantmakers for Effective Organizations, 2003; Beesley and Shebby, 2010; Wing, 2004). Having the ability to fulfil a capacity-building mission therefore means that an organization has: (a) sufficient numbers of staff that possess the necessary knowledge and skills; (b) appropriate and adequate technical and management systems; (c) suitable physical infrastructure; and (d) ample financial and other resources (Wing, 2004). Thus, capacity building, concluded Wing (2004), is not limited to just training personnel or the provision of technical assistance, but may also include overhauling systems, remodelling physical infrastructure, recruiting new personnel, and improving the efficiency of the use of existing resources (Wing, 2004). Capacity-building is often seen as a change process targeted at "aligning beliefs and new or refined practices with desired growth targets" within an organization (Harsh, 2010) followed by continuous engagement with stakeholders, evaluation and iterative changes to processes and systems (Fixsen et al., 2005; UNDP, 2008; Barrett, Kincaid and March, 2013). Capacity-building in research management should therefore aim to address individual and organizational capacity to ensure enhanced organizational performance.

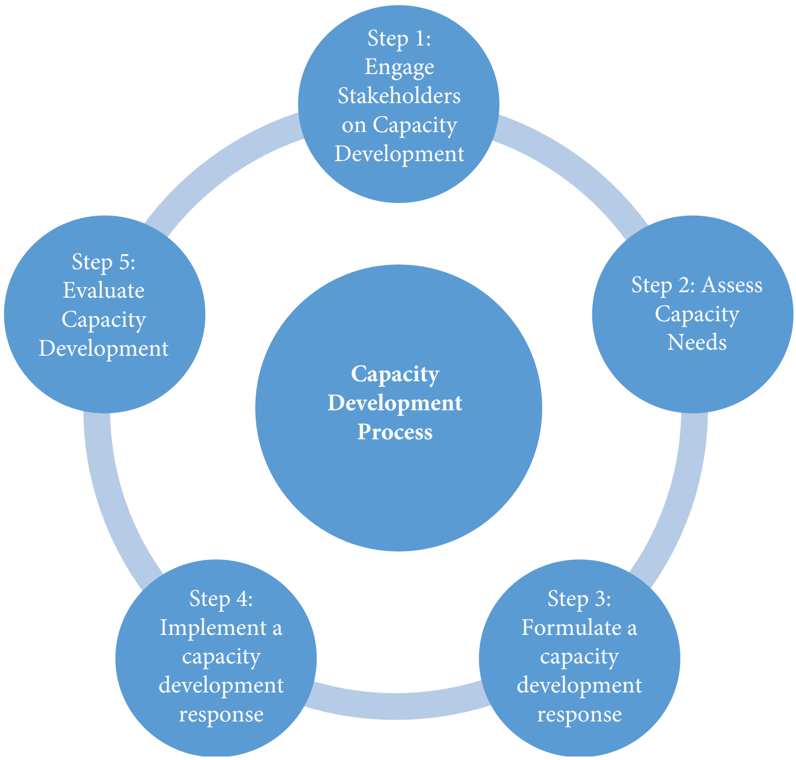
Donors globally, too, have begun to be involved in research management, partly recognizing that such practices are essential, to ensure the smooth operation of their granting and other research-related responsibilities. This is evident from the inclusion of research management as a focus area in many granting programmes such as the World Health Organization Special Programme for Research and Training in Tropical Diseases, the United Kingdom Research and Innovation (UKRI) funding programme, the African Academy of Sciences/Wellcome Trust DELTAS programme and now the SGCI.

Conceptualizing a research management capacity-building approach for the SGCs

The capacity-building approach that was recommended by the United Nations Development Programme (UNDP, 2008) for public sector organizations (see Figure 9.1) was used as a reference for the conceptualization of the approach to strengthening the capacity of SGCs to manage research. The UNDP approach provides a common point of reference for their staff and national and international partners supporting national capacity-building initiatives. The approach involved the following five steps: (1) engaging the stakeholders; (2) assessing the capacity needs; (3) formulating the response; (4) implementing the capacity-building response; and (5) evaluating the capacity development (UNDP, 2008).

The engagement of stakeholders (step 1) was done at two levels: first, engagement with the leadership and senior managers of the SGCs; and second, engagement with employees about the project and their roles and responsibilities. The first forum and launch of the SGCI was held in Kenya in 2015 and brought together senior managers of SGCs and their equivalents in Africa as well as resource persons and key stakeholders in STI in Africa. The participants included 34 senior management representatives from 12 SGCs based in Kenya, Uganda, Tanzania, Rwanda, Ethiopia, Malawi, Mozambique, Zambia, Zimbabwe, Burkina Faso, Cote D'Ivoire and Namibia. The objectives of the forum were to develop a shared understanding of the SGCI and to provide an additional opportunity for SGCs and other stakeholders to provide feedback and input on priority areas of the SGCI, based on national or regional capacity strengthening needs, as well as on how best to 'scale up' or share lessons from the 'first generation partners', with other SGCs from the rest of the continent.

Figure 9.1: Capacity Development Process



Source: Adapted from UNDP (2008), p.8

Another engagement was held in Namibia later in 2015 and the purpose was to present and solicit feedback from the SGCs on the proposed implementation plan for Theme 1 of the SGCI, focusing on strengthening research management capacity. The meeting was attended by heads of the SGCs from Uganda, Malawi, Namibia, Cote d'Ivoire, Mozambique, Senegal and Zimbabwe. The role of the SGCs as partners in the SGCI was stressed and hence the need to interact and learn from each other.

Following a competitive process by the funders (implementing partners), the selection of the Collaborating Technical Agency (CTA), the Southern African Research and Innovation Management Association (SARIMA) to lead on Theme 1 was finalized and the coordinator at each SGC was identified as the main contact person for liaising with. A consultation and planning meeting was held between the CTA and the SGCs in Johannesburg in October 2016. The objective was for the CTA team to engage with the leadership of the SGCs, to discuss the preliminary needs assessment findings and to co-create with them on a research management capacity-development intervention plan that was geared towards their needs. The engagement with employees about the project and their role and responsibilities was done during the needs assessment discussed below.

Capacity-building programme needs assessment methodology

The needs assessment (step 2*)* provided an opportunity to engage with the staff in the SGC and to ascertain their training and capacity-building needs. The design of the needs assessment questionnaire was iterative; the first draft was circulated to implementing partners, ahead of the SGCI Annual Meeting in Kigali. A member of the CTA team led the consultation with the SGCs in two short plenary sessions and the SGCs had the opportunity to study the questionnaire and provide input (Mouton and Coates, 2016). As a result of input from the SGCs in the second plenary session, the process for collecting the data was altered. Instead of collecting individual responses to an online questionnaire, each SGC coordinator collected responses, discussed them internally and submitted a consolidated response from the SGC. The questions were available in English, French and Portuguese. It was deemed that aggregated data per SGC would be sufficiently detailed to provide for analysis by SGC and across the SGCs (Mouton and Coates, 2016).

The data was shared with the SGC coordinators at a consultation and planning meeting and validated by each SGC before finalizing the needs assessment report. The information supplied by each SGC was expected to provide a detailed view of their needs, the needs across the SGC sector, and a fairly detailed view of the types of training and delivery modes most in demand. To establish priority areas for training in this programme, the SGCs were asked to identify and rate the desired competency and knowledge areas that would most likely increase organizational capacity. The information was aggregated in order to establish the demand for courses, the prioritization of course delivery and the favoured delivery methods.

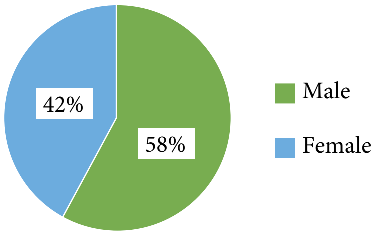
Research management capacity needs of the SGCs

Gender profile of staff for research management capacity-building at the SGCs

A total of 191 SGC staff members were nominated for the capacity-building intervention, with numbers varying widely across the SGCs, from less than ten in the SGCs that were newly established to 30 in those that were reasonably established (see Figure 9.2). The number of individuals that were nominated by the SGCs to participate in the research management capacity-building interventions is evidence of the demand that the SGCs had for research management capacity building. Of the 191 persons, 80 were female and 111 were male. The aggregated gender data across all SGCs are also shown in Figure 9.2 and illustrate a female to male ratio of 42 per cent to 58 per cent, which is somewhat indicative of the staff gender differences within each SGC (Mouton and Coats, 2016).

Figure 9.2: Gender Profile of SGC Employees Nominated for Capacity Building in Research Management

Country	Total	Male	Female
Botswana	5	5	0
Burkina Faso	9	7	2
Cote d'Ivoire	6	3	3
Ethiopia	15	10	5
Ghana	18	11	7
Kenya	3	1	2
Malawi	11	10	1
Mozambique	13	7	6
Namibia	10	5	5
Rwanda	11	3	8
Senegal	6	2	4
Tanzania	21	11	10
Uganda	22	16	6
Zambia	30	14	16
Zimbabwe	11	6	5
Total	191	111	80



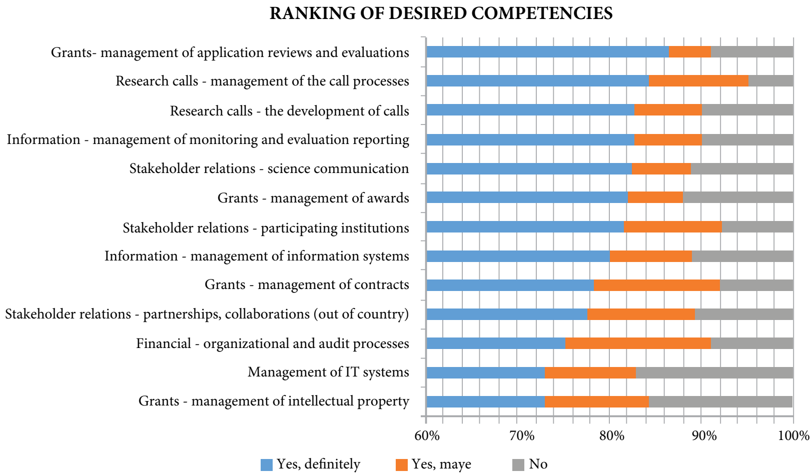
Source: Adapted from Mouton and Coates (2016, p. 9)

Ranking of research management competencies and knowledge areas

SGCs were asked to rank from a list of *research management competency areas,* those that were desired (deemed as important to improve the competency levels of staff in order to improve organizational performance) and which should form part of the capacity-building intervention. The responses are shown in Figure 9.3 and indicate that all 13 competencies were rated important with the most important – *Grants – management of application reviews and evaluations* being rated at 86 per cent and the least important – *Grants – management of intellectual property* at 73 per cent. When ranked by the combined 'important and moderately important' responses, all 13 competencies were rated at between 95 per cent and 83 per cent, indicating a strong desire for training to strengthen these competencies. A significant number of staff felt most competent about two areas: (i) managing stakeholder relations with participating institutions in-country; and (ii) partnerships and collaborations out-of-country; and least competent about another area of stakeholder relations, which is science communication and public awareness (Mouton and Coats, 2016).

Next, the SGC staff had to rank a list of *research management knowledge areas* by importance. The results indicated that the demand for training was high with most areas showing that over 100 persons would be nominated to attend training in each of the knowledge areas (when consolidating the numbers for high importance and moderate importance). Figure 9.4 presents the ranking by the SGCs of their top three priority knowledge areas in order to establish the highest priorities in the circumstance where the range of training courses may have to be restricted. The identification of priorities was also used as a guide to the prioritization of the order of delivery of the training programmes.

Figure 9.3: Ranking of Desirable Research Management Competencies



Source: Adapted from Mouton and Coats (2016, p.10)

Figure 9.4: Ranking of Priority Knowledge Areas by SGCs when Restricted to Choice of Top Three Priority Knowledge Areas (KA)

Top Three Desired Knowledge Areas	Number of SGCs rating KA as one of three highest priorities
Research impact assessment: assessing the impact of research projects.	7
Advanced training in M&E and performance management (framework design)	6
Advanced training in research management	5
Basics of grants management	5
Advanced training in grants management	5
Basics of research management	4
Understanding the nature and processes of peer review and evaluation.	2
Risk management at SGCs	2
Managing partnerships, collaborations and stakeholder relations (in-country and out-of-country)	2
Writing funding proposals	2
Understanding and using IT systems	1
Advanced training in IT systems (design)	1

Top Three Desired Knowledge Areas	Number of SGCs rating KA as one of three highest priorities
Knowledge utilization and impact: How to optimize the uptake and impact of research findings	1
Introduction to the domain of research ethics (ethical codes, informed consent, confidentiality of research, the rights of minorities and children and animals in research)	1

Source: Adapted from Mouton and Coats (2016, p. 36, 38)

The highest demand was clustered around the areas of research management, grants management and research project impact assessment. The demand for knowledge acquisition was clustered around general organizational improvement. There was no demand by SGCs for acquisition of knowledge in the area of understanding of gender in research and innovation systems, even though this area ranked well when the data was analysed by the percentage of individual responses. However, given the on-going concern about the low numbers of women in STI – particularly in Africa – and the perspective of the sustainable development goals, the knowledge area of gender in STI was included as a key priority area since the SGCs had to embrace the importance of gender to effectively build their science systems going forward.

In the final selection of the priority knowledge areas, it was important to recognize that the SGCs had different mandates, which required different knowledge areas and different depths of knowledge in specific areas. In addition, the differences in level of maturity of the SGCs had to be also considered. For example, the Uganda National Council for Science and Technology that is comparatively mature and stable was more in need of advanced training in comparatively few areas. The Tanzania Commission for Science and Technology was mature but engaged in organizational redevelopment and the STI ministries in Botswana and Ghana were still in the process of gaining legal status and had very limited grant funding to manage. These two groups of SGCs therefore required a cohort to acquire basic competency in a broad range of knowledge areas. There were also others such as the National Research Fund (NRF) Kenya and the Ministry of Science and Technology in Ethiopia that had recently gained legal status, had significant responsibility to perform well immediately, and required both basic and advanced level training in the core knowledge cluster areas (Mouton and Coats, 2016).

Mode of delivery of the capacity-building programme

The SGCs were required to rank the potential delivery modes of the capacity-building programme. The responses (see Figure 9.5) indicated that certification was more compelling for the SGCs; overall, they preferred to have an academic certificate accredited by a university in Southern Africa, which required scholars to have at least an undergraduate degree and/or a certificate offered by a research management association, which recognized prior and experiential learning as well as academic credentials. Eleven of the 15 SGCs indicated that the two certification modes were equally important. Certificate short courses delivered online were also considered an acceptable learning mode.

Figure 9.5: Mode of Delivery for the SGC Capacity Building Intervention

Type of Delivery Mode	Number of SGCs rating as very important
Certified Research Manager (workshops and work experiences resulting in a certification from a Research Management Association)	11
Academic Certificate in Research Management (accredited by a University in Southern Africa, 6 short courses delivered online and 1-week block of time)	11
Practical training workshops (with other SGCs for networking and learning opportunities)	10
Learning visits (to NRF and other SGCs in Africa)	9
Practical training workshops (in-house only)	8
Short courses (delivered online)	7
Learning visits (to International SGCs)	6
Conferences on research management (regional / international)	6
Webinars	2

Source: Adapted from Mouton and Coats (2016, p. 54)

Of the non-certificated modes of delivery, collegial learning was favoured or practical workshops where other SGCs were present including the National Research Foundation (NRF), South Africa, a non-participant SGC. This option offered networking and practical learning opportunities. An in-house offering (offered regionally) was also favoured. Learning from international SGCs (not African) was less favoured, and webinars mode was the least favoured.

A research management capacity-building intervention plan

The results of the needs assessment helped in gaining a better understanding of the research management capacity needs of the participating SGCs. With this understanding and through engagement with the SGCs, a broad intervention programme was co-created (step 3) (see Figure 9.6). The intervention programme was implemented (step 4) and provided for on-site or regional training workshops, professional development opportunities, platforms to facilitate collaboration and learning such as exchanges and learning visits to more established SGCs, and a structured benchmarking tool for SGCs to assess and learn from each other's processes and practices. It was also designed to be complementary and to reinforce the knowledge and skills acquired through the different SGCI interventions.

Figure 9.6: SGC Research Management Capacity-building Intervention Plan

5-day on-site training of SGC employees on the practical aspects of research management and grants management

- SGCI Annual Regional Forums, Research Management (e.g. SARIMA) Conferences

Learning and Sharing Good Practices

- Learning Visits to NRF (S.A) or other SGCs within the SGCI
- Technical Assistance Programme – based on an EOI process
- Online Benchmarking

Creating New Knowledge Levels

- Professional Certificate in Research Management through six 6-week online short courses in Introduction to Research Management; Introduction to Intellectual Property, Technology Transfer and Commercialization; Grants and Contracts Management; Ethics and Integrity in Research; Gender in Science, Technology and Innovation; and Science, Technology and Innovation (STI) Indicators

Towards Sustainable Capacity

- Professional Recognition of Research Management Professionals

Source: Authors

Building sustainable research management capacity of the SGCs

Building staff skills and confidence

The intervention focused first on building the staff skills and confidence and a common understanding of research management in the SGC context, through an *on-site training programme* on the practical aspects of research and grants management. The on-site training was designed around two foundational building blocks: customization as well as dialogue and action. The customized programme for on-site training was developed by considering the desired knowledge areas identified by a particular SGC during the needs assessment and through consultation with the SGC. The on-site training programmes have typically covered the following broad learning areas: research management at research performing organizations and at SGCs; the philosophy of merit-based science granting; the science-policy nexus and the pitfalls of donor-agency relationships in a developing science system; designing funding instruments, partnerships and collaboration; merits and pitfalls of peer review; research ethics and integrity; managing research for impact; developing funding initiatives and processing proposals; financial control, and monitoring and evaluation of funding programmes.

A briefing session between the trainers and senior SGC officials was deliberately included before the onset of the programme to ensure contextualization of the training content. A session was also dedicated to an overview of the national STI landscape and the strategic approach employed by its national government in setting funding priorities, as well as an outline of its existing funding mechanisms, presented by a local expert. At the end of the training programme, the SGC(s) were required to brainstorm, capture and prioritize practical action points for improving their research management practices and hence their ability to effectively contribute to building their science systems. To facilitate implementation of the action points, staff from human resources and finance departments participated to extend these actions to the review of capacity gaps and the improvement of job specifications. These action items were also presented to the leadership of the SGCs.

The intervention programme allowed for sufficient flexibility to align it with the needs of the SGCs. For example, the three francophone SGCs opted for a joint training workshop offered in French and wanted to focus on issues specific to their region. Similarly, two smaller, less advanced SGCs in East Africa were grouped together to share their experiences with each other.

Over 200 delegates were reached through the on-site training intervention. The participants confirmed, through feedback, that this mode of delivery afforded them the opportunity to critically reflect on the SGC's research management practices and to strengthen their relationships with their beneficiary institutions. Some SGCs, for example the Fundo Nacional de Investigação (FNI) in Mozambique, wanted to establish a mechanism to fully understand the needs of their research community and have recognized the need to establish a new unit specifically dedicated to managing relationships with beneficiaries.

SGCs and their stakeholders have furthermore recognized the need for beneficiary institutions to develop or strengthen their research management practices. The National Commission on Research, Science and Technology in Namibia, for example, has started drafting a guideline document that explicitly outlines the roles and responsibilities of the research offices or institutional points of contact (designated authorities) to not only strengthen its relationships with its beneficiaries, but also to support beneficiaries to improve their own practices.

The on-site training programme allowed the CTA to reach more staff members per CTA than would have been possible when offering regional or joint workshops only. However, it was important for SGCs to participate in *joint workshops* to allow for the sharing of practices, robust discussions and to facilitate collaborative efforts. For this reason, specialized and cross-cutting research management topics such as gender in research and innovation; science diplomacy; monitoring and evaluation; impact assessment; and stakeholder engagement and networking were also offered during relevant conferences and at the SGCI annual regional meetings.

Learning and sharing good practices

Learning and sharing of good practices was facilitated through two interventions. The first intervention involved a comprehensive week-long *learning visits and technical support programmes* that supported the implementation of the action items prioritized during the on-site training. The CTA utilized its experience in running research and innovation management exchange programmes to conceptualize a two-faceted programme to facilitate mutual learning, sharing and technical assistance.

One facet of the programme focused on creating opportunities for SGC staff to undertake a 5-day learning visit to the NRF, South Africa or any other participating SGC. Learning visits were planned around periods that would optimize exposure, interaction and learning, for example, in times that peer-review panels were gathering or at the time of the NRF's annual Research Administrators Workshop, a major event organized annually by the Grant Management and Systems Administration unit of the NRF in South Africa.

The second facet created the opportunity for participating SGCs to host a technical expert at the SGC during which this expert offered technical support in any area aligned with the action points as identified by the SGC with the overall aim of strengthening the SGCs' research management practices. These visits have allowed for councils to identify and address very specific areas of improvement. Namibia has, for example, now introduced an appeals process, a more comprehensive articulation of allowable and non-allowable expenditures, adjusted its reporting periods, and established a monitoring and evaluation committee dedicated to developing a framework for M&E to guide all funded projects. Ghana, which has recently established its STI fund, focused on the development of its operating manual and identified further support needs on this. Further technical assistance was provided to the SGCs in online grants management, documenting research competitions and scientometrics.

The second intervention involved an online benchmarking exercise that provided the framework for learning and sharing among SGCs. For the duration of the project, SGCs participated in an online self-assessment using a benchmarking tool developed by the Association of Commonwealth Universities (ACU). This tool allowed SGCs to not only draw reports on their own data but also to compare their data with that of the other SGCs. Not all SGCs, however, completed the benchmarking. This may have initially been because the benchmarking was an unfamiliar process and sharing data may have exposed some of their operational shortcomings. We did try to include a face-to-face session in upcoming regional and annual meetings to contextualize the benchmarking and lay out the pros and cons but in a multi-layered programme like the SGCI, time did not allow for this.

Creating new knowledge levels

Creating new knowledge levels in research management professionals was achieved through a *fully online, university-accredited certificate* *programme in research management*. Three principles guided the implementation of the courses, that is, quality, accessibility and a relevant and needs-based content. On quality, the course content was developed using expert practitioners who were able to incorporate regional perspectives. The programme was accessible to Anglophone, Lusophone and Francophone countries as the course content was available in English, Portuguese and French. Although bandwidth was raised as a concern especially by the Francophone countries, the online platform that was used was optimized for low bandwidth conditions and was already deployed in several African countries. Since the target audience are professionals, it was anticipated that the courses will equip learners to perform better within their current job roles. The content was designed to provide a balance between theoretical inputs and practical application, and was supported through case studies, work-based assignments and facilitated online discussions. Furthermore, the participation of learners from multiple countries allowed for an enriched experience through shared learning on real-world situations, broadening of own perspectives and building of professional networks.

Six online courses, certified by a highly ranked South African university were offered as part of the Certificate in Research Management including fundamentals of research management; intellectual property, technology transfer and commercialization; programme evaluation; research grants and contracts management; ethics and integrity; and research and gender in science, technology and innovation. A total of 69 SGC staff members from 13 SGCs successfully completed the online programme.

Towards sustainable research management capacity

The final level of the intervention targeted sustainable capacity by *recognizing research management professionals* through the peer-review of a portfolio of evidence (PoE) and maintenance of the status through the completion of continuous education points (CE Points). Professional recognition was granted to a research manager for professional knowledge, based on recognition of prior learning, experience, functional and transferable expertise, regardless of whether such competencies were achieved formally. This was a way of recognizing what individuals already knew and were able to do and was based on the premise that people learn both inside and outside formal learning structures. An International Professional Recognition Council (IPRC) was established in 2017, consisting of experienced research managers to perform the peer-review. Candidates were required to submit a PoE to demonstrate the nature of their prior knowledge and experience acquired over a number of years. For the first round of professional recognition of research managers, eight applications were received from SGCs, of which two met the criteria for review by the IPRC. One applicant was granted provisional status while the other applicant was not successful. This final level of the intervention took place in the final year of the SGCI project and is expected to continue even after the project ends as the applicants make use of the capacity-building programme.

Lessons learnt and stories of success

The final step in the research management capacity-building programme focused on evaluating the capacity development programme (step 5). This was actually a continuous process of learning, consulting, processing and adapting the programme as necessary as a result of the lessons learnt. We share in this section, some of the lessons learnt and some of the pockets of success and impact that the project has had on the SGCs, the CTA and partners.

There is no doubt that the intervention strengthened both individual and institutional capacity at the SGCs to manage research, understand the role that research management could play in their operations and in their national science systems, and position the organizations themselves to receive larger funding resources from international partners to disburse. This was evident from SGCs like NRF Kenya which is now disbursing funds of over $US30 million in a single call in 2020; a substantial increase from the budget amount of almost $US5 million that they had available to disburse in 2015/2016.

From the start of the project, the needs assessment confirmed that there was a clear demand for capacity-building in general research management to improve individual and organizational performance across all SGCs. It was the foundation for the co-creation and development of the targeted capacity-building intervention for the participating SGCs. The intervention provided an opportunity for a pipeline as well as different access points for professional development of research managers at SGCs, from early career research managers or new entrants to the profession to mid-career management level professionals and experienced management and strategic level professionals. Adapting to local contexts and the changing policy landscapes within which many SGCs operate is critical to the success of any human and institutional capacity development effort. As such, the adoption of a co-creation approach was extremely important.

The on-site training demonstrated the unique requirements of different SGCs to strengthen their capacity; the customized approach to training and the availability of different types of interventions was therefore necessary. Sub-Saharan SGCs have been found to operate within fragmented and uncoordinated national systems of innovation. For many SGCs, it was the first time that they had hosted a diverse group of beneficiaries in a setting that not only allowed for mutual capacity development but also lesson sharing and relationship building. Trainers were careful to craft the technical content and related exercises to encourage interaction, and to foster a sense of common purpose – strengthening the research management practices. The feedback received from participants confirmed that the training offered them the opportunity to critically reflect on their operational procedures, policies and processes as well as to establish strong relationships with their beneficiary institutions and regional research and innovation management communities of practice. All this enhanced the ability of the SGCs to effectively contribute to building their science systems.

Learning visits and technical support were very practical and resulted in immediate and tangible improvements in areas that were at the centre of the role that SGCs have to play in building their science systems. Even though the technical visits had an internal focus, many of the SGCs invited their stakeholders to participate in the process. This contributed to transparency and a better understanding of the internal constraints of the SGC and allowed for inputs that could support seamless processes. The sustainability of the SGCI relies partly on the extent to which SGCs embrace the building of quality-driven organizational cultures and strong relations with research management communities of practice. A significant area of success is the relationship building that occurred as SGC-to-SGC as well as SGC-to national stakeholders during the implementation of the intervention. SGCs were now interacting more with their university stakeholders and also with the research management association in their region; they were now increasingly recognized as a respected part of the national science system.

As part of the interventions, a good practice guideline on the quality of research competitions was co-developed by the CTA, the funding partners and the SGCs with inputs from various other STI actors. The guideline identifies the key components that constitute a high-quality research funding competition and serves as a resource for SGCs to benchmark, review and continuously improve the quality of their research funding competitions now and beyond the SGCI. The good practice guideline was used practically by several of the SGCs including FNI, NRF Kenya and UNCST; it provided the opportunity for the SGCs to receive insights into the design of their calls for research projects. One of the SGCs reported that "*following your assistance in reviewing and designing our research call launched in December, 2018, the response was quite good and we didn't experience any concerns/queries from the applicants as we did during our first call in 2016.*"

As indicated earlier, the online benchmarking exercise was included in the intervention for the SGCs to streamline existing processes and to identify weaknesses and hence appropriate interventions for improvement. It was administered annually and for most SGCs that participated, it was based on their desire to learn from each other and share aspects of good practice. The actual outcome was lower than expected as some of the SGCs did not understand the context of the benchmarking survey and reported contradictory data each year. This could have been attributed to the staff turnover observed at some of the SGCs. Although this was discussed earlier as part of implementing the learning and sharing good practices aspect of the intervention, it is discussed again here to re-emphasize that benchmarking is an important tool for demonstrating success across different areas of research management that the SGCs indicated were a priority.

The steps in the intervention were highly interconnected, reinforced learnings and were necessary as individual staff members went through different stages in their careers. All the interventions contributed to collectively supporting and reinforcing organizational growth and capacity strengthening of SGCs in the management of research. For example, the online university certificate programme did not only contribute to improved knowledge but would also be used as evidence for accomplished training in research management when individuals applied for professional recognition in future. While we did not achieve a 100 per cent pass rate for the online certificate programme and the professional recognition programme by the time the SGCI project ended, it's important to remember that the concept of research management was new for many SGCs and hence many of the SGC staff did not necessarily identify themselves as research managers.

An important contribution of the project was to emphasize the SGC staff roles as research managers within their science systems and to identify the skills and competencies required for these roles. Even though the uptake for professional recognition was not as high as we wanted, we know that this was an extraordinary experience for the staff and leadership that participated in this programme, and that they will continue to demonstrate the competences from the learnings of the intervention. We know that this will change in future as SGC staff collect evidence of their research management skills and competency development and experience. We know that the research management capacity-building intervention together with the other interventions implemented through the SGCI will have sustainable systemic impact that will allow SGCs to better fulfil their role as key agents in a healthy science system.

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- The SARIMA Committee for leadership, commitment and support for the project; and
- The SARIMA Working Group members for their commitment and contributions.

Notes

1 https://www.ucf.edu/online/degree/research-administration-m-r-a/
2 https://arma.ac.uk/professional-development/
3 https://researchmanagement.org.au/content/professional-development/
4 http://www.cra-cert.org/
5 https://www.sarima.co.za/professionalisation/
6 http://www0.sun.ac.za/crest/pgdip-rma/

[7] https://www.aasciences.africa/aesa/programmes/research-management-programme-africa-rempro-africa
[8] https://sgciafrica.org/en-za/home

References

African Union, 2014. *23rd Ordinary Session of the African Union Heads of State and Government Summit: Agriculture and Food Security in Africa. Malabo, Equatorial Guinea, 26-27 June 2014.* Available at: https://au.int/en/newsevents/29258/23rd-ordinary-session-african-union-ends-malabo (Accessed 23 October 2018).

African Union Development Agency, 2019. *African Innovation Outlook III 2019*. Johannesburg: AUDA-NEPAD

Asongu, S. and Nwachukwu, J.C., 2017. Increasing foreign aid for inclusive human development in Africa. *Working Papers of the African Governance and Development Institute, 17/020.* African Governance and Development Institute.

Barrett, S., Kincaid, D. and March, A., 2013. Building coaching capacity. *Presented at the 2013 PBIS Leadership Forum*.

Beesley, A.D. and Shebby, S., 2010. Evaluating capacity building in education: The North Central Comprehensive Center. Paper presented at the Annual meeting of the American Educational Research Association. May 2010. Denver, Colorado.

Carter, I. and Langley, D., 2009. Overview of research management and administration. *Perspectives: Policy and Practice in Higher Education,* 13(2), pp.31–32

Connolly, P. and York, P., 2002. Evaluating capacity-building efforts for non-profit organizations. *Organization Development Practitioner,* 34(4), pp.33–39

Dyason, K., Williamson, C., Moyo, S. and Jackson, J., 2017. *Report of the professionalization of research management in Southern Africa.* Geneva: World Health Organization, TDR Programme.

Fixsen, D.L., Naoom, S.F., Blase, K.A., Friedman, R.M. and Wallace, F., 2005. *Implementation research: a synthesis of the literature*. Tampa, FL: University of South Florida, Louis de la Parte Florida Mental Health Institute, The National Implementation Research Network (FMHI Publication #231).

Grantmakers for Effective Organizations, 2003. *Grantmakers for Effective Organizations: Theory of change*. Prepared by Steven La France and Rick Green. Washington, DC: Grantmakers for Effective Organizations.

Harsh, S., 2010. Chapter 1: Gaining perspective on a complex task: a multidimensional approach to capacity building. In: S. Harsh, K. Bradley, K. Good, and J. Ross, eds. 2010. *Capacity building technical assistance: Change agent analyses*. Charlestown, WV: Edvantia, Appalachia Regional Comprehensive Center, p. 2.

Houghton, J. and Sheehan, P., 2000. A primer on the knowledge economy. Centre for Strategic Economic Studies, Victoria University of Technology. *CSES Working Paper No. 18*. Melbourne, Australia.

Kirkland, J., 2009. Research management. *Perspectives: Policy and Practice in Higher Education,* 13(2), pp.33–36

Linnell, D., 2003. *Evaluation of capacity building: lessons from the field*. Alliance for Nonprofit Management. [Online]. Available at: http://seerconsulting.com.au/wp-content/uploads/2009/09/Evaluation-of-CapacityBuilding-Lessons-from-Field.pdf (Accessed 5 September 2018).

Mouton, J. and Coates, C., 2016. *Science Granting Council Initiative, Building Sustainable Research Management in Science Granting Councils in Sub-Saharan Africa (SRMinSGC): Capacity Building Needs Assessment Survey*. Stellenbosch: Centre for Research on Evaluation, Science & Technology, Stellenbosch University.

Mouton, J., Gaillard, J. and van Lill, M., 2015. Functions of Science Granting Councils in sub-Sahara Africa. In: N. Cloete., P. Maasen and T. Bailey, eds. 2015. *Knowledge Production & Contradictory Functions in African Higher Education*. Cape Town, South Africa: African Minds, pp.148–170.

Olsson, Å. and Meek, L., (eds.) 2013. *Effectiveness of research and innovation management at policy and institutional levels in Cambodia, Malaysia, Thailand and Vietnam*, Paris: OECD.

Organisation for Economic Co-operation and Development, 2010. *The OECD Innovation Strategy. Getting a Head Start on Tomorrow*. Paris: OECD.

The Royal Society, 2011. *Knowledge networks and nations: global scientific collaboration in the 21st century*. London: Royal Society.

United Nations Development Programme (UNDP), 2008. *Capacity Development Practice Note*. New York: United Nations Development Programme.

Weber, A.S., 2011. The role of education in knowledge economies in developing countries. *Procedia Social and Behavioral Sciences,* 15, pp.2589–2594.

Williamson, C., Dyason, K., and Jackson, J., 2020. Scaling up professionalization of research management in Southern Africa. *Journal of Research Administration*, 34(1), pp.88–98

Wing, K.T., 2004. Assessing the effectiveness of capacity-building initiatives: seven issues for the field. *Non-profit and Voluntary Sector Quarterly,* 33(1), pp.153–160

World Bank, 2007. *Building knowledge economies: advanced strategies for development*. World Bank Institute Development Studies. Washington DC: World Bank.

10

Knowledge Exchange and Networking Among the Science System Actors in Sub-Saharan Africa

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Abstract

Knowledge exchange and networking (KEN) is a process that brings together researchers, users of research and wider public and private groups, communities and entrepreneurial individuals to exchange ideas, evidence and expertise. KEN is about developing mutually beneficial partnerships to support innovation and find solutions to the most pressing global challenges. Done effectively, it allows all participants to add value and impact to new ideas through engagement and collaboration. Ultimately, KEN has the capacity to drive transformational impact and enhance the societal application and benefits of African research. This chapter explores key concepts and mechanisms of KEN and identifies the mechanisms that work most effectively in an African context with particular focus on the science granting councils (SGCs) and other science system actors in sub-Saharan Africa (SSA). This chapter reviews and recommends good practices for sustaining KEN in order to co-create, share, and domesticate knowledge and its products among the

target beneficiaries. It further explores the opportunities for embedding and sustaining networks to support knowledge exchange within the science system. The chapter identifies the benefits and challenges of KEN with a view to providing sustainable solutions to Africa's science system. The chapter finally draws practical lessons from the Science Granting Councils Initiative in sub-Saharan Africa (SGCI) to embellish how KEN has enhanced uptake, capacities and capabilities among the SGCs and other science system actors in SSA.

Introduction

Science, Technology and Innovation (STI) is recognized as a key driver of socio-economic development by enhancing national industrial productivity and competitiveness (Oyelaran-Oyeyinka, et al., 2018). Iizuka, Mawoko and Gault (2015) explain that STI activities in Africa were initially influenced by the Science and Technology Consolidated Plan of Action (CPA) which was endorsed in 2005 by the African Ministerial Council on Science and Technology (AMCOST) and adopted in 2007 by the Heads of State and Government. The CPA had three pillars, namely, technological innovation, knowledge production, and capacity building. After seven years of implementing the CPA, the African Union (AU), in recognition of the pivotal place of STI in socio-economic development, developed and adopted the 10-year Science, Technology, and Innovation Strategy for Africa (STISA-2024).

Although Marcelle, Daniels and Whisgary (2014) acknowledge that Africa is steadily embracing STI to provide a platform for socio-economic development, they argue that responses to STISA have been insufficient, uncoordinated and may not be providing the ideal level of constructive engagements deserving of such a policy document with continental implications. They suggest that there is great need for a platform of sustained research and exploration on these issues. Despite its challenges, STISA demonstrates AU's commitment to mainstream STI in development. It also highlights the priority STI areas of focus at both the national and regional levels.

Many actors contribute to the development and mainstreaming of STI in socio-economic development in sub-Saharan Africa (SSA). Among these players are science system actors. Hessels (2013) argues that science system actors are individuals or organizations which coordinate or contribute to the activities within a science system. Such actors may be grant makers, regulators or direct researchers. Datta (2018) adds that such actors may be drawn from the public (government), private or development sectors of an economy. It has been observed that science system actors operate in isolation and do not have comprehensive mechanisms for sharing the knowledge that different actors generate (Oyeyinka, et al., 2018). According to Parinov and Neylon (2011), science system actors are now under more pressure not only to measure but also to demonstrate the impact of their work than before. Examples of science system actors include donor agencies, universities and other research institutions, private sector companies (industry), science granting councils (SGCs) as well as individual researchers and beneficiaries.

Under its theme on enhancing networking and collaborations among the SGCs and with other actors in the innovation system, the Science Granting Councils Initiative (SGCI) commissions topical papers which inform Masterclass sessions held annually. These commissioned papers have resulted in the publication of policy briefs, research papers and journal articles.

This chapter explores key concepts of, and mechanisms for, knowledge exchange and networking (KEN) and identifies the mechanisms which work most effectively in an African context with particular focus on the SGCs and other science system actors in Africa. The chapter further reviews and recommends good practices for sustaining KEN in order to co-create, share, and domesticate knowledge and its products among the target beneficiaries. It further explores the opportunities for embedding and sustaining networks to support knowledge exchange within the science system. The chapter also identifies the benefits and challenges for KEN with a view to providing sustainable solutions to Africa's science system. The chapter also draws practical lessons from the SGCI to embellish how KEN has enhanced uptake, capacities and capabilities among the SGCs and other science system actors in SSA.

Key knowledge exchange and networking concepts

This section describes key KEN concepts. Some of the concepts defined include knowledge, knowledge exchange, knowledge networking and KEN.

What is knowledge?

The understanding of what constitutes knowledge is as diverse as the number of people considering it. Therefore, knowledge is perceived as being polysemic with the meaning adopted being determined by the context and purpose for which it is being attached. Sharp (2007) argues that knowledge is difficult to define because it is multifaceted, dynamic and contextual. According to Davenport and Prusak (1998), knowledge is a fluid mix of framed experiences, values, contextual information and expert insights which provide a framework for evaluating and integrating new experiences and information. Nonaka, Toyama and Nagata (2000) define knowledge as a dynamic human process of justifying personal belief towards the truth. Sharp (2007) perceives knowledge as the integration and reuse of ideas, experience, skills, intuition and lessons learned that influence how people solve problems and make decisions, as well as the way they work to continually create tangible outcomes of brand value and business worth.

Knowledge can also be defined as a progression of data and information. Theirauf (1999) defines data as the unstructured collection of facts and figures. Liew (2007) argues that data is basic, unrefined and unfiltered symbols and signals. He explains that symbols may consist of text, numbers, diagrams or images, while signals may include sensory readings of light, sound, smell, taste or touch. When data is organized and processed, it becomes information. Alexander (2002) explains that some of the processes that transform data into information include classifying, cleaning, interpreting, linking, sorting or summarising of captured data. Introna (1992) explains that the transformation of data to information may also include putting it into context because information is historical, contextual and perspectual. It is moulded by life experience to provide understanding. Thus, data can be perceived as the raw material which is processed to generate information. Bellinger, Castro and Mills (2004) explain that information is processed from data so as to provide answers to "who", "what", "where" and "when" questions. They suggest that knowledge is the appropriate collection and application of information in a manner that makes it possible to answer the questions "how" and "why". Therefore, knowledge is not just a mere collection of information but also involves the cognitive analysis of the same to correctly answer the "how" and "why" questions. In other words, knowledge is the ability to apply information appropriately to understand, attend to or explain phenomena. Ackoff (1999) argues that wisdom is the capacity to understand which knowledge to apply in which situation. Thus, wisdom deals with values and the exercise of judgement.

In the context of this chapter, knowledge is perceived as: (i) facts held as true in specific contexts; (ii) the ability to act or the capacity for effective action; (iii) awareness, familiarity, acquaintance with an object, situation, phenomenon or event; (iv) experience; (v) adverborial knowledge (knowledge of what and when); (vi) skills, know-how (performatory knowledge); (vii) cognition or recognition; (viii) understanding (know-why); (ix) a commodity, intellectual asset; and (x) the sum-total of what is known. All the above can be categorized into cognitive abilities which generally relate to the performance of tasks; acquaintance which relates to familiarity and personal experiences; and facts garnered from observation, perception or reason. Regardless of the category of meaning, knowledge and knowing are valuable for, and essential to, all forms of human endeavour.

Knowledge exchange

According to UNICEF (2015) knowledge exchange is the systematic process of sharing experiences, ideas, successes and challenges in order to support the performance of specific tasks within an organization or community. The main purpose of knowledge exchange is to connect practitioners to learn from one another. Sharing experiential knowledge leads to the discovery of new approaches, which fuels innovation as well as personal or institutional improvement.

London School of Economics and Political Science (2020) defines knowledge exchange as a two-way process which involves sharing knowledge, experience, ideas, evidence or expertise between parties in ways intended to be mutually beneficial. Knowledge exchange is contrasted with knowledge dissemination by emphasising that while the former concept utilizes two-way interactions, knowledge dissemination involves one-way approaches and media. Knowledge exchange provides a means of enhancing individual or organizational impact by increasing the visibility and accessibility of knowledge or knowledge products. Knowledge exchange goes beyond a mere exposition of knowledge to mutual learning of new skills, ideas or best practices. Knowledge exchange, in certain circumstances, involves collaborative identification and solving of specific problems. Therefore, knowledge exchange approaches, tools and results may vary from case to case.

Economic and Social Research Council (ESRC) (2020) argues that knowledge exchange efforts work best when they have been designed with specific objectives. Therefore, selecting knowledge exchange approaches strategically works better than merely imitating what other people or organizations have applied. Given that knowledge exchange is a collaborative process, it is imperative that a working relationship between the parties be established prior to starting the actual exchange.

Among science system actors, knowledge exchange involves the sharing of knowledge obtained through research and experience between researchers (or research institutions) and strategic publics in the system including direct beneficiaries, practitioners, policymakers as well as other stakeholders. Therefore, knowledge exchange is only one step in a more complex process of knowledge generation (or collection), organization, validation, learning, uptake and preservation. It is critical because it provides the means by which science system actors can influence society positively and stimulate (facilitate) socio-economic development. It is also a means through which science system actors learn from the communities they work with, thereby providing a feedback loop of seamless collaborative learning and uptake of knowledge. This is in recognition of the fact that although knowledge is deemed to originate from science system actors through research, the same needs to be validated and enriched through interaction with the community where it has been developed. Thus, the knowledge is enriched with diverse perspectives brought forth by the community through myriad forms of cross-fertilization of ideas (National Academy of Sciences, 1994). According to the World Bank (2017), knowledge exchange facilitates peer-to-peer learning which provides a powerful way to share, replicate and scale up what works when addressing societal challenges, adding that when done right, knowledge exchange can build the capacity, confidence, and conviction of individuals and groups to act.

Knowledge networking

Seufert, Von Krogh and Back (2004) define knowledge networking as bringing together a number of people, resources and relationships among them, in order to accumulate and use knowledge primarily by means of knowledge creation and transfer processes, for the purpose of creating value. Networking is a means of breaking barriers to knowledge exchange and learning. It enables the linking of knowledge islands and silos to facilitate effective creation and uptake of knowledge. According to Skyrme (2007), knowledge networks are enabled through behaviour such as trust, reciprocity, and mutual support; clear identification of a shared purpose; formation of teams and knowledge champions whose roles are clearly defined and accepted; frequent and appropriate communication; a culture of sharing; seamless knowledge management processes; and written or unwritten rules of engagement. Seufert, Von Krogh and Back (2004) argue that the openness and richness of networks foster a fertile environment for the creation of entirely new knowledge, while also accelerating the innovation rate. Knowledge networking is therefore perceived as the process of creating and sustaining knowledge networks. Owing to the dynamic nature of knowledge, knowledge networks are emergent.

Knowledge networks can involve individuals, teams and organizations (Mentzas et al., 2001). According to Chatti, Jarke and Frosch-Wilke (2007), knowledge networking benefits from the social aspects of knowledge creation and learning. They emphasise the role of community building to leverage, create, sustain and share knowledge in a collaborative way, through participation, dialogue, discussion, observation and imitation. The typology of knowledge networks is diverse. While some are formal, others are less formal, or even totally informal. Some are large while others are small. Members of networks may belong to one or more networks at the same time. In some networks, they may be in the core while in others they may choose to remain in the periphery. Furthermore, some networks may be virtual (online) while others may be physical (offline).

Hustad (2004) argues that knowledge is created and shared through networks which he described as "communities of knowing". He further explains that the creation and sustenance of such networks have lately relied on ICT platforms. Citing the example of Ericsson, Hustad (2004) explains that many organizations have shifted from the "philosophy" of knowledge management to knowledge networking which facilitates people to share and reuse knowledge and experience and to locate specialists and initiatives in order to improve organizational performance. According to Plum and Hassink (2011), a large number of knowledge networks are created to solve specific practical problems.

In summary, it is important to note that knowledge, knowledge exchange and knowledge networking all fall under the broad area of knowledge system. Knowledge System (KS) comprises of an organized structure and dynamic process for: (i) generating and representing content, components, classes, or types of knowledge; that is (ii) domain specific or characterized by domain-relevant features as defined by the user or consumer; (iii) reinforced by a set of logical relationships that connect the content of knowledge to its value (utility); (iv) enhanced by a set of iterative processes that enable the evolution, revision, adaptation, and advancement of knowledge; and (v) subject to criteria of relevance, reliability, and quality (GSSD, n.d.). A knowledge system will encompass the actors, their roles, the contexts and contents, and the existing linkages that make the system work. This system strengthens the KEN mechanisms.

Rationale

The process of developing knowledge either through a research procedure or informal means most times excludes outsiders from that knowledge production process. Irrespective of its origins, knowledge shapes decisions and implementations, while the learning that occurs through the knowledge production process influences future actions (Fazey, Fazey and Fazey, 2005). This means that if one is to generate a particular knowledge afresh each time, lots of human and material resources will be wasted because of the frequencies of doing similar things to produce similar results by different people all the time. If this was the case, the world would have been so stagnated that there would not be much progress, improvements and innovations. Imagine a world where any knowledge produced remained with the producer alone. Learning would have been impossible. It therefore becomes imperative to share knowledge generated, for others to learn from it, improve on it and probably produce more and better knowledge products. Consequently, the main rationale for knowledge exchange is to share information that could be useful in one way or another to the recipients of the information both at the short, medium and long term. Knowledge exchange provides the opportunity to connect people together so that they can share their work, discuss it, learn from each other, collaborate in it, co-produce and use the knowledge to improve and innovate on their own works and practices. Sharing knowledge, especially experiential knowledge, is a key ingredient in innovation and is essential to achieve continual learning from experience which can be applied to improve work (UNICEF, 2015).

When the people concerned with knowledge exchange come together, they form a network or network of networks, and are able to facilitate and foster mutually exclusive sharing of data, information, expertise and skills between and among themselves, implying that the actors have something to gain from the interactions in a knowledge exchange process. Knowledge exchange and networks therefore form the basis through which individuals, groups, organizations and other professional bodies come together to share ideas, co-generate and co-produce new ideas, implement it and use it for further production of knowledge that will be useful in providing solutions to the challenges facing mankind. One such network is the SGCI in SSA.

Knowledge exchange makes use of specific tools and approaches. These include tools for fostering in-person (face-to-face) exchange and tools that make use of virtual platforms for exchanging and sharing information. They also include platforms and software tools that enable online networking and knowledge sharing across geographic and organizational barriers, supporting communities of practice to grow, co-create solutions, share successes and key resources.

This chapter therefore aims to provide an understanding of the key concepts and mechanisms for achieving an effective KEN, especially among the science system actors in Africa. The chapter uses case examples to demonstrate how KEN can work in specific contexts in Africa while also drawing from the SGCI. It further explores the benefits and challenges to KEN and provides practical solutions and recommendations for implementing KEN in any science or related systems.

Approach

To achieve the above stated objectives, the authors employed multiple approaches to generate proven data and information required for writing this chapter. These include: (i) desk studies where relevant published and grey literature on the subject matter were reviewed and compiled; (ii) interviews and case study examples where information generated from practical examples on some KEN mechanisms were equally utilized; and (iii) experiential learning from the SGCI masterclasses which were used to support the body of literature, interviews and case examples generated for the purposes of preparing this chapter.

Every year since 2016, delegates from 15 participating SGCs in 15 countries and other science system actors within Africa and beyond converge to interact and share knowledge, lessons and experiences from their respective countries under the SGCI. Data and information generated from these events were used to enrich the chapter with practical realities as well as contexts that will fit into African realities.

Mechanisms for knowledge exchange and networking

Organizations apply myriad mechanisms to facilitate KEN. The choice of a mechanism is determined by many factors including organizational mandate, vision and mission; organizational structure and culture; socio-economic and environmental factors in the community where the organization operates; as well as organizational knowledge capabilities and maturity levels. Some of the mechanisms that the science system actors can apply for KEN are discussed in this section.

Co-location and co-access to facilities

This is a KEN mechanism which facilitates the sharing of knowledge infrastructures such as laboratories, workshops, innovation hubs, ICT infrastructure for data storage and bandwidth, and office spaces. Co-location and co-access to facilities enables the pooling of physical resources for purposes of research and innovation. In this model of KEN, universities and research institutions can house start-ups, small and medium enterprises (SME) and innovators in a framework which enables the housing institutions not only to mentor the housed entities but also to help them reduce their overhead expenditure until they are able to stand on their own. This mechanism enables innovators to experiment with emerging ideas without having to worry about exorbitant overheads during their infancy stage. Co-location also enables small actors to easily access expertise within universities and other research institutions.

Several models of co-location and co-access to facilities exist in SSA. However, the most dominant are innovation and incubation hubs hosted by universities, research centres and technological companies. So successful have these been that they have together created a critical innovation landscape described as the "Silicon Savannah", a term used to describe the technology ecosystem in some African countries popular for producing fast growing social enterprises. Some of the successful hubs include Co-creation Hub (CcHUB) in Nigeria; iHub in Kenya; KLab in Rwanda; invoTECH and mLAB in South Africa; and Ghana Innovation Hub of Ghana, to mention but a few.

Collaborative research

Another mechanism for KEN is collaborative research. This is research conducted through the collective efforts of two or more individuals or institutions. Collaborative research may be conducted by members of two or more departments in an institution working together on a common project; a researcher from a private company working with researchers based in a university or research centre; and researchers from two or more institutions working on a research project of common interest. Collaborative research may also be considered from a disciplinary perspective. Therefore, research can be described as either unidisciplinary, multidisciplinary, interdisciplinary or transdisciplinary.

In unidisciplinary research, all the collaborating researchers are from the same discipline while in multidisciplinary scenarios, the researchers are drawn from more than one discipline. Interdisciplinary collaborative research occurs when multiple researchers work from within their own disciplines but focus on solving a common problem. Transdisciplinary collaborative research occurs when researchers use a shared conceptual framework to address a research problem by involving even the target end-users in identifying the challenges and co-creating the solutions.

Currently, there is a strong drive towards collaborative research globally (Wray, 2002; Cummings and Kiesler, 2005). A number of research funding agencies now pay special attention to collaborative research proposals. The benefits of collaborative research include: ability to share and exchange resources; opportunities for the researchers to learn from each other; division of labour which ensures timely completion of research projects; specialization associated with collaborative research which enhances the quality of research outputs and outcomes; and credibility and validity of research projects, outputs and outcomes. Beaver (2004) argues that outputs from collaborative research projects are generally of a higher quality than those from individual (lone) researchers. Therefore, collaborative research products are more authoritative and stand a higher chance of being cited or applied. Jean-Louis and Lomas (2003) explain that people and organizations participate in collaborative research to: broaden the range in choices in defining research problems and designing methodologies; better interpret research findings; encourage greater use of research findings to solve problems and address issues; and stimulate change in the way researchers think, practitioners take action or society uses knowledge. Disadvantages of collaborative research revolve around conflicts among the research teams, donors or parent institutions; poor coordination of collaborative research work plans, which may result in delays in attaining research milestones; and difficulty in the attribution of intellectual property resulting from research projects (Davenport, Davies and Grimes, 1998; Sprunger, 2017).

Jean-Louis and Lomas (2003) argue that there seems to be a new spirit of cooperation between researchers in the production of scientific knowledge. They explain that there is new understanding that knowledge production in society is collaborative rather than monolithic. Researchers have come to understand that there are many aspects of knowledge which can only be effectively accommodated through collaboration between multiple researchers. This understanding has blurred the frontiers between individual actors in research and encouraged greater collaboration.

Co-design and co-delivery of programmes

Science system actors can also exchange knowledge through co-design and co-delivery of academic programmes. According to Martin, Stevens and Arbour (2017), co-design and co-delivery of programmes enables diverse stakeholders to participate in the design and delivery of programmes which meet their specific needs. In the context of KEN, academic institutions can work with other science system actors to identify knowledge gaps which they can bridge through collaboratively designed and delivered academic programmes. Such programmes may include undergraduate, postgraduate and short courses which are tailored to meet specific knowledge needs. A key tenet of the co-design and co-delivery approaches is that users, as 'experts' of their own experience, become central to the design and uptake process, thereby owning it.

Vargas and Venezia (2015) explain that co-design involves deciding on and designing together courses, curricular pathways, and support systems, as well as professional development opportunities and data platforms, that impact what and how people learn. They also explain that co-delivery is the sharing and coordinating of faculty and staff, facilities and other resources to carry out the co-designed learning experiences and supports. The key tenets of co-design and co-delivery of programmes include concepts such as participation, working together, influencing and being influenced, power sharing and clarity of purpose.

Svendsen and Laberge (2006) propose the concept of "co-creative" engagement process in which multiple stakeholders can network and co-create innovative solutions to complex challenges affecting them. These networks are aimed at building trust and mutual understanding to enable collective action. The success of co-creative processes is hinged on the relationship between the stakeholders in the community. Diverse views, backgrounds and interests of network members are seen as providing opportunities for creativity, innovation and learning.

The advantage of co-design and co-delivery of programmes lies in the fact that it fosters participatory approaches in meeting collective knowledge needs of a community of stakeholders (Jessup et al., 2018). The use of this approach as a means of enhancing KEN benefits from the fact that the solutions proposed emanate from the perspectives of multiple stakeholders, thereby making them rich and optimized for each context. Solutions designed in this way are more likely to be acceptable to both providers and end users, and therefore adopted and sustained. Ward, et al. (2018) opines that for co-design and co-delivery approaches to succeed, the actors should be willing to work within the teams to meet shared goals; listen to, and consider, different perspectives and opinions; communicate clearly and regularly; make contributions readily and unreservedly towards solving the communal knowledge challenges; and forego personal benefits for the sake of the communal good of the network.

The co-design and co-delivery approach are an effective mechanism for fostering industry-academia partnerships that lead to the development of effective competency-based curricula and hands-on educational systems. Such partnerships have led to the training of highly skilled graduates that meet the needs of the industry and are able to support economic growth and development.

IP commercialization

Scientific and technological research and applications ordinarily result in intellectual property (IP) products through new creations or innovations. Some of the IP products can be developed further and commercialized to generate revenue for the scientists. Although scientists are creators of knowledge, they ordinarily lack business skills or infrastructure to sell their IP products. They can partner with SMEs or corporates to commercialize their products. Similarly, they can create start-up companies, commonly known as spinoffs or spinouts, to develop, produce and sell the IP products. IP owners may also license existing companies to produce or sell IP products under specific terms and conditions of engagement. Rasmussen (2008) explains that the IP commercialization model embraced by an entity depends on its needs, context and the IP product.

Commercialization is the process of bringing an IP product into the market for sale and exploitation. Markman, Siegel and Wright (2008) argue that IP commercialization enables private, public, and even non-profit organizations to mobilize their idle, unexploited, and underutilized discoveries, inventions and innovations into the open market. They explain further that increased IP commercialization has led to the emergence of new organizational forms and functions that promote research, knowledge and technology commercialization, such as technology transfer offices (within for-profit and non-profit organizations), science parks, incubators, and industry-university research centres. They add that for universities and public research institutions, the trend towards commercialization reflects pressures to maximize the social return on public investment in research and efforts to enhance self-sustenance.

IP commercialization is an elaborate process requiring legal as well as business product development and production skills. Universities interested in commercializing their IP products have created outfits which manage this process in ways which safeguard the interests of the university, the scientists, researchers and the society. Commercialization enables producers of knowledge to facilitate its application to make the world a better place. Thus, commercialization provides a means of validating scientific knowledge.

Communication and engagement

Science system actors can exchange knowledge through communication and engagement. Indeed, communication is the means of exposing scientific knowledge to its potential users or brokers. Both verbal and non-verbal communication is invaluable in the dissemination and uptake of knowledge in the form of research products. One of the most common means of communicating research is through scholarly communication. This is a genre of communication which focuses on disseminating scientific knowledge through peer reviewed publications such as journal articles, conference papers, monographs, posters as well as theses and dissertations, among others. The distinguishing attribute of scholarly communication is the role of peer review as a means of quality control and assurance.

Scientific knowledge can also be disseminated through the mass media. This can be done through featured articles, opinion pieces as well as news items. The advantage of using the mass media for scientific communication is that it reaches a large audience. Furthermore, mass media products are simplified and can appeal to many people, going beyond the academia. The mass media provides a means of reaching out to potential beneficiaries of scientific knowledge as well as policy formulators and implementers. The mass media also brings benefits associated with multimedia capability.

Science system actors can also establish communication facilities such as libraries and resource centres through which knowledge is collected, collated, organized, stored and perpetuated. Using emerging technologies exemplified by the Internet, such facilities can increase the reach and longevity of knowledge products. In the context of open access publishing, such facilities can enhance access to knowledge products through creative commons and federated collection development frameworks.

Knowledge may also be shared through engagement which entails the use of interaction platforms such as events to co-create, validate or apply knowledge by a strategic group. Engagement also implies the creation and use of networks and alliances to mobilize resources for knowledge creation, sharing and use. Science system actors can use public relations, lobbying, advocacy and activism to generate, collect and promote access to knowledge products.

Communication and engagement may also include knowledge sharing techniques such as communities of practice; knowledge café; storytelling; drama, music and theatre; indigenous knowledge and practices; public information; best practices; demonstrations; protocols; manuals; standard operation procedures; topical tables; conferences; mind mapping; webinars; residencies; apprenticeship; and job shadowing, among other techniques.

Continuing professional education

This is the process of continuously developing the important skills of professionals in a discipline. It is used as a means of keeping the professionals abreast with the developments in the discipline and bridging skill gaps encountered during practice. Continuing professional development is achieved largely through formal training, professional registration examinations, short courses, and other professional events. Some professional associations have set mandatory thresholds for professional development and require their members to attain a set number of scores annually by taking short courses recognized by the associations.

Continuous professional education provides a framework for professionals to update their skills as a means of coping with emerging demands of their practice (Lessing and Dewitt, 2007). Continuous professional development programmes are specific and specialized. This enables the participants to continue building on their skills without having to take a long-term post-graduation training (Ryan, 2003). It also facilitates re-certification of professionals in fast-changing fields such as medicine (Wasserman, Kimball and Duffy, 2000); ensures the retention of professionals in the discipline by keeping them interested in the practice (Opfer and Pedder, 2010); as well as builds the capacity of the professionals on emerging tools and technologies (Marshall, Punys and Sykes, 2008).

Consultancy

This is a practice where experts offer professional advice or service to other parties, normally at a fee. Ideally, consultancy is a form of knowledge exchange where a professional with expert knowledge shares knowledge with another party. Consultants provide expert knowledge in the form of recommendations, advice, opinions or implementation of specific projects. Thus, consultants are specialists hired to perform a specific task for a specific period of time under specific terms by individuals or organizations.

Consultancies enable experts to share their knowledge. Science system actors can use consultancies as capacity-building opportunities through which experts expose their knowledge and also strengthen the capacity of the clients. Given the costs associated with employing experts fully, consultancy provides an affordable option of benefiting from them without having to keep them in fulltime employment. The best way to benefit from the skills of consultants is to build a training aspect to all consultancies which enables the organizations to acquire some knowledge from the experts. This may be done by ensuring the consultants work closely with client's staff. For consultancies to work effectively for them, science system actors should ensure that they select consultants carefully. Many people masquerading as consultants are quacks only interested in gaining unfairly from organizations which are desperate for expert services.

The SGCI Masterclass

The SGCI Masterclass serves as a one-stop-shop for the presentation, learning, exchange, sharing and documentation of stories of change on topical science, technology and innovation (STI) issues emanating from the participating 15 SGCs in SSA. The main aim of the masterclass is to present to the science system actors, a theme bordering around STI issues by a qualified professional in the chosen area of importance. The delegates are usually drawn from the 15 participating SGCs in the 15 countries and other science system actors from Africa and the rest of the world. The masterclass paper is intended to provide insightful and critical knowledge, information, experiences and case studies capable of stimulating discussions and debates during and after the masterclass. Discussions around the paper enable the SGCs to learn good practices from across the world and be able to use the outcomes from the masterclass to initiate policy-oriented interventions in their respective countries. We have offered below brief descriptions on how the SGCI masterclass has been highly successful as a KEN mechanism:

How the theme of the masterclass paper is selected: The theme of the masterclass paper is usually agreed upon by a range of actors within the SGCI. At first, the Collaborating Technical Agency (CTA) responsible for convening the SGCs reaches out to the participating 15 SGCs who are the primary beneficiaries of the Initiative, to identify themes of their choice that will be relevant in achieving their mandates as councils. These themes are collated, ranked and shared with the Initiative's Management Team (IMT) for approval. Once approved, the chosen theme is communicated back to the SGCs and arrangements for commissioning qualified authors who will write the paper will commence.

How the author(s) of the masterclass paper is selected: As soon as approval for the theme of the masterclass paper is received from the IMT, the CTA develops a concept note on the theme as well as the Terms of Reference (ToR) for the potential author(s) of the masterclass paper, which are then used to seek for Expressions of Interest (EoI) from potential authors. An advert is then placed by the CTA and distributed widely among the STI community in Africa and beyond. Known authors with suitable qualifications and experience on the chosen theme are also encouraged to submit applications. Applications are reviewed based on pre-set criteria by at least three experts and their scores ranked according to their performances and then submitted to the IMT for their final review and approvals. Usually the pre-set criteria are based on team composition, qualifications and experience, annotated table of contents submitted, and work plan for the writing of the paper. In liaison with the IMT, the CTA appoints the preferred author(s) with clearly set out timelines and deliverables.

How the masterclass paper is reviewed: The CTA and IMT jointly review the draft paper submitted by the authors at least twice before the final paper is presented during the masterclass. The first draft of the paper is usually reviewed in-depth to ensure that the paper aligns with the intended objectives and research questions posed in the concept note and ToR. All comments and inputs on the drafts of the paper are collated by the CTA and sent to the authors for revisions on the paper. Once the paper is certified satisfactory by the CTA and IMT, the CTA now distributes the final draft masterclass paper to all the delegates to that year's masterclass (otherwise called Annual Forum) to enable them to read the paper and prepare their comments, observations, interventions and questions ahead of the masterclass.

How the masterclass paper is presented: The author(s) of the masterclass paper prepares the presentation for the masterclass which is reviewed by the CTA ahead of the presentation. The agreed final paper is presented by the lead author and supported by another co-author (sometimes). The SGCI masterclass is also designed in such a way that other professionals provide perspectives to the paper presented. In these perspectives, the professionals try to contextualise and adapt the paper to the practical realities of the science system in Africa. Thereafter, some selected heads of research councils (HORCs) who would have been pre-informed of their roles provide their perspectives on the paper, drawing from their own countries' experiences. This helps to provide lessons and good practices on the subject that could be of relevance to other countries present. An open discussion on the paper follows with all participating delegates entitled to contribute. All the presentations and discussions are documented and used to enrich the final masterclass paper, produce the proceedings of the masterclass, and may be used to set the stage for the next theme of another masterclass. A session is always created during the masterclass event for the SGCs to share stories of change and knowledge uptake from the previous masterclasses. Box 10.1 shows examples of knowledge uptake from the SGCs.

How the masterclass paper is published: The masterclass paper is revised by integrating the inputs, comments and observations received during the masterclass. From the revised paper, three key knowledge products are usually produced. They include research paper, policy briefs and journal articles. These knowledge products target different audiences including researchers, policymakers and practitioners. The publications from the SGCI have helped to create wide visibility about the Initiative and greater understanding of the aims and objectives of the Initiative in supporting research and evidence-based policies that can contribute to economic and social development in Africa.

Box 10.1: Examples of knowledge uptake from the SGCI Masterclasses

1. In Uganda, a National Research and Innovation Support Framework was established to augment R&D funding towards the recommended regional level (1% of GDP) and consciously

finance scientific innovation. The masterclass paper on 'New Approaches to Funding Research and Innovation in Africa' contributed to this outcome.

2. In Uganda, the Uganda National Council for Science and Technology (UNCST) revised the national research guidelines to include windows of support for social innovations; platforms for academia-industry research collaboration and for greater alignment with regional and global development strategies. The Council is also revising its strategy and approaches to stakeholder engagement in ways that enable co-investment, co-creation and incentivising multi-stakeholder platforms on various aspects of STI development. The masterclass paper on 'Towards Effective Public-Private Partnership in Research and Innovation' contributed to these outcomes.
3. In Mozambique, the National Research Fund (FNI) commenced discussions with relevant agencies in the country on how to address the funding limitation for research and innovation development and the need for the establishment of a national research agenda in the country. This is an outcome from the masterclass paper on 'New Approaches to Funding Research and Innovation in Africa'.
4. Again, in Mozambique, the FNI has reinforced the establishment of partnerships and exchange of experience with the SGCs in the region. They have started in-country actions to bring the private sector into the research agenda and have signed a memorandum of understanding (MoU) with the in-country national representative of the private sector to start a partnership relation for research and innovation. These are outcomes with contributions from the masterclass paper on 'Towards Effective Public-Private Partnership in Research and Innovation'.
5. In Malawi, the National Commission for Science and Technology (NCST) has fostered partnerships with other STI system actors especially with the higher education sub-sector and held for the first time, a major national meeting on STI in the country. The masterclass paper on 'Towards Effective Public-Private Partnership in Research and Innovation' contributed to this outcome.
6. In Senegal, the Research and Innovation Directorate has undertaken actions in the country to promote public-private partnership, for example, the introduction of Board of Directors

in universities and opening up of universities and research institutions for enterprise development, among others. The masterclass paper on Public-Private Partnership contributed to this outcome.

7. In Botswana, the Department of Research Science and Technology (DRST) is reviewing effective and sustainable approaches for boosting research funds in the country. This came after the lessons learnt from the masterclass paper on 'New Approaches to Funding Research and Innovation in Africa'. The Department is also working with other partners to develop the 'National Private Engagement Strategy' based on lessons learnt from the Public-Private Partnership masterclass paper.

Benefits and challenges of knowledge exchange and networking

This section presents the benefits and challenges of knowledge exchange and networks with a view to providing insights on when, why, and where it can be applied in a science system so as to achieve the key objective of learning lessons from knowledge for development.

Benefits of knowledge exchange and networking

The benefits of KEN as a means of enhancing knowledge creation, organization, sharing, validation and perpetuation are diverse. They include, but are not limited to, the following:

Process benefits: Effective KEN can result in myriad process benefits for science system actors. Some of these benefits include streamlined processes; enhanced efficiency; timesaving; reduction of process errors; increased process transparency; reduced redundancies; and reduced transaction costs. Essentially, KEN results in optimized processes which are efficient and cost-effective.

Employee benefits: In the age of knowledge workers, employees are a valuable resource to the organization, more than capital and physical resources. It is in the interest of progressive science system actors to ensure that they attract, motivate and retain the best possible human capital. KEN is one of the strategies through which this can be achieved. This is because when done effectively, KEN leads to increased organizational learning; enhanced staff motivation; improved personal knowledge base; increased staff retention; improved teamwork; enhanced staff participation; and shorter staff on-boarding time.

Customer benefits: Science system actors largely exist to meet the needs of specific clientele or publics. Without these publics, the organizations may cease to exist – at least not as they are currently established. Therefore, meeting customer expectations and needs is a critical determinant of organizational survival. KEN can enable organizations to attain increased understanding of customers; improved customer satisfaction; better communication with customers; improved quality of services and products; enhanced customer retention; reduced turnaround time; and increased collaboration with customers.

Financial benefits: Organizations require financial resources to operate. Nothing much can be achieved without this resource. Ironically, it is one of the rarest resources for science system actors in SSA. KEN can generate varied financial benefits for the organizations. These include better analysis and mitigation of risks; increased financial turnover; increased market share; optimized marketing strategies; reduced marketing costs; reduced operational costs; and improved decision making.

Innovation benefits: Science system actors compete for resources, namely donors, collaborators, infrastructure and staff. The capacity of the organizations to survive and thrive in the increasingly competitive environment depends on their level of innovation. KEN can lead to improved research and development; increased generation of new knowledge; better application of technologies; development of new products and services; development of new business segments; enhanced quality of services and products; and improved organizational continuity.

Other benefits: Several other benefits can be drawn from effective KEN. These include increased productivity; enhanced coordination and resource pooling; prompt solution of problems; grounded knowledge and learning culture; better management of change; increased flexibility and adaptability; enhanced competitiveness; development and application of standards; improved reputation and relationships; reduced personnel requirements; increased organizational synergy; enhanced knowledge sharing and diffusion; visible use of organizational resources; and emergence of positive organizational values, among others.

Challenges of knowledge exchange and networking

The following challenges are likely to hinder effective KEN among science system actors in SSA:

Inadequate resources: Most science system actors in SSA lack adequate financial, human and physical resources to facilitate effective KEN. They largely rely on inadequate budgets and donations from philanthropic organizations and individuals outside the region.

Knowledge hoarding: Many bearers of knowledge are not willing to share their knowledge. Many factors lead to this. However, the most dominant cause is insecurity when knowledge owners feel that by exposing their knowledge, they would lose the power associated with it. Thus, it may result in job or influence losses.

Poor leadership: KEN initiatives need to be designed and promoted by knowledge champions and brokers. Many science system actors in SSA lack experienced knowledge champions and brokers. This hinders their vision and leads to ineffective KEN initiatives.

Culture of imitation: Many science system actors in SSA fall to the temptation of copying other organizations, some of which operate in different contexts. This results in stunted knowledge growth. Copying what is already being done limits an organization's competitive advantage.

Lone ranger syndrome: Some science system actors are secretive in their efforts to remain competitive. Therefore, they keep their plans and resources under wraps, thereby limiting their capacity to benefit from their communities. There is power in numbers. Organizations which work in isolation cannot tap the benefits derived from collaborative networks.

Inadequate frameworks for collaboration: Most countries lack policy and legal frameworks that stimulate effective KEN. Science system actors may be willing to network and exchange knowledge but may be hindered in the process by loopholes in existing policies and legislation.

Key policy recommendations for sustaining knowledge exchange and networking

The following key policy recommendations are proffered to enhance effective KEN in Africa:

1. **Strengthen systemic coordination and learning among the science system actors:** The current linkage system and coordination between and among the science system actors in Africa is relatively weak. This is exacerbated by low financial investments,

institutional failures, poor public-private partnerships and low capabilities in the science system. There is therefore an urgent need for responsible government ministries, departments and agencies (MDAs) such as the SGCs to make deliberate efforts to coordinate and establish mechanisms for sectoral interactions across public and private entities to share knowledge, ideas and innovations that will optimize government efforts in the knowledge production, commercialization and utilization continuum. All the critical actors in the science system must work together and offer synergies and complementarities to one another so as to sustain socio-economic development at national, regional and continental levels.

2. **Establish open science policies and frameworks:** To increase the opportunity for knowledge sharing and exchange among the science system actors, there is need for African governments to embrace and establish open science policies and frameworks that will compel knowledge generators to easily share and exchange their knowledge in the science system and hence prevent knowledge hoarding. This applies mostly to knowledge that has been generated using public funds. Open Science (OS) is defined by the Research Innovation Network as "science carried out and communicated in a manner which allows others to contribute, collaborate and add to the research effort, with all kinds of data, results and protocols made freely available at different stages of the research process" (Di Giorgio, 2017). Thus, OS connotes the opening up of the entire research process from agenda-setting, data generation and analysis, to dissemination and use with the aid of various emerging digital and physical platforms and tools. In this context therefore, OS is viewed as "transparent and accessible knowledge that is shared and developed through collaborative networks" (Vicente-Saez, 2018) and is guided by a number of principles, including open data, open access, open innovation, open source, open methodology, citizen science, and open peer-review, among others (Vetro, et al., 2016).
3. **Strengthen state and non-state institutions and networks that generate and utilize knowledge:** For knowledge to be shared or exchanged, it has to first of all be generated. It therefore becomes imperative for both state and non-state institutions involved in knowledge generation to be strengthened with adequate resources to effectively generate robust knowledge that could be shared among the various actors in the science system. Such resources will include human capital, financial investments, infrastructure and incentive

structures, among others. Most importantly, strengthening public-private partnerships in knowledge generation, dissemination and utilization makes it possible for an inclusive and sustained production and utilization of knowledge. Existing networks and platforms that share knowledge around science, technology and innovation in Africa should also be supported to continually create platforms for sharing and exchanging knowledge on the continent. An example of such institutions is the African Technology Policy Studies Network (ATPS) which has been rated for many years as the most networked think tank in Africa (McGann, 2020).

Conclusion

Knowledge is now the most important organizational asset, arguably ranking above land, capital and labour. Organizations in the modern age thrive or fail based on their capacity to create or access valuable knowledge. Many organizations, in their efforts to leverage their intellectual assets have focused on individual, lone-range projects without realizing that knowledge management is a social activity which works better in collaborative environments. Knowledge is one of the few assets that grow exponentially when shared. Organizations which work in STI environments rely on knowledge creation and sharing to thrive. Therefore, they need to embrace the philosophy of co-creation, sharing and use of knowledge. One of the strategies that can facilitate this is KEN.

This chapter has delved into the details of what KEN means and how it works; the different mechanisms of KEN that can be employed; its benefits for science system actors in SSA; the challenges likely to hinder its effective execution and how the same can be mitigated as well as key policy recommendations for effective KEN. Whereas we acknowledge that this chapter cannot have covered all the issues pertinent to KEN among science system actors in SSA, it adds to the many voices out there discussing this important issue. It is, therefore, a contribution to the ongoing discourse and body of knowledge on this important theme.

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References

Ackoff, R. L., 1999. *Ackoff's Best*. New York: John Wiley & Sons.

African Union, 2014. *Science, technology and innovation strategy for Africa 2024 (STISA-2024).* Addis Ababa: African Union.

Alexander, A.S., 2002. *Chapter 3: Data, information and meaning*. [Online]. Available at: https://repository.up.ac.za/dspace/bitstream/handle/2263/27367/03chapter3.pdf (Accessed 17 April 2018).

Beaver, D. D., 2004. Does collaborative research have greater epistemic authority? *Scientometrics*, 60(3), pp. 399–408.

Bellinger, G., Castro, D and Mills, A., 2004. *Data, information, knowledge, and wisdom*. [Online]. Available at: http://www.academia.edu/download/35500195/bellinger_on_ackoff_data_info_know_wisdom.pdf (Accessed 17 April 2018).

Chatti, M. A., Jarke, M. and Frosch-Wilke, D., 2007. The future of e-learning: a shift to knowledge networking and social software. *International journal of knowledge and learning*, 3(4-5), pp.404–420.

Cummings, J. N. and Kiesler, S., 2005. Collaborative research across disciplinary and organizational boundaries. *Social studies of science*, 35(5), pp.703–722.

Datta, A., 2018. *Strengthening research systems: concepts, actions and actors*. K4D Helpdesk Report. Brighton, UK: Institute of Development Studies.

Davenport, S., Davies, J. and Grimes, C., 1998. Collaborative research programmes: building trust from difference. *Technovation*, 19(1), pp.31–40.

Davenport, T. H. and Prusak, L., 1998. *Working knowledge: How organizations manage what they know*. Boston: Harvard Business Press.

Di Giorgio, S., 2017. *Open Data, Open Science, Open Access*. [Online]. Available online at: http://training.parthenos-project.eu/wp-content/uploads/2017/07/Open-Data-Open-Science-Open-Access-Transcription-ENGLISH.pdf (Accessed 11 June 2019).

Economic and Social Research Council (ESRC), 2020. *Tips for doing knowledge exchange*. [Online]. Available at: https://esrc.ukri.org/research/impact-toolkit/tips-for-doing-knowledge-exchange/ (Accessed 8 January 2020).

Fazey, I., Fazey, J.A. and Fazey, D.M.A., 2005. Learning more effectively from experience. *Ecology and Society,* 10(2), p.4.

Global System for Sustainable Development (GSSD), (n.d.). *Knowledge meta-networking for decision and strategy*. [Online]. Available at: https://gssd.mit.edu/knowledge-system (Accessed 14 April 2020).

Hessels, L. K., 2013. Coordination in the science system: theoretical framework and a case study of an intermediary organization. *Minerva*, 51(3), pp.317–339.

Hustad, E., 2004. Knowledge networking in global organizations: the transfer of knowledge. In: *Proceedings of the 2004 SIGMIS conference on Computer personnel research: Careers, culture, and ethics in a networked environment*, pp. 55–64. New York City: ACM.

Iizuka, M., Mawoko, P. and Gault, F., 2015. Innovation for development in Southern & Eastern Africa: challenges for promoting ST&I Policy. *UNU-MERIT Policy Brief 1*, pp.1–8.

Introna, L.D., 1992. *Towards a theory of management information*. Unpublished DCom-Thesis, Department of Informatics, University of Pretoria, Pretoria.

Jean-Louis, D. and Lomas, J., 2003. Convergent evolution: the academic and policy roots of collaborative research. *Journal of health services research & policy*, 8(S1).

Jessup, R. L., Osborne, R. H., Buchbinder, R. and Beauchamp, A., 2018. Using co-design to develop interventions to address health literacy needs in a hospitalised population. *BMC health services research*, 18(1), p. 989.

Lessing, A. and De Witt, M., 2007. The value of continuous professional development: teachers' perceptions. *South African Journal of Education*, 27(1), pp.53–67.

Liew, A., 2007. Understanding data, information, knowledge and their inter-relationships. *Journal of Knowledge Management Practice*, 8(2), pp.1–16.

London School of Economics and Political Science, 2020. Introduction to knowledge exchange and public engagement. [Online]. Available at: https://info.lse.ac.uk/staff/services/knowledge-exchange-and-impact/kei-guide/introduction-to-kei (Accessed 08 January 2020).

Marcelle, G., Daniels, C. and Whisgary, D., 2014. A strategy for leading science, technology and innovation in Africa. *HSRC Review*, 13(1), pp.25–26.

Markman, G. D., Siegel, D. S. and Wright, M., 2008. Research and technology commercialization. *Journal of Management Studies*, 45(8), pp.1401–1423.

Marshall, G., Punys, V. and Sykes, A., 2008. The continuous professional development (CPD) requirements of radiographers in Europe: an initial survey. *Radiography*, 14(4), pp.332–342.

Martin, K., Stevens, A. and Arbour, S., 2017. The process of developing a co-design and co-delivery initiative for mental health programming. *Journal of Psychosocial Rehabilitation and Mental Health*, 4(2), pp.247–251.

McGann, J. G., 2020. *2019 Global Go To Think Tank Index Report (2020)*. TTCSP Global Go To Think Tank Index Reports. 17. [Online]. Available at: https://repository.upenn.edu/cgi/viewcontent.cgi?article=1018&context=think_tanks (Accessed 8 April, 2020).

Mentzas, G., Apostolou, D., Young, R. and Abecker, A., 2001. Knowledge networking: a holistic solution for leveraging corporate knowledge. *Journal of Knowledge Management*, 5(1), pp.94–107.

National Academy of Sciences, 1994. *The knowledge exchange process: from research into practice.* [Online]. Available at: https://www.ncbi.nlm.nih.gov/books/NBK236316/ (Accessed 8 January 2020).

Nonaka, I., Toyama, R. and Nagata, A., 2000. A firm as a knowledge-creating entity: a new perspective on the theory of the firm. *Industrial and Corporate Change*, 9(1), pp.1–20.

Opfer, V. D. and Pedder, D., 2010. Benefits, status and effectiveness of continuous professional development for teachers in England. *The Curriculum Journal*, 21(4), pp.413–431.

Oyelaran-Oyeyinka, B., Ozor, N., Vallejo, B. and Abejirin, B., 2018. *Towards effective public-private partnerships in research and innovation: a perspective for African science granting councils*. Nairobi: African Technology Policy Studies Network.

Parinov, S. and Neylon, C., 2011. Science as a social system and virtual research environment. *Journal of Artificial Societies and Social Simulation*, 14(4), p. 10.

Plum, O. and Hassink, R., 2011. Comparing knowledge networking in different knowledge bases in Germany. *Papers in Regional Science*, 90(2), pp.355–371.

Rasmussen, E., 2008. Government instruments to support the commercialization of university research: Lessons from Canada. *Technovation*, 28(8), pp.506–517.

Ryan, J., 2003. Continuous professional development along the continuum of lifelong learning. *Nurse Education Today*, 23(7), pp.498–508.

Seufert, A., Von Krogh, G. and Back, A., 2004. Towards knowledge networking. In: *Business Engineering–Die ersten 15 Jahre*. Springer, Berlin, Heidelberg. pp.289–308.

Sharp, P., 2007. MaKE first steps–how a definition of knowledge can help your organisation. *The Electronic Journal of Knowledge Management*, 5(4), pp.487–496.

Skyrme, D., 2007. *Knowledge networking: creating the collaborative enterprise*. Routledge.

Sprunger, J. G., 2017. The benefits of engaging in collaborative research relationships. *APS Observer*, 30(10).

Svendsen, A. and Laberge, M., 2006. Beyond consultation: a co-creative approach to stakeholder engagement. [Online]. Available at: http://www.sfu.ca/sustainabledevelopment/cli/beyondconsultation.pdf (Accessed 10 January 2020).

Thierauf, R. J. 1999. *Knowledge management systems for business*. Westport, Connecticut, USA: Greenwood Publishing Group.

United Nations International Children's Emergency Fund (UNICEF). 2015. 'What is knowledge exchange?' [Online]. Available at: https://www.unicef.org/knowledge-exchange/ (Accessed 8 January 2020).

United Nations International Children's Emergency Fund (UNICEF). 2015. 'Learning and knowledge exchange' New York: UNICEF.

Vargas, J. and Venezia, A. 2015. *Co-Design, Co-Delivery, and Co-Validation: Creating High School and College Partnerships to Increase Postsecondary Success*. Boston: Jobs for the Future.

Vicente-Saez, R. and Martinez-Fuentes, C., 2018. Open Science now: A systematic literature review for an integrated definition, *Journal of Business Research*, 88, pp.428–436. https://doi.org/10.1016/j.jbusres.2017.12.043.

Vetro, A., Canova, L., Torchiano, M., Minotas, C. O., Iemma, R. and Morando, F., 2016. Open data quality measurement framework: Definition and application to Open Government Data. *Government Information Quarterly*, 33(2), pp.325–337. doi:10.1016/j.giq.2016.02.001.

Ward, M., De Brún, A., Beirne, D., Conway, C., Cunningham, U., English, A. and McDonnell, S., 2018. Using co-design to develop a collective leadership intervention for healthcare teams to improve safety culture. *International Journal of Environmental Research and Public Health*, 15(6), p1182.

Wasserman, S. I., Kimball, H. R. and Duffy, F. D., 2000. Recertification in internal medicine: A program of continuous professional development. *Annals of Internal Medicine*, 133(3), pp.202–208.

World Bank, 2017. The art of knowledge exchange'. [Online]. Available at: https://www.thegef.org/sites/default/files/publications/GEF_WB_AoKE_English.pdf (Accessed 8 January 2020).

Wray, K. B., 2002. The epistemic significance of collaborative research. *Philosophy of Science*, 69(1), p150–168.

11

Measuring the Effectiveness of National Science Systems

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Abstract

Monitoring, evaluation and learning (MEL) is important for measuring the strength and impact of any type of intervention – in this case the African national science systems. The capacities of science granting councils (SGCs), level of government commitment to funding research, quality of research outputs and research relevance are some of the indicators used to measure the strength of a national science system. This chapter aims to de-mystify MEL and provide simple steps that SGCs could use to institutionalize MEL. The chapter describes findings from the work done by the Association of African Universities in Cote d'Ivoire, Senegal and Burkina Faso in reviewing the capacities of their MEL systems. The chapter demonstrates the link between the SGC MEL systems and the strength, focus and relevance of a country's science system for its economic, social and political development.

Background and purpose

With the intensification of global competition for strengthening national economies, science, technology and innovation (STI) and research and development (R&D) have emerged as key factors in boosting national competitiveness, long-term economic growth, and better quality of life (Hu, 2015; Pianta, 2017). By investing in science research, governments expect job creation and increased incomes resulting from inventions, new products, processes and services, and the development of new industries.

The positive connection between R&D investments and economic growth as well as the hope that countries can leapfrog several stages of development by capitalizing on the abundant technologies to improve the lives of their citizens, presents a great interest for policymakers. As a result, many developing countries have been increasing STI investments for the implementation of various national R&D programmes and management of research institutes (Lee, et al., 2008).

Although not sufficient, funding for science and research in sub-Saharan Africa (SSA) has increased over the past years (UNESCO, 2016). At the national level, science granting councils (SGCs) are key vehicles for channelling such funding (Chataway, et al., 2019). The SGCs are essential actors in national systems of innovation. In a well-structured science system, SGCs play a critical role in facilitating STI policies, channelling government's R&D investments, building research capacity through appropriate scholarships and bursaries, setting and monitoring research agendas and priorities (Chataway, et al., 2019; Mouton, et al., 2015).

Entrusted with the responsibility of setting and monitoring research priorities, and promoting national systems of innovation and completeness, a key concern about the functions of the SGCs is to demonstrate the 'impact' of their research funding activities, or the value that public investment in research generates for increasing scientific competitiveness and excellence in wealth creation, productivity and social well-being. In this context, impact is understood as the change that the activities of the SGCs produce. Since SGCs operate based on public funds, the onus is on them to account to internal and external stakeholders, including governments, donors, the academic community (researchers) and the public, for the funds they are allocated and the returns on the research that these funds support. Therefore, it is imperative that the SGCs measure the extent to which their portfolio of funding and activities are delivering the intended results and benefits.

Finding adequate methods to measure impact, the time lag between the research outcome and the research activities that are supposed to have generated it, and the problem of unravelling the extent to which funded research results are the sole or most significant causes of the effect produced are some of the key problems identified in the literature (Reale, et al., 2017).

As demands for greater results grow, so do the demands for effective and functional monitoring, evaluation and learning (MEL) systems to support grant management. A functioning MEL system at the SGC level provides a continuous flow of information that is useful internally and externally. Several questions arise as SGCs assess the utility and usefulness of their MEL systems:

1. What is the value of MEL to SGCs?
2. Do SGCs in SSA have effective and functioning MEL systems?
3. How can an SGC sustain/improve its MEL system to produce trustworthy, timely and relevant information on the performance of research projects?

The purpose of this chapter is to understand how SGCs in SSA measure the impact of their activities by assessing the status of their MEL systems. The chapter projects the value of MEL and reports the current state of MEL within some selected SGCs. It highlights the strengths and key areas that require strengthening and recommends strategies for building effective MEL systems.

The chapter is structured as follows: part two provides the contextual background of SGCs, clearly stating their functions and contributions to national science systems; section three presents the theoretical perspective of an MEL system and what it has to offer to research funding institutions – SGCs; and part four presents the discussion on the state of MEL in seven SGCs. The final section highlights key areas that require strengthening and policy recommendations.

The need for monitoring, evaluation and learning (MEL) in SGCs

Despite their notable contributions to the national science systems, some SGCs in SSA face challenges in tracking the overall impact of their activities. Most of these SGCs are struggling to demonstrate that their funding goes to excellent scientists who produce excellent results, to account for the public money spent, and to show the scientific as well as economic and societal impact delivered from these investments.

As suggested by Mackay (2007), MEL is one means to approach this challenge. Recent literature shows that MEL frameworks are essential for identifying, collecting and analysing relevant data on STI (Chux Philippe and Almamy, 2018; OECD, 2018; Tijssen and Hollanders, 2006).

Today, many research funding organizations are realising the benefit of 'knowing what they know' and being able to extract that knowledge to improve operations and decision making (Tijssen and Hollanders, 2006).

Research shows that effective policymaking requires information on whether research funding organizations are doing things right and whether the desired results are being achieved (Reinhardt and Milzow, 2012). Strong MEL systems provide the means to compile and integrate all the necessary information into the policy cycle, thus providing the basis for enabling sound fund management and accountability (Karver, Kenny and Sumner, 2012).

Key properties of science systems are associated with the idea of effectiveness and efficiency (Sandström and Van den Besselaar, 2018). The structure of research funding is increasingly competitive, and policy-makers have become more concerned about how to get the most value for public funds, that is, how to get the best possible results from the investments in research (Stephan, 2012).

Literature shows that results-based MEL serves as an essential tool for demonstrating the effectiveness and efficient use of public resources (Annecke, 2008; Atkinson, Wellman and Xaba, 2003). According to Frølich (2008), the main rationale of MEL systems in research funding organizations is to increase the accountability of the organization over their spending of public R&D funds.

Most studies have concluded that MEL can be used to stimulate research organizations to increase the volume or quality of their outputs, to prioritize certain fields of research, develop greater interaction with industry and to increase their socio-economic impact (Atkinson, Wellman and Xaba, 2003; Geuna and Martin, 2003; Hicks, 2012; Tapper and Salter, 2003).

Görgens and Kusek (2010) explained that a functioning MEL system provides a continuous flow of information that is useful internally and externally. Internal use of information from the MEL system is a crucial management tool that helps research directors to ensure that specific targets are met.

MEL systems can promote transparency and accountability within research funding organizations and agencies. External and internal stakeholders will have a clear sense of the status of research projects, programmes and policies (Görgens and Kusek, 2010).

The Organisation for Economic Co-operation and Development (OECD) and the United Nations Educational, Scientific and Cultural Organization (UNESCO) have been the driving forces behind the use of monitoring frameworks to collate good STI statistics within the industrialized world. The new Oslo Manual (OECD, 2018) lays emphasis on developing and implementing a focused, evidence-based and dynamic monitoring and evaluation (M&E) system for the STI sector in order to adequately track the impact of STI investments in stimulating creativity and responding to the national, regional and global challenges for sustainable development.

However, despite the widespread adoption of STI policies[2], institutional developments, and regional efforts to collate STI data and build related indicators – through the adaptation of the African Science, Technology and Innovation Indicators (ASTII) initiative – in SSA, STI indicator M&E is still infantile and is yet to firmly take root at the regional or national levels.

The UNESCO Institute for Statistics (UIS) identified the following factors as the main challenges many SSA countries face in measuring STI statistics: poor coordination among research institutions, universities and the private sectors; weak M&E and statistical system at the national level; the changing landscape of R&D investment; and difficulty in measuring traditional knowledge, among others (UNESCO, 2010). Similarly, Chux et al. (2018) argued that one reason for the weaknesses in the evaluation of STI policies and indicators in the sub-region is the lack of an integrated MEL framework that measures the contribution of research institutions to national, regional and continental indicators of impact.

Both papers - Chux et al., (2018) and UNESCO (2010) – recommend the institutionalization of R&D statistics through the adaptation of robust MEL frameworks at the institutional, national and regional levels. Chux et al. (2018) highlighted the importance of MEL systems in collecting and analysing STI indicators to support knowledge-based economies in SSA. According to them, for the process of tracking and synthesizing STI indicators to be sustained, it has to be institutionalized by strengthening M&E systems at the national and regional levels.

The concept of monitoring, evaluation and learning: a theoretical perspective

MEL is a powerful public management tool that can be used to improve the way governments and organizations achieve results. Just as governments need financial, human resource and accountability systems, governments also need good performance feedback systems.

Conceptually, MEL is widely used in African discourses, unlike international literature where evaluation or programme evaluation is used (Basheka and Byamugisha, 2015)"title-short":"The state of monitoring and evaluation (M&E.

There are many related terms and concepts in the field of MEL. These can be confusing (Patton, 2013). Different countries and different development agencies often use varying definitions of similar concepts (Görgens and Kusek, 2010; Mackay, 2007). However, in its ordinary usage, monitoring means observing the progress of an intervention and is continuous, while evaluation is an activity that judges the worth (Scriven, 2007). On the other hand, learning – a recent addition to the M&E concept – refers to the process through which information generated from M&E is reflected upon and intentionally used to continuously improve a project's or policy's ability to achieve results.

Görgens and Kusek (2010) argue that M&E is a combination of two processes that are different yet complementary. It is, therefore, a process of systematically collecting and analysing information on on-going projects, and comparison of the project outcome or impact against the project intentions (Wanjiru and Kimutai, 2013).

The OECD (2002) defines monitoring and evaluation as a continous and systematic process of collecting, analysing and reporting on the progress and achievement of an intervention. In their definition, the OECD highlights the importance of M&E in management decision making, such as resource or fund allocation.

The OECD further noted that "Monitoring keeps track of intervention implementation in real-time and answers the question like 'What is happening?'" (OECD, 2002, p. 27). On the other hand, the OECD explained that evaluation is a systematic and structured approach of assessing on-going or completed interventions. The aim is to examine if an intervention has delivered or achieved its objectives, development efficiency, impact and sustainability. The OECD added that evaluation can occur during or after an intervention and could focus on tracking the impact of an intervention or assessing the pathways (how) towards the achievement of the impact.

Implicit in the descriptions of monitoring and evaluation is that the two, though mutually exclusive, can complement each other (Görgens and Kusek, 2010).

Monitoring, evaluation and learning systems

An MEL system could be manual or automated. Well-designed MEL systems facilitate ease of data collection, archiving, retrieval, analysis and reporting. Just like the concept of MEL, the precise definition of an MEL system varies between different organizations and programmes. In most cases, an MEL system refers to all the indicators, tools and processes that are used to measure if a programme has been implemented according to the plan (monitoring) and is having the desired result (evaluation). An MEL system is often described in a document called an MEL plan. An MEL framework is one part of that plan.

In principle, an MEL system is a set of components that are related to each other within a structure and serve a common purpose of tracking the implementation and results of a project (Samdi, 2007). The objective of an MEL system is to guide the collection, analysis, use and dissemination of information that allows the tracking of progress made by an intervention. An MEL system is also used as a means to facilitate understanding of the causes of good and poor performance (Mackay, 2007).

A good MEL system is more than a mere statistical task or an external obligation. For an MEL system to be effective and efficient, it must be planned properly, managed efficiently and provided with adequate resources, making it sustainable.

Key functions of an MEL system

MEL systems support the use of information to improve performance: Mackay (2007) stressed the importance of learning from M&E analysis. According to him, the value of conducting an M&E analysis lies in the use of the information to enhance implementation and decision making. Mackay (2007) emphasized the need for learning as a key component of M&E.

MEL systems that are aligned to the functions of an organization could support policy-making by providing evidence for effective activities and intervention programmes: Mackay (2007) argued that MEL information can support policy making by providing evidence about the most cost-effective types of government activity, such as different types of employment programmes, health interventions, or conditional cash transfer payments. Similarly, Clark, Sartorius and Bamberger (2004) noted that the purpose of MEL activities was to provide government officials, managers and civil society with better means for learning from experience, improving service delivery, planning, allocating resources, and demonstrating results as part of accountability. Kawonga, Blaauw and Fonn (2012) implied that MEL systems could play an important role in producing reliable and timely information which is useful in evaluating policies, setting priorities, planning, and monitoring the effectiveness and impacts of interventions.

Through years of practical experience, Woodhill (2005) noted that any effective MEL system needed to fulfil the following five functions: accountability; supporting operational management; supporting strategic management; knowledge creation; and empowerment by building the capacity, self-reliance, and confidence of beneficiaries and implementing staff and partners to effectively guide, manage and implement development initiatives.

Components of a functional monitoring, evaluation and learning system

The identification of the key components of an MEL system and the mechanism of collaboration between the components is fundamental in designing a trustworthy, timely, relevant and reliable system (Mtshali, 2015). Applying this rationale, the World Bank identified 12 main components of a functioning monitoring, evaluation and learning system.

These components have been adopted by governments, NGOs and private organizations in measuring performance (Görgens and Kusek, 2010). The 12 component approach was formally adopted by USAID (2009) for their MEL capacity-building efforts (see Figure 11.1).

While any programme can apply the 12 components, it is important to note that the 12 components are not 12 implementation steps. They are not intended to be implemented sequentially; however, to have an effective M&E system, all the components need to be present and working to an acceptable standard.

In their book "Making Monitoring and Evaluation Systems Work" Görgens and Kusek (2010) explained that these 12 components could be applied to a national MEL system or to a sub-national (decentralized) MEL system or to the MEL system of an individual or private organization. Görgens and Kusek (2010) remarked that when developing plans for strengthening an MEL system, stakeholders can focus on any of the 12 components at any level of the MEL system.

Görgens and Kusek (2010) noted that this framework of MEL components can be used to assess the strengths of an organization's MEL system by assessing the strengths of each of these components using diagnostic tools that ask a series of questions about each of the components. In the context of this chapter, the 12 main components of an MEL system proposed by the USAID (2009) have been re-categorized into key components to assess the status of MEL in some selected SGCs in SSA.

Figure 11.1 The 12 Components of a Functional MEL System

1.	Structure and organizational alignment for MEL systems
2.	Human capacity for MEL systems
3.	MEL partnerships
4.	MEL plans
5.	MEL work plans with costs
6.	Advocacy, communication and culture for MEL systems
7.	Routine monitoring
8.	Periodic surveys
9.	Databases useful to MEL systems
10.	Supportive supervision and data auditing
11.	Evaluation and research
12.	Using information to improve results

Source: adapted from USAID, 2009

The status of MEL in selected science granting councils in sub-Saharan Africa

The purpose of the MEL status assessment was to provide insights into the current state of MEL capacity of the SGCs. It aimed to provide an understanding of the key MEL components; identify lessons and opportunities; and contribute to the enhancement of MEL as a project management tool.

Methodologically, the study was conducted across seven SGCs in SSA, particularly Côte d'Ivoire (PASRES), Senegal (La Direction du Financement de la Recherche Scientifique et du Développement Technologique – DFRSDT), Burkina Faso (Fonds National de la

Recherche et de L'Innovation pour le Développement – FONRID), Ghana (Ministry of Environment, Science, Technology and Innovation – MESTI), Malawi (National Commission for Science and Technology – NCST), Botswana (Department of Research, Science and Technology – DRST), and Mozambique (Fundo Nacional de Investigação – FNI). The assessment was initially meant for three francophone SGCs – Côte d'Ivoire (PASRES), Senegal (DFRSDT) and Burkina Faso (FONRID)) – but was later extended to cover all the 15 anglophone SGCs under the SGCI project. Seven responses were received out of the 15 SGCs under the SGCI project. The relatively low response rate meant that findings could be quantified only to a limited extent.

The assessment was conducted using a participatory rapid assessment approach. The information used for analysis came from four main sources: document reviews, field interactions, online surveys and interviews which involved MEL officers, project officers and different categories of people that are in one way or another involved in MEL activities in the SGCs.

The data was collected using a Capacity Assessment Tool (CAT) developed around the 12 key components of MEL. The CAT was based on a self-assessment approach where the representatives of the SGCs were required to reflect on their strengths, weaknesses, opportunities and threats.

Much of the data from the assessment were in textual form, resulting from interviews, meetings and document reviews. The quantitative data gathered from the survey was analysed using Microsoft Excel to generate a MEL Wheel[3] (Spider chart) which illustrates the key issues that address the objectives of the study.

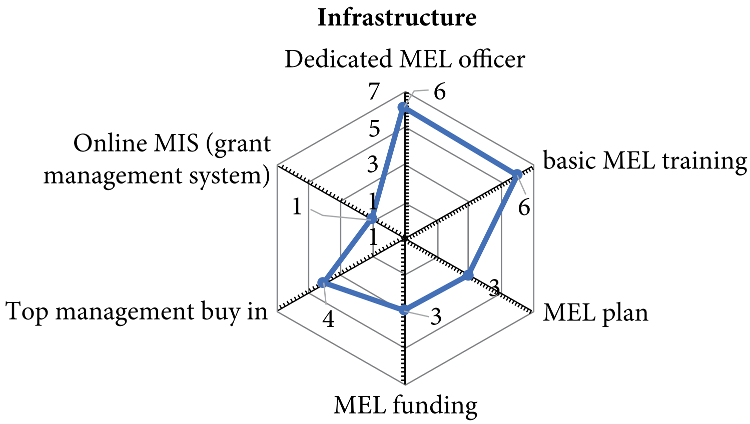
Findings from the MEL status assessment

This sub-section presents the discussion of the results of the MEL status assessment study. The section is divided into two main parts, with the first covering MEL infrastructure assessment while the second touches on the key components of MEL. The findings are presented using a MEL Wheel (spider chart) showing the collective picture of MEL capacity across all the seven SGCs assessed.

Infrastructure

One of the key aspects of understanding the way in which MEL systems work within an organization is to assess the infrastructure in place to undertake MEL functions. Under infrastructure, the study assessed the following: the availability of dedicated MEL staff to undertake MEL activities; MEL plan; online grant management system; MEL funding; the capacity of MEL staff; and the buy-in of top management to support MEL activities.

Figure 11.2 Infrastructure



Source: Authors

1. **Staff capacity**

   Figure 11.2 presents a snapshot of MEL infrastructure available within the seven SGCs. The results indicate that the majority of the SGCs (six out of seven) have in place dedicated staff to fulfil the mandate of the MEL functions. However, further probing through interviews revealed that monitoring, evaluation, and learning roles, for most SGCs, is part of the responsibilities of programme managers.

   Assigning MEL responsibilities to programme managers is a very common arrangement among the SGCs assessed. Some respondents attributed this to the inadequacy of funds to hire extra staff to handle MEL activities. According to the respondents, mainstreaming MEL responsibilities enables SGCs to maximize, in a very cost-effective manner, the impact of MEL within the SGCs.
2. **Skills and training**

   Ensuring that MEL staff are adequately equipped to make informed decisions about the use of specific tools and processes is essential to building and maintaining a strong MEL system (Basheka and Byamugisha, 2015)"title-short":"The state of monitoring and evaluation (M&E. The results in Figure 11.2 show that the majority (six out of seven) of MEL staff across the seven SGCs have undergone some basic or fundamental training in MEL. The SGCI collaborating technical agencies (CTAs) – the New Programme for Africa's Development (NEPAD) and the Southern African Research and Innovation Management Association (SARIMA) – were cited by the respondents as key partners in delivering MEL training and technical assistance.

However, despite undergoing basic training in MEL, nearly all the respondents indicated the need for additional training and (or) technical support of one type or another. When asked about what MEL area they needed strengthening in, more than half of the respondents cited the Theory of Change.

3. **Funding for MEL activities**

Most respondents did not indicate that funds were a constraint to MEL operations. However, when asked about the percentage share of MEL to the total budget of the council, the results revealed that the levels of funding towards MEL were 2 per cent or less. While there are no hard and fast rules on what the norm in percentage terms should be, this appears to be somewhat on the lower side.

It is important to note that more than half of the respondents did not or could not provide information on the size of the overall MEL budget. One explanation offered was that some MEL costs came out of project management costs, and specific breakdowns were not readily available. Lai, Hancock and Muller-Praefcke (2012) argued that the lack of clarity and transparency on MEL budgetary allocations could impact negatively on MEL planning and implementation. It could also be symptomatic of a lack of priority accorded to MEL by top management (Lai, Hancock and Muller-Praefcke, 2012).

4. **MEL guide or plan**

The MEL plan is the fundamental document that details a programme's objectives, the interventions developed to achieve these objectives and describes the procedures that will be implemented to determine whether or not the objectives are met. To achieve the desired goal of an MEL plan, it is essential to involve stakeholders in its development. In our status assessment of MEL plans or guidelines, there appears to be a general lack, awareness of or access to MEL guidance and reference materials among the SGCs. When asked about the existence of MEL guidelines, the majority of respondents (four out of seven SGCs) reported not to have any sort of guiding documents to inform their practice of MEL. Organizational strategic plans were cited as the closest project/programme guiding documents.

The three SGCs that reported to have an MEL plan in place indicated that the MEL guidelines are developed at the national level (with little institutional/staff/stakeholder participation) and (or) at the project level for funded projects (donor requirements). Furthermore, we found that these MEL plans or guidelines are mainly geared towards financial monitoring and accountability, and operational management with little attention to tracking project/programme impact and institutional performance.

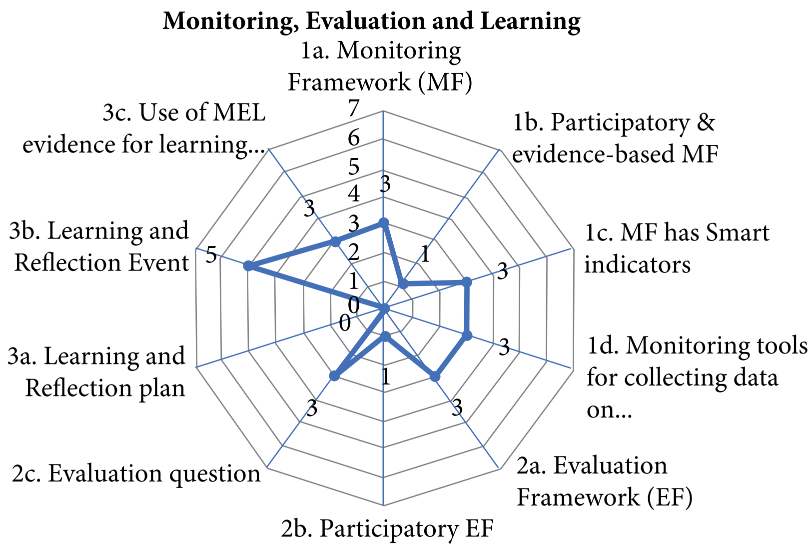
In summary, factors behind the availability and use of MEL guidance materials are a bit unclear among the SGCs. But what is apparent from the assessment is a need across the SGCs for MEL guidance and technical support on a range of MEL topics, in particular the Theory of Change.

5. **Utilization of technology**
In recent years, the MEL process is turning into a spry new creature with technology. With increasing emphasis on real-time feedback, more rigorous data collection, and quantifiable results, the spread and use of information and communication technologies (ICT) in monitoring, evaluation and learning (ICT4MEL) have sparked a massive interest. In our assessment, the respondents were asked: "whether they have in place online MEL systems". Despite the clear benefits of integrating technology into the MEL and grant management processes, the results in Figure 11.2 show that only one SGC has an online MEL or grant management system in place. Generally, SGCs generate and keep information manually (in written form, e.g. progress reports). This makes it difficult for others to access it, as information is often kept in the office of the MEL officer or programme manager only.

How MEL is organized in the seven selected SGCs

This sub-section discusses how MEL is organized within the seven selected SGCs. Here, the assessment is presented under three broad categories: the first category examines how monitoring is conducted within the selected SGCs; it assesses the availability of monitoring frameworks, stakeholders' involvement in designing the monitoring framework, and its indicators as well as the availability of monitoring tools for collecting data against indicators. The second and third categories touch on the tools and processes of evaluation and learning, respectively.

Figure 11.3: Overall Assessment of the Strengths of MEL for Seven SGCs in SSA



Source: Authors

1. **Monitoring frameworks**

   Frameworks are key elements of MEL systems that depict the components of a project/programme and the sequence of steps needed to achieve the desired outcomes. Our assessment revealed that out of the seven SGCs, only three had monitoring frameworks in place – this includes logical frameworks and results-based frameworks. Through our desk review of organizational documents, we noticed that more innovative frameworks (e.g. Theory of Change, Outcome Mapping, Most Significant Change, etc.) are not yet widespread among the SGCs. None of the SGCs assessed had a Theory of Change that comprehensively illustrates how and why desired changes are expected to happen.

   Just like the development of MEL guidelines – as discussed in the previous section – our results showed that the designing of monitoring frameworks among the SGCs assessed are non-participatory. Monitoring frameworks are normally developed at the national level (with little institutional/staff/stakeholder involvement) and (or) at the project level for funded projects (donor requirements).

The results of our follow-up question ("does your monitoring framework have SMART indicators"?) showed that all the three SGCs that reported to have monitoring frameworks also have in place "SMART" indicators at all levels, thus input, output, and outcome levels. In this context "SMART" is an acronym that stands for: Specific, Measurable, Appropriate, Realistic and Timely.

When asked if there exist monitoring tools for collecting data against the indicators, all the three SGCs that reported to have monitoring frameworks indicated that they have monitoring tools to collect data against the indicators. Through our desk review, we discovered that the methodologies used for data collection and processing within the SGCs are mainly conventional.

2. **Evaluation frameworks**

   Regarding evaluation frameworks, we found that out of the seven SGCs that responded to the survey, three reported to have evaluation frameworks with detailed evaluation questions that are linked to outcomes/outputs indicators, data sources, and data collection methods. Further assessment showed that there is little stakeholders' involvement in designing of these frameworks. This result confirms our earlier findings regarding MEL plans and monitoring frameworks.

3. **Learning and reflection plans**

   Learning has become a critical aspect of MEL and organizational development. Organizations are expected to "learn" from M&E evidence to ensure that they keep up with increasingly challenging operational environments as well as make informed decisions. As presented in Figure 11.3, the results from the survey showed that none of the SGCs have in place a structured plan for learning and reflection. Additionally, the respondents expressed their doubts about the practical use of evidence from MEL analysis for strategic decision making.

   Furthermore, our follow-up analysis indicated that, despite not having well-defined learning frameworks, most SGCs (five out of seven) have regular (e.g., quarterly, semi-annual and annually) reflection events to openly and critically discuss expected and unexpected project outcomes.

Lessons from the MEL status assessment in the seven SGCS

Based on the MEL status assessment presented above, several specific areas were underscored as strengths, weaknesses and opportunities. This sub-section synthesises the experiences from the seven SGCs relating to several notable lessons (strengths, weaknesses and opportunities) from the assessment.

1. **Human capacity: some staff in place to carry out MEL activities, but inadequate in terms of numbers and capacities**
   One of the key strengths identified (across all the seven SGCs assessed) regarding human capacity is the availability of staff with basic training to carry out MEL activities – six out of the seven SGCs assessed reported having MEL staff with fundamental training in MEL in place. However, it was noted that there is a common practice among the SGCs where existing programme managers are assigned with MEL responsibilities in addition to their regular roles. The downside to this approach is that, because the programme managers have other functions to perform, it increases their workloads and MEL activities may end up not taking place at all or may take place in silos (even in councils where there are shared guidelines and proceedings for MEL). According to Ferreiro (2017), if this occurs, knowledge and learning will not transcend from the level of the individual or the specific unit in which that individual works to the level of the organization (or, if it does, it happens only occasionally rather than systematically). Ferreiro (2017) argued that such dynamics can be reinforced by the diverging requirements of donors. As MEL in this type of system is primarily programme-centred, the diverging requirements of donors may impose extra difficulty when attempting to ensure consistency in MEL approaches.

   Further, limited capacities in MEL skills, as well as poor awareness of MEL tools, were noted as a challenge both to system implementation and utilization. Even with staff in place (six out of seven SGCs), the assessment revealed that MEL activities in most SGCs were not implemented effectively.
2. **Funding for MEL is inadequate and unclear**
   Although the majority of the respondents did not indicate that funds were a constraint to MEL operations, issues regarding MEL funding were unclear. For SGCs that responded to the question on the size of the MEL budget, this worked out at 2 per cent or less of the total

budget of the council. Despite getting a very low response on the per cent share of MEL in the total budget, we believe that 2 per cent is low and could be an underestimation of the total funds spent on MEL-related activities. The reason for this is that estimates tend to overlook the "hidden" MEL costs. That is, an expenditure that by nature is more difficult to allocate to MEL efforts but that does have an impact on the overall implementation of the MEL system.[4] Not having in place a clear budget line for MEL activities can negatively affect MEL operations. It is therefore essential for SGCs to allocate funds to MEL activities in their budgeting.

3. **MEL planning/guiding document is non-participatory and for most SGCs, non-existent**

   From the assessment, there seems to be a general lack, awareness of or access to, MEL guidance and reference materials. In most SGCs, MEL planning is non-participatory and often designed at the national level and (or) by funding organizations as part of the funding requirements with little or no staff and stakeholder involvement. According to Clark et al. (2004), if the MEL guiding or planning document is designed in a participatory manner, it increases ownership, project success, transparency and accountability.

   Similar lessons were drawn from our analysis of other MEL guiding documents – Monitoring, Evaluation and Learning Framework – where for most SGCs, these frameworks were developed in non-participatory ways or were non-existent. Further, we noted that the adoption of innovative frameworks such as Theories of Change, Outcome Mappings, and Most Significant Changes are not yet widespread among the SGCs.

   On the positive side, it is noteworthy to mention the following key strengths among the three SGCs that reported to have MEL frameworks in place:

   (i) All three SGCs have SMART indicators at all levels – input, output, outcomes and impact level
   (ii) All three SGCs have monitoring tools in place for collecting data against the indicators
   (iii) All three SGCs have detailed evaluation questions that are linked to input/outcomes indicators, data sources and data collection methods.

4. **Adoption of new information management technologies is lagging (monitoring is done manually)**
   The use of innovative information management technologies, such as online grant management and digital MEL systems to facilitate data collection, analysis and reporting appears to be lagging in nearly all the SGCs assessed. Methodologies used for data collecting, reviewing and processing grant information as well as reporting on project progress and success are mainly manual and conventional. This makes it difficult for SGCs to fully ensure transparency and accountability.
5. **Learning and reflection events are organized regularly but there is a lack of demonstrable support for MEL in decision making**
   One of the key strengths identified in our analysis is the reflection and learning culture across the SGCs assessed. Learning and reflection events are organized regularly (e.g., quarterly, semi-annually and annually). At these events, project successes, failures and unexpected outcomes are critically reviewed and documented. Despite the remarkable learning and reflection culture across the SGCs, it was observed that most SGCs do not rely on evidence from MEL in making strategic decisions. This is partly because decisions are normally taken at the national level with little staff and stakeholder participation.

Institutional policy recommendations

The status assessment yielded a wealth of information on how MEL is organized in the seven SGCs. The assessment revealed limitations and weaknesses in the current MEL approaches and practices, which require addressing if the utility of MEL is to be better asserted and potential pitfalls avoided. Against this background, the present section discusses major policy recommendations aimed at strengthening MEL processes within the SGCs to provide relevant, timely and reliable information.

Senior-level buy-in to support MEL

Leaders of SGCs must lead the development and sustaining of MEL frameworks and systems. Engaging the senior leadership within governments ensures that MEL processes and activities are valued, understood, accepted and supported by all stakeholders within the council. It also promotes commitment and ensures that adequate funding is available.

Proper designing of MEL frameworks and MEL systems

Leaders of SGCs should facilitate the redesign (if already in place) or development of institutional MEL guiding documents that set out the MEL frameworks, activities, tools, indicators, budget, reflection and learning processes, and MEL systems. The designing of the MEL frameworks and systems should be done in a participatory manner and in harmony and linked with national MEL plans.

Funding and human capacity needs for MEL

Leaders of SGCs should plan and properly allocate resources (financial and human) for MEL activities so that they are an integral part of the council's budget and staffing. A separate budget line should be created for MEL costs. In addition, capacity development and adequate staffing for MEL must be part of the wider human resource development within the councils. MEL skills development and knowledge enhancement should also be undertaken as part of broader institution building and human resource development programmes, as essential management and attitudinal capacity rather than as ad hoc exercises confined to MEL designated staff.

MEL frameworks with "SMART" indicators

SGC leaders are advised to develop appropriate MEL frameworks with "SMART" indicators. This should be done collaboratively with all stakeholders involved (preferably through an MEL working group) so that the framework and indicators are unanimously owned and endorsed.

Routine monitoring and data collection procedures

Leaders of SGCs must implement and institutionalize routine monitoring of the activities of the council – including both programme monitoring and financial monitoring. SGCs should expand their use of innovative approaches to MEL, using ICT-enabled tools to harness the power of technology to reduce the costs of gathering data. The transition from manual to online MEL and grants management systems will make data collection, analysis and reporting more effective and efficient.

Critical reflection and learning processes and events

Leaders of SGCs should institutionalize reflection and learning processes as these will enable staff and stakeholders to meet regularly (e.g. quarterly, semi-annually and annually) to critically reflect on and discuss the successes, failures, expected and unexpected outcomes, problems, and lessons learned from MEL reports for future improvement. Lessons learned from these events should be well documented and widely shared within the SGCs.

Conclusions

Well-designed MEL systems are a critical and integral part of measuring the performance of national science systems. SGCs in Africa would derive several benefits from strengthening their MEL systems – including but not limited to improved accountability to funders, access to basic operational information to support management decisions, access to information to guide strategic decisions concerning the research programmes, generating new insights, and building the capacities of the stakeholders of national science systems. Measuring the effectiveness of national science systems in SSA is important because it provides justification for investments made and for increasing those investments, as necessary. The evidence of the effectiveness of national science systems would also help African countries to invest in the most impactful research projects to solve their developmental problems. In addition, such evidence would entice other development partners to contribute towards the strengthening of Africa's national science systems.

Notes

[1] The SGCI is a multi-funder initiative that aims to strengthen the capacities of 15 science granting councils in Sub-Saharan Africa in order to support research and evidence-based policies that will contribute to economic and social development.

[2] The Monrovia Strategy, July 1979, the Lagos Plan of Action (LPA) for the Economic Development of Africa (1980–2000), and the Science, Technology, and Innovation Strategy for Africa 2024 (STISA-2024).

[3] The M&E Wheel is a widely used self-assessment and planning tool for change initiatives and organization capacity building. It is used to assess what organizations are doing and how they are doing it.

[4] A recent report addressing MEL systems in NGOs in the UK showed that when unpacked (i.e. more systematically including hidden costs), the average organizational level of MEL spending was around 17.5% (cf. an initial estimate of 5% to 10% based on formal budget allocations). This rose to some 20% when considering the proportion of project-based funding going towards MEL. See: https://www.bond.org.uk/data/files/publications/Investing_in_MEL.pdf

References

Annecke, W., 2008. Monitoring and evaluation of energy for development: The good, the bad and the questionable in M&E practice. *Energy Policy* 36, pp.2839–2845.

Atkinson, D., Wellman, G., Xaba, M., 2003. *A monitoring and evaluation manual for municipal water and sanitation management.* Water Research Commission Report 1287/1/03. Pretoria: Water Research Commission.

Basheka, B.C., Byamugisha, A.K., 2015. *The state of monitoring and evaluation (M&E) as a discipline in Africa: From infancy to adulthood?* [Online]. Available at: https://repository.up.ac.za/bitstream/handle/2263/58169/Basheka_State_2015.pdf?sequence=1 (Accessed 31 August 2020).

Braun, D., 1993. Who governs intermediary agencies? Principal-agent relations in research policy-making. *Journal of Public Policy,* 13, pp.135–162.

Caswill, C., (2004). Turbulent delegation: The governance of European research councils and research policy. In: S MacGregor (ed.) *The Impact of Social Science Research on Social Policy: Governance and Management.* Swindon: ESRC

Chataway, J., Dobson, C., Daniels, C., Byrne, R., Hanlin, R., Tigabu, A., 2019. Science granting councils in Sub-Saharan Africa: trends and tensions. *Science and Public Policy*, 46(4), pp.620–631, https://doi.org/10.1093/scipol/scz007

Chux, D., Philippe, M., Almamy, K., 2018. *Evaluating Public Policies in Africa: insights from the Science, Technology, and Innovation Strategy for Africa 2024 (STISA-2024).* [Blog]. Available at: https://blogs.sussex.ac.uk/policy-engagement/files/2019/02/2018-12-STISA-PB-Chux-Daniels.pdf (Accessed 1 September 2020).

Clark, M., Sartorius, R., Bamberger, M., 2004. *Monitoring and evaluation: Some tools, methods and approaches*. Washington, DC: World Bank.

Ferreiro, C.H., 2017. *Monitoring, Evaluation and Learning Practices of Local Governments and Local Governments Associations*. [Online]. Available at: https://issuu.com/uclgcglu/docs/cib_ucgl_2017 (Accessed 31 August 2020).

Frølich, N., 2008. *The politics of steering by numbers: debating performance-based funding in Europe*. NIFU STEP.

Geuna, A., Martin, B.R., 2003. University research evaluation and funding: An international comparison. *Minerva* 41, pp.277–304.

Görgens, M., Kusek, J.Z., 2010. *Making monitoring and evaluation systems work: A capacity development tool kit*. Washington, DC: The World Bank.

Hicks, D., 2012. Performance-based university research funding systems. *Research Policy,* 41, pp.251–261.

Hu, A.G., 2015. Innovation and Economic Growth in East Asia: An Overview. *Asian Economics Policy Review*, 10, pp.19–37.

Karver, J., Kenny, C., Sumner, A., 2012. *MDGs 2.0: What goals, targets, and timeframe?* IDS Working Paper. pp.1–57.

Kawonga, M., Blaauw, D., Fonn, S., 2012. Aligning vertical interventions to health systems: a case study of the HIV monitoring and evaluation system in South Africa. *Health Research Policy and Systems*, 10, p.2. doi: 10.1186/1478-4505-10-2

Lai, K., Hancock, J., Muller-Praefcke, D., 2012. *Stocktaking of M&E and Management Information Systems Selected agricultural and rural development projects in South Asia*. Rome: FAO Investment Centre.

Lee, H., Lee, C., Seol, H., Park, Y., 2008. On the R&D priority setting in technology foresight: a DEA and ANP approach. International Journal of Innovation Technology and Management. 5, pp.201–219.

Mackay, K., 2007. *How to build M&E systems to better support government*. Washington, DC: World Bank.

Mouton, J., Gaillard, J. and Milandré Van Lill, M., 2015. Functions of science granting councils in Sub-Saharan Africa. In Cloete, N., Maassen, P. and T. Bailey (eds.) *Knowledge production and contradictory functions in African higher education. Cape Town: African Minds*, pp.148–170.

Mtshali, Z., 2015. *A review of the monitoring and evaluation system to monitor the implementation of early childhood development within Gauteng Department of Health* (PhD Thesis). Stellenbosch: Stellenbosch University.

NEPAD, 2014. *African Innovation Outlook (AIO-II)*, Pretoria: NEPAD Planning and Coordinating Agency (NPCA).

OECD, D., 2002. *Evaluation and Aid Effectiveness, Glossary of Key Terms in Evaluation and Results Based Management*. Paris: OECD, Development Assistance Committee.

OECD, E., 2018. *Oslo Manual 2018. Guidelines for Collecting and Interpreting Innovation Data*. 3rd ed. Paris: OECD.

Patton, M.Q., 2013. Inquiry into Appreciative Evaluation. *New Directions For Evaluation*, 100, pp.85–98. https://doi.org/10.1002/ev.102

Pianta, M., 2017. Innovation and economic change. *Economics of Innovation and New Technology*. 26, pp.683–688.

Reale, E., Avramov, D., Canhial, K., Donovan, C., Flecha, R., Holm, P., Larkin, C., Lepori, B., Mosoni-Fried, J., Oliver, E., 2017. A review of literature on evaluating the scientific, social and political impact of social sciences and humanities research. *Research Evaluation*, 27, pp.298–308.

Reinhardt, A., Milzow, K., 2012. *Evaluation in research and research funding organisations: European practices*. Strasburg: ESF Member Organisation Forum on Evaluation of Publicly Funded Research.

Rip, A., 2000. Higher forms of nonsense. *European Review*, 8(4), pp.467–485. https://doi.org/10.1017/S1062798700005032

Samdi, 2007. *Capacity-building for Monitoring and Evaluation in the South African Government*, Pretoria: Government Printer.

Sandström, U., Van den Besselaar, P., 2018. Funding, evaluation, and the performance of national research systems. *Journal of Infometrics*, 12, pp.365–384.

Scriven, M., 2007. *Key evaluation checklist (KEC).* [Online]. Available at: http://michaelscriven.info/images/KEC_7.25.2013.pdf (Accessed 31 August 2020).

Stephan, P.E., 2012. *How economics shapes science*. Harvard University Press Cambridge, MA.

Tapper, T., Salter, B., 2003. Interpreting the process of change in higher education: The case of the research assessment exercises. *Higher Education Quarterly* 57, pp.4–23.

Tijssen, R., Hollanders, H., 2006. *Using science and technology indicators to support knowledge-based economies*. Maastricht: UNU-MERIT.

UNESCO, 2010. *Measuring R & D: challenges faced by developing countries*. Montreal: UNESCO Institute for Statistics.

UNESCO, 2016. *UNESCO Science Report: Towards 2030*, (2nd ed.) Paris: UN Educational, Scientific and Cultural Organization.

USAID, 2009. *12 Components Monitoring & Evaluation System Assessment*. [Online]. Available at: https://www.unaids.org/sites/default/files/sub_landing/files/1_MERG_Assessment_12_Components_ME_System_2.pdf (Accessed 31 August 2020).

Wanjiru, W.E., Kimutai, G., 2013. *Determinants of Effective Monitoring And Evaluation Systems In Non-Governmental Organizations Within Nairobi County, Kenya*. Kenyatta University Masters Dissertation. Unpublished Thesis.

Woodhill, J. 2006. "M&E as Learning: Rethinking the Dominant Paradigm." In de Graaff, J.,Cameron, J., Sombatpanit, S., Pieri, C. and J. Woodhill. 2006. *Monitoring and Evaluation of Soil Conservation and Watershed Development Projects*, Enfield: World Association of Soil and Water Conservation. pp.103-122.

Index

In recent years a significant amount of attention has been placed on the role of science, technology and innovation for Africa's social and economic transformation. This book builds on the efforts made in this area and argues that more needs to be done to strengthen African Science Systems. We use the term 'Science' and 'Science Systems' recognising that what is important is not just the study and accumulation of knowledge but also its application and use. This book brings together the findings of research conducted by academics, practitioners and policy makers during the first phase of the Science Granting Councils Initiative. It argues that building stronger and more broadly defined science systems requires recognition and critical study of relevant concepts and theories. It also focuses on key areas that require empirical study and analysis. This book focuses specifically on the key role of what are known as 'Science Councils' in Africa as providing a mediating role between the actors, organisations and institutions involved in African Science Systems. It also argues that – in order for Science Councils to be more effective- there is a need for more 'science on science' or the study of how science systems function and how they can be strengthened to assist African countries reach their social and economic development goals.

> *"Building science [Science, Technology and Innovation] systems is perhaps the most formidable challenge facing African countries for several reasons. The science gap between Africa and the advanced regions of the world is huge and it is widening by the day. Unfortunately, it does not appear as if the prevailing policy recognition of the role of science in development is taken too seriously in Africa. Yet, there is a glimmer of hope in the institutions set up for the building and rejuvenation of STI systems. This book explores the hope that is there for STI systems in the science granting councils in Africa. Importantly, the book discusses and analyses the experiences and lessons from these councils in some African countries and points the way to enhancing the building of science systems on the continent. In an age when sustainable development has become a dominant paradigm, understanding the role of science granting councils in development is almost an urgency for African countries."*
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> – Prof. George Owusu Essegbey Chief Research Scientist, Science and Technology Policy Research Institute (STEPRI), Council for Scientific and Industrial Research (CSIR), Accra, Ghana

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