NEW APPROACHES FOR FUNDING RESEARCH AND INNOVATION IN AFRICA – RESEARCH PAPER

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New Approaches for Funding Research and Innovation in Africa

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The African Technology Policy Studies Network (ATPS) is a transdisciplinary network of researchers, policymakers, private sector actors and the civil society promoting the generation, dissemination, use and mastery of Science, Technology and Innovations (STI) for African development, environmental sustainability and global inclusion. In collaboration with like-minded institutions, ATPS provides platforms for regional and international research and knowledge sharing in order to build Africa's capabilities in STI policy research, policymaking and implementation for sustainable development.

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About Science Granting Councils Initiative

The Science Granting Councils Initiative in Sub-Saharan Africa (SGCI) seeks to strengthen capacities of Science Granting Councils (SGCs) in Eastern, Southern, Central and West Africa in order to support research and evidence-based policies that will contribute to economic and social development. It is 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).

The objectives of SGCI are to strengthen the ability of participating SGCs to 1) manage research; 2) design and monitor research programmes, and to formulate and implement policies based on the use of robust science, technology and innovation (STI) indicators; 3) support knowledge transfer to the private sector; and; 4) establish partnerships with one another, and with other science system actors. The implementation of these objectives is achieved through regional training courses, individualised on-site training sessions, on-line training, webinars and, collaborative research. The SGCI works with 15 councils in Kenya, Rwanda, Uganda, Tanzania, Ethiopia, Cote d'Ivoire, Burkina Faso, Senegal, Ghana, Zambia, Mozambique, Botswana, Malawi, Namibia and Zimbabwe.

The SGCIs principle output include 1) more effective research management practices among Councils, 2) 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 indicators, 3) increased knowledge transfer to the private sector and 4) increasingly coordinated and networked Councils. More effective Councils are expected to strengthen national science systems, and ultimately lead to nationally-led research that contributes to development in participating African countries.

About the African Technology Policy Studies Network (ATPS)

The African Technology Policy Studies Network (ATPS) is a trans-disciplinary network of researchers, policymakers, private sector actors and the civil society promoting the generation, dissemination, use and mastery of Science, Technology and Innovations (STI) for African development, environmental sustainability and global inclusion. ATPS has over 1,300 members and 3000 stakeholders in over 51 countries in 5 continents with institutional partnerships worldwide. We implement our programs through members in national chapters established in 30 countries (27 in Africa and 3 Diaspora chapters in the Australia, United States of America, and United Kingdom). In collaboration with like-minded institutions, ATPS provides platforms for regional and international research and knowledge sharing in order to build Africa's capabilities in STI policy research, policymaking and implementation for sustainable development.

About Scinnovent Centre

The Scinnovent Centre is a science, technology and innovation (STI) policy think tank registered in Kenya as a not-for-profit company. Their preliminary concern is that despite advancements in science, technology and innovation (STI), poverty levels in Africa are increasing; environment degradation is worsening; the ecosystem has become more fragile; sustainability has been compromised and livelihoods threatened.

So they ask three big questions: Why have the developments in science, technology and innovation not made any significant difference in African development? Why have STI policies not translated into practical change on the ground? How come pockets of success piloted across countries have not scaled?

Acknowledgement

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Abstract

It is without doubt that African countries' individual and collective aspirations of economic development through research and innovation are in line with trends worldwide. Similarly, like elsewhere in different parts of the world, African countries have been exploring different approaches, institutional reforms, models and mechanisms towards more efficient and effective funding and financing of research and innovation. This commissioned paper derives from a study which used a combination of primary and secondary data sources to inform current debates and reviews on re-organization of research and innovation funding in Africa. The study specifically sought to identify and analyse "new approaches for funding research and innovation in Africa". Study findings show that the importance of research and innovation is rated medium to high and is increasing in most of the African countries. This is demonstrated by practice, institutional and policy provisions for science, technology and innovation (STI), which have been instituted in the last few years. A number of dynamic new funding models have been developed, adopted and deployed in countries and sectors to deal with the realities of decreasing funding for research and innovation from traditional sources. These models, encompassing partnerships, co-funding and multi-disciplinary approaches, seek to ensure context-driven, efficient and effective utilisation of scarce resources. Challenges ranging from insufficient political will to lack of implementation plans and uncoordinated approaches to STI were said to be stalling the expansion and sustainable deployment of the new funding models.

This study advances a number of recommendations on how science granting councils, national governments, private and no-profit sectors and development partners can leverage their access to global intellectual resources and convening power to further strengthen availability of capabilities and funding for different stages of the research and innovation value chain.

1.0 Introduction

The innovation principle which argues that innovation is the "single most important driver of societal prosperity and is indispensable for sustainable development and economic growth" (ERF, 2015) underscores the important role that knowledge and innovation generation, translation, and commercialisation play especially as countries transition to the knowledge-based economy (KBE). This is important for African countries, which need to rapidly industrialise and achieve economic development. However, generation and translation of research and innovation into useful economic growth depends on sustained and focused investment. Depending on the stage of activity on the research-innovation-commercialisation spectrum, investment approaches range from government investment into research and innovation as a public good; what Mazzucato (2011) calls the entrepreneurial state; to philanthropy and other social investors as well as the state in the "valley of death"; to commercially driven financial institutions funding of entrepreneurship. This study sought to identify and analyse exemplar case studies of new approaches to funding research and innovation from African countries and across the world. The intention was to demonstrate the funding mechanisms and models, the institutional architecture as well as policy and strategy environments that the case studies crystallise which can be considered by African countries after contextualisation to local realities. We are aware that models have economic, geographic and other political economy complexities and therefore a direct juxtaposition would lead to failure.

What this paper intends to do is to unpack the rationale behind the funding mechanisms and models so that African governments, Science Granting Councils, the private sector, philanthropy organisations and foundations, amongst others, can learn from elsewhere in their separate and collective efforts to sustainably fund research and innovation on the continent.

We consider research as the robust knowledge generation activities by a broad range of actors using the scientific method carried out in universities, research institutions as well as the private and public sectors. Recognising this broad range of players in the research terrain is important for crafting policies, strategies and funding mechanisms that harness the potential of these knowledge generators and others in innovation. In this paper, we adopt the OECD/Eurostat (2005) definition of innovation as the introduction of new or significantly improved products (goods or services), processes, organizational methods, and marketing methods in internal business practices or in the open marketplace. For the purpose of this paper and especially looking at the need of Africa to harness research and innovation for rapid economic development, we adopt Tait et al (2017)'s definitions of disruptive and incremental innovations. This distinction is important because the dynamics of financing, regulating and governing incremental and disruptive innovations are different. We will discuss this further in the case studies in section 4. Tait et al (2017) describe incremental and disruptive innovation as follows:

> **"Incremental innovation** fits well with the current business model of a firm. It generates competitive advantage and contributes to the economy through more efficient use of resources, or elimination of wasteful or environmentally damaging practices. It is likely to have a pre-existing regulatory framework in place, will not lead to sectoral transformations and is unlikely to lead to stakeholder or citizen concerns or opposition".
>
> **"Disruptive innovation** involves discontinuities in innovation pathways, requires new areas of research and development, creation of new modes of production and new markets. It can lead to sectoral

transformations, the displacement of incumbent companies, and the creation of entirely new sectors with significant societal and economic benefits. There may be no obvious regulatory precedent to govern potential human and environmental safety issues, in some cases it may lead to citizen and stakeholder concerns from an early stage of development. For a disruptive innovation, there may be no existing business model on which a company can build, and there may also be a need to create a new value chain, or to create a new role in an existing value chain".

Disruptive innovations tend to produce innovative technologies over which intellectual rights property claims can be made. However, because of absence of clear pathways to market and the lack of fully developed or co-evolved value chains, they need state intervention through funding and institutional infrastructure; innovation brokers to temporarily support and create a conducive innovation ecosystem that allows innovative technologies to take root on the market (Banda et al, 2018). Research and innovation that generates disruptive innovations is not usually attractive to traditional funders and is the main candidate for new and innovative new funding models universally. Omidvar et al (2014) assert that with innovative technologies such as regenerative medicine, the most viable funding models are characterised by significant public or philanthropic components. On the other hand, funding research and innovation that generates incremental innovations will be less challenging because of existing pathways to market exist, value chains are functional and the technology would have been adequately de-risked.

Financing research and innovation for sustained economic growth and industrial development for Africa requires a joined-up thinking of the knowledge and innovation generation – translational activities – commercialisation linkages/value chain. Funding only one aspect of this value chain will not optimise the benefits that innovation gives to economic growth. From a financing perspective using literature we split the three phases to build a conceptual framework (Fig 3) that links investing in

public goods – solving the valley of death/market failure challenge – and making financial systems work for commercialisation and establishment of innovations on the market. Key players in these three phases are governments, philanthropy, angel investors, impact investors, venture capitalists and various other financial system actors and institutions.

We are cognisant of the fact that research and innovation occurs in public, private and non-profit sectors; increasingly in the public-private partnership arena especially for medical health technologies in Africa. Universities are a key public actor in research and innovation, which is why the funding of research and innovation requires an understanding of the university-industry-public sector complex and how institutional architectures, policy and strategy designing are critical to supporting research and innovation, for example through innovative procurement for emerging technologies and new-to-geography innovations (Chataway et al, 2016).

Many African countries face immense problems of large proportions of unemployed youths. Young people (15 to 24 years) constitute about 37% of the working age population, but account for more than 60% of all unemployed people in Africa (AfDB, 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, which 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 (Tassey, 2011). As already mentioned, the relationship between R&D and innovation is highly complex, though it is often illustrated using simplified linear models. Fig 1 below, shows iterative steps between research and innovation investments connected by learning and feedback flows both “downstream” from research to design and development, and “upstream” from the development and design to research. An opportunity for developing countries and different sectors is that innovation does not necessarily require progression through all steps in a successive, linear fashion, but rather there are multiple “entry points” to this process.

Overlap and redundancy increase the chances that an innovative idea will be funded to bring the idea from the invention stage to release as a new product or process in the marketplace.

We use Figure 1 as part of our conceptual framework in conjunction with Figure 2.

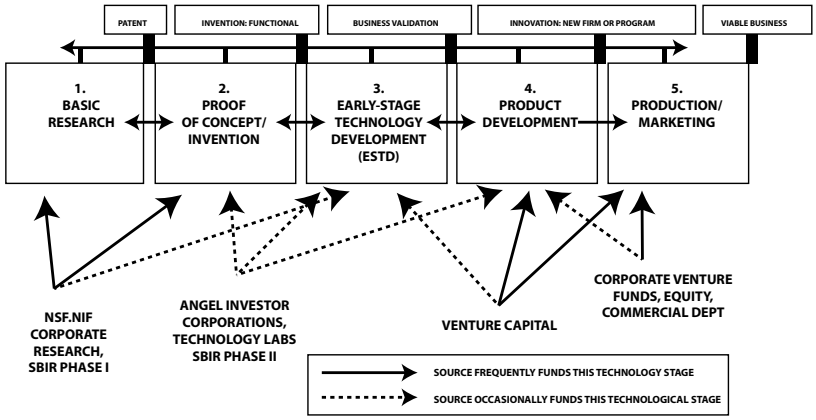

Figure 1"Upstream" and "Downstream" Steps Linking Research to Design and Product Development

Adapted from: Branscomb, L.M. and P.E. Auerswald. Between Invention and Innovation: An Analysis of Funding for Early-Stage Technology Development, 2002.

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 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). It follows therefore that due to the political and often unpredictable and dynamic nature of research and innovation, reviewing and evaluating funding approaches for research and innovation and outputs thereof cannot just follow the linear and formulaic approach characteristic of some economic tools in use, for example cost benefit analysis (Lindner, 2011). Scholars in policy-orient-

ed research agree that despite the contributions value for money tools make towards assessing impact, relevance and roles of different funding approaches, mechanisms or frameworks, a parallel and complementary suite of tools is needed to capture the role, relevance and value of such approaches from the political, social and relationship-based nature of decision-making and knowledge uptake which arises from research and innovation (Davis et al, 2008).

1.1 Problem Statement

Africa needs to industrialise and achieve rapid economic growth to improve the livelihoods of citizens and attain amongst other imperatives robust infrastructure that supports health, energy, environmental and food security as well as full employment that leverages the demographic dividend highlighted in Agenda 2063. Appropriation of new knowledge generated by contextualised research and innovation is a key driver for sustainable and inclusive socio-economic development. However, research and innovation are resource-intensive, depending to a large extent on sustainable and focused funding buttressed by an innovation ecosystem purposively designed to harness innovations and turn them into useful products and services for society. Many African countries do not yet have these conditions in place. Given the aforementioned, funding of research and innovation in Africa requires new models that take a deliberate systemic approach to building coalitions of agents and actors in innovation systems (national, sectoral, regional and technological), policy and governance design and architecture and funders that support appropriate emerging technologies and innovations.

It is now widely acknowledged that Science, Technology and Innovation (STI) plays a significant role in driving economic growth and development through enhanced industrial activities and competitiveness backed by increased production efficiencies (Oyeyinka et al, 2018; Chataway et al., 2009; NACETEM, 2010; NEPAD, 2006). While more than two-thirds of African countries have moved to design and adopt STI policies and strategies (The African Capacity Building Foundation, 2017), a majority

of the countries still lack the requisite capacity to leverage and benefit from investment in STI (Oyeyinka et al, 2018). They have not solved the challenge of sustainably funding research and innovation and as a result they are failing to effectively generate and deploy knowledge and technological innovations for socioeconomic growth (ACBF, 2017), by harnessing introduction of new as well as improvements of products and services for various economic sectors such as agriculture, mining, manufacturing, health and services. Thus, the financing challenge spans basic, applied and translational research as well as entrepreneurship (SME financing) to support commercialisation of research and innovation.

Given the complexity and expanse of literature and cultures of funding across the world, it is impossible to discuss all models of funding research and innovation. Consequently, this paper explores and discusses some exemplars of new or innovative funding models and mechanisms that may be adopted to sustainably fund research and innovation in African countries. The case studies explored are not exhaustive and we are aware of the need for contextualisation and ground-truthing for different African settings. As described earlier we circumscribed our focus to the research-translation-commercialisation spectrum, which we argue has not been treated in a systematic way in relevant policy and academic literatures focusing on Africa. Limited attention has been paid to assessing whether the funding vehicle; its structure, governance and support measures or funding models are optimal for technological and non-technological innovations in-country.

We have therefore used literature, research findings and a survey to analyse some case studies that highlight different funding models and mechanisms, and the institutional architectures that support those funding models and mechanisms and the governance and policy foundations and rationalisations that have been deployed. Thus, the paper covers the domain of science granting councils (SGCs), government, philanthropy, commercial and other social funding models for research and innovation (section 4.2).

1.1 Aim of This Paper

This paper is situated in the backdrop of declining or stagnant national and international research funding sources and the increasing need for new models to fund research and innovation highlighted in the problem statement above. African countries have an opportunity to avoid technology and development lock-in as well as path dependencies by leapfrogging infrastructure and industry challenges of pioneers through carefully integrating their transition to KBEs with achievement of SDGs and leveraging their endowments in natural resources and an imminent demographic dividend (African Union Roadmap, 2017). This is possible through context-specific and locally grounded generation of new knowledge from research and innovation. Funding these endeavours requires designing sectoral and national policies and strategies for investing in local research and innovation, for which scientific knowledge is a key component. In order to inform the current debates, reviews and re-organization of investment in African research and innovation, this paper aims to systematically identify and analyse "new approaches, mechanisms, schemes or models for funding research and innovation in Africa" paying particular attention to lessons that can be drawn from these for potential applicability in African countries. Research and innovation is a function of and leans to a great extent on knowledge-sharing and lesson-drawing, thus policy and practice processes on research and innovation in Africa can benefit from experiences elsewhere. The study on which this paper is based was guided by the following key research questions:

1. How important is the funding of research and innovation among African countries and what is the evidence to demonstrate the level of importance?

2. What are the new and innovative funding approaches (schemes, models and mechanisms) that have been applied across the world and what lessons could be drawn for African countries?

3. What historical and current factors facilitate or constrain the implementation of the funding approaches and how have/can the gains be enhanced or the challenges resolved?

4. What institutional reforms accompanied the new approaches and how could Africa re-position its own institutional architecture for enhanced research and innovation funding?

5. How are other broader issues pertinent to research and innovation broadly being taken into consideration towards more efficient and effective funding for research and innovation?

In order to gather evidence to address these questions, and as will be explained further in the methodology section, a number of methods were deployed, including literature reviews covering documents from national science councils/commissions and other funding agencies, interviews with representatives from the 15-country African Science Granting Councils Initiative[1] , and interviews with expert stakeholders from institutions such as the African Academy of Sciences and African researchers in the diaspora and Africa working in key research, academic and policy institutions.

1.2 Outline of The Paper

The rest of the paper is structured as follows: section 2 discusses literature on research and innovation in Africa, with a special emphasis, among others on the role and contribution of research and innovation in Africa's development; and theoretical roots and political economy of the governance and financing of research and innovation in Africa - couched in governance and capabilities frameworks (organisational, technological, management, institutional and financial capabilities).

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[1]The SGCI works with15 councils in Kenya, Rwanda, Uganda, Tanzania, Ethiopia, Cote d' Ivoire, BurkinaFaso, Senegal, Ghana, Zambia, Mozambique, Botswana, Malawi, Namibia and Zimbabwe.

The literature review specifically seeks to situate debates on funding approaches for research and innovation within the context of Africa's development agendas and imperatives in order to lay a firm basis for further empirical interrogation of the extent to which the emerging research and innovation funding approaches play roles in meeting the continent's industrial, economic and social development goals.

Section 3 builds on the literature review to outline the conceptual framework and methodology for document analysis and stakeholder interviews that were carried out, while Section 4, organised around the five key research questions, provides and analyses findings of the data collection processes, including, among others, the value of research and innovation in different countries; historical and current funding approaches; motivation behind use of such models; reasons for changing to new models; impact of the new models; emerging challenges and opportunities for research and innovation funding. Section 5 advances some conclusions and recommendations on approaches for funding research and innovation broadly and their link to the development imperatives of African countries.

2.0 Literature Review

In this section, we discuss relevant literature that focuses on the investment of resources for public good [knowledge generation], solving the valley of death challenge [translational activities and de-risking early commercialisation stages] and making financial systems work for late stage commercialisation.

Investment in production of public goods

Funding models for research and innovation are inherently linked to debates on economic development, technology catch-up, and leapfrogging, with innovation considered a key transmission mechanism. It is widely accepted that a nation's economic growth depends on its capacity to educate, innovate, and build (Juma, 2016). Empirical research and surveys of business activities show that innovation leads to new and improved products and services, better marketing methods and organisational architectures. Economies that invest in and have consistently high levels of innovation tend to achieve high levels of growth (Atkinson and McKay 2007). Long-term national investments in basic and applied R&D play an important role in the flow of market-based innovations through a complex system that leverages the combined talents of scientists and engineers, entrepreneurs, business managers and industrialists (National Science Board, 2012). From tackling health and food security issues, to promoting economic growth, innovation has become a key driver of economic success, while an innovation systems approach has become a desirable option for organising policy processes at national level.

The first stage of the research–translation-commercialisation triad is research and innovation, which requires sustainable and innovative

funding and investments mostly by the state. For-profit driven activities, the private sector is active especially where they can claim monopoly to the market through intellectual property rights such as patents, trade secrets or trademarks. For areas that the state may not have the capacity to go it alone, public-private-partnerships and charities are active. For governments, the tool used is allocation of resources to research and development (R&D) as a proportion of GDP (Gross Domestic Product), and targets can be set at national or supra-national level. African countries adopted the Lagos Plan of Action in 1980 to allocate 1% of GDP to R&D. However, despite consistent acknowledgement of the importance of R&D in the continent's economic and industrial development and improved productivity (Mugwagwa et al, 2018); a large majority of the African countries have not met the Heads of States' commitment to allocate at least 1% of GDP R&D. Only Kenya, which allocated 0.8% and Mali and South Africa 0.7% of GDP in 2015, have come near the goal (UIS, 2016)[2]. Africa's low domestic investments in research and innovation in particular, and in science, technology and innovation broadly worsened after the 2008 global financial crisis and the subsequent 2008–2012 global recession which caused reduced budgetary allocations to R&D globally.

Reinforcing the funding challenge, the Science-Business Forum's third United Nations Environment Assembly (2017) reports that mobilizing resources is a key challenge, especially for science (ATPS, 2017). After the global recession and lately the "more internal focus" and "our own first" approaches adopted by most donor countries, emerging economy governments in general and African governments in particular increasingly need to explore innovative approaches to upscale and sustain domestic investment in research and innovation that supports economic transformations.

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[2] *https://sdg.uis.unesco.org/2016/09/14/how-much-does-your-country-invest-in-research-and-development-rd/*

This is necessary to halt widening knowledge gaps between developed and developing economies and ensuring that developing economies make more significant knowledge contributions towards, amongst other fields; a food-, health- environmental- and cyber-secure global space (Mackintosh et al, 2018) but also reap the dividend from innovations where intellectual property rights can be claimed.

Given the reality of declining investment in research, deteriorating research quality and outputs in Africa - only 10% of research is conducted in developing countries; only 2% of the 3000 journals from the developing world are listed in Medline; and that most Ebola research has been conducted in the USA (Kumwenda et al, 2017[3]) – it is imperative that Africa explores new approaches, sources, tools and institutional arrangements to improve the funding of research and innovation. Ozor (2015) and World Bank (2008) argue that in order to increase funding/ financing opportunities for research and innovation under the current global financial crises and national cutbacks in research and development (R&D) budgets, new approaches and considerations must be made. A key policy hook for increased international and local 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.

The reduction in investment in R&D is not only peculiar to Africa, the same situation also prevails in developed economies; for example, the EU's target to raise overall R&D investment to 3% of GDP by 2010 was shifted to 2020 after the 2010 deadline was missed (UIS, 2016). The 3% 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% target. The leaders are Japan at 3.6%, Israel with at 4.1%, South Korea at 4.3%. Austria, Germany and Switzerland hover around the 3% target, as does the United States (UIS, 2016).

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[3] *https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5442483/*

Solving the valley of death challenge

The middle portion of the research-translation-commercialisation chain usually fails to attract finance that takes a product from proof of concept, safety and efficacy for example to product launch on the market. Osaka and Mizawi (2006) called this the valley of death (see Figure 2). The general explanation is that following successful research and development, technology transfer and product launch; the phase between product launch and success as a new product typically is difficult to attract investment for by venture capital and other financial institutions.

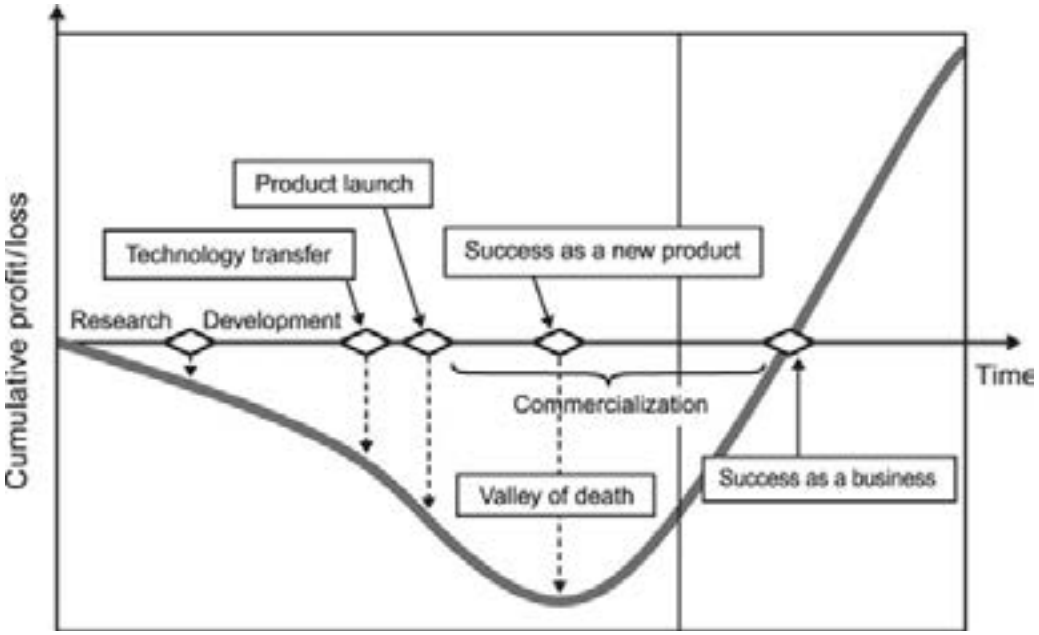

Figure 2: The valley of death graph illustrating the phase between product launch and success as a new product on the market.

In a study on regenerative medicine, an emerging technology with no clear path to market Banda et al (2018) found that this phase and even earlier ones are characterised gaps in value chains. Some supporting industries or businesses with complementary value chains, either as supplier-type or buyer-type linkages, may not have co-evolved at the same time to support the innovation's rapid uptake by the market. The earlier phases, Omidvar et al (2014) argue, are a terrain for philanthropy and government investment as they are the players with patient capital that can de-risk the early stages of technologies and innovations before the market can

adequately support it. In a study on support to regenerative medicine and emerging disruptive innovations in the UK health sector, Banda et al (2018) identified a new institutional architecture - the Cell and Gene Therapy Catapult (CGTC) - acting as an innovation broker which bridges technology, skills and value chain gap challenges (see Case Study 3). The CGTC went on to build a current good manufacturing plan (cGMP) plant where innovators who cannot afford to build cGMP plants optimise production of therapies and even produce therapies for clinical trials. We will discuss later how innovation brokerage such as this could help African countries to link up the research-innovation-commercialisation funding ecosystem so that there is seamless support for all activities.

Funding late stage commercialisation and SMEs

In this section, we consider sources for SME financing as the last step of putting innovations on the market. In well-developed financial systems, venture capital (VC) is an option for university spin offs, start-ups and emerging firms. Historically, sources of finance for enterprise set-up were own finance or loans from family and friends, and firm growth was funded by retained earnings and bank debt (Lazonick and O'Sullivan, 1997a, 1997b). Bank debt, however, is dependent on management quality and experience whereas VC is more interested in a promising innovation and they can provide management experience and networks. VCs invest with an exit plan and the most common is sell-off to private or public markets (Bhattacharya and Thakor, 1993). The Pecking Order Theory suggests that firms choose as first choice bank debt because it is less onerous on reporting and accountability. The second choice of funds are hybrid bonds and the last resort is equity (Myers, 1984; Myers and Majluf, 1984).

With particular reference to Africa, SMEs can benefit from bank monitoring as argued by Diamond (1991) for other territories. The challenge for the last stage of the research-innovation-commercialisation triad is that the most prevalent funder in Sub-Saharan Africa, the commercial bank, is not geared to support SMEs and VC private equity, except for Kenya and South Africa. Echoing this, a UNIDO expert group on finance discussing

access to finance for the African pharmaceutical sector showed that there is a general lack of early stage investors in Africa and few investors avail small deal sizes generally below US$500,000. (Personal Communication). Consequently, private equity, VC and stock markets are still underutilized in financing innovation and enterprises in many African countries. Financial systems on the continent generally are not deep and are incapable of supporting long-term projects (Beck and Hesse, 2009; Beck et al., 2009, 2011) and debt finance is not attractive for emerging SMEs because of high interest charges and spreads (Andrianova et al., 2010; 2011). However, evidence shows that just throwing money at the challenge will not resolve the access to finance issues, as there are complex finance capability issues (Banda, 2013). The university spinouts and emerging SMEs need to know the type of funding they require, where they get it from, how they need to write robust project proposals that convince funders to invest in the commercialisation of their innovations (ibid).

Procurement as industry policy is a possible financing mechanism, and it works based on assuring a market for emerging innovative technologies. 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% of the federal R&D budgets from all government departments and agencies with large R&D budgets to contract R&D services from SMEs (https://www.sbir.gov/). 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 (http://www.cradle.com.my/faq/). Ethiopia and Zimbabwe for example have used this approach to support local production of pharmaceuticals (see Chataway et al, 2016; Mackintosh et al, 2016 for detailed descriptions). In the health sector, this calls for aligning public health policy, finance policy and industry policy.

2.1 Building The Conceptual Framework

The paper's rationale, data collection, analysis and interpretation perspectives are informed by neo-Schumpetarian thinking which argues that systems of innovation do not emerge from industrialisation or technological advancement efforts alone, but as Edquist (1997) notes, from processes that are 'lengthy, interactive and social [and in which] many people with different talents, skills and resources have to come together'. Innovation systems require deliberate development and embedding within country-specific institutional and technological contexts (Lundvall, 1992; Pyka et al, 2009) and we extend this to financial system architectures for research and innovation. R&D and other intangible investments such as investments in software, higher education, and worker training are key inputs driving innovation (NSB 2012) while national investments in basic and applied research and development importantly contribute to the flow of market-based innovations in ways that can be characterized as an "innovation ecosystem." The term "ecosystem" emphasizes complexity of the innovation process – one that is highly dynamic, has many interdependencies, and is always evolving (Edquist, 1997). This ecosystem is nurtured not only by R&D but also includes education and the ability to build/implement technology.

Therefore, while investment in R&D is a key factor in the rate of and capacity for innovation, public policies, including monetary policy, tax policy, standards, procurement, regulatory policy, the availability of a skilled technical workforce, and market access are also important in establishing an environment that fosters innovation (NSB, 2012). Part of the consideration of research and innovation approaches and their impact includes unpacking the complex, yet strong relationship between R&D investment, innovation, economic growth and job creation and identifying the right mix of investment practices and public policy that foster national prosperity and increase national access to the global economy (Atkinson and McKay 2007).

We constructed our conceptual framework (Figure 3) based on Figure 1 and Fig 2, literature discussed earlier on investment in research and innovation through the research-translation-commercialisation spectrum and our knowledge of variety of funders and funding options in Africa and elsewhere. The players funding basic and applied research are well established in literature and include science-granting councils, various state agencies, and special interest groups. For commercialisation, we used financial intermediation theory, which covers various players from venture capitalists to banks required to support entrepreneurship.

Figure 3: Conceptualisation of the researchers and innovators, their activities and funding rationalisation

For the commercialisation of innovations in the last stage, we used financial intermediation theory, which explains the role of financial institutions in an economy (Scholtens and van Wensveen, 2000; Thakor, 1996). We are also cognisant of the critique of Lyall (2007) about the omission by traditional systems of innovation of "the interactions between system actors (firms/science base/intermediaries) and the policy regime, especially in situations where there are state institutions that act both as funders and a broker between innovators and policy makers, for example, some SGCs. The actors along the translation pathways from research-innovation-commercialisation in (Fig 1) interact with funders, policy makers and other industry, university and public players sometimes through multi-level governance systems, especially in countries that run federal type governments and/or are members of regional economic communities.

Actors in such countries may need to negotiate for example innovation or industrial policy at county level, national level as well as at regional economic community (REC) or African Union level.

2.2 The Political Economy of Research and Innovation in Low-And-Middle-Income Countries

Our analysis of funding models and mechanisms for research and innovation is situated in the context of the wider political economy of economic and industrial development, as well as research and innovation in low-and-middle-income countries. According to Collinson (ed) (2003) 'Political economy analysis is concerned with the interaction of political and economic processes within a society: the distribution of power and wealth between different groups and individuals, and the processes that create, sustain and transform these relationships over time.' Whilst research and innovation activities might lead to a certain economic activity prospering, in this case successful contribution by research to different facets of national economies, this success in itself is determined by and can generate a political constituency with an interest in perpetuating the economic progress, especially if people benefit from it; that is policy makers, researchers and user communities for whom opportunities are availed. Interests, ideologies (individuals' values or beliefs systems) and institutions are important facets for political economy analysis, both as drivers, motivating factors or incentives for uptake of research and innovation outputs and as rules (formal or informal) that help to define, shape, structure and embed research and innovation broadly, and mechanisms for funding the same, in particular (Collinson, 2003). We also adopt and apply in our analysis the three key analytical lenses of political economy; agents/actors, structural features and institutions.

Mouton (2008) and Waast and Krishna (2003) chronicle the rise and fall of science in sub-Saharan Africa and we use them as the backbone to understand the political economy of science funding. We are cognisant of the fact that there has always been scientific knowledge in Africa even

before colonial times, however for brevity we are delimiting our analysis to the colonial, pre-independence to post-independence eras and we discuss key events such as the Second World War, the oil crisis of the 1970s and its impact on balance of payments, the economic structural adjustment era and finally the financial crisis of 2008.

Following a similar vein, we situate the political economy of African funding of research and innovation in select key political, regional integration and economic shocks that shaped and influenced the locus of funding for research and the reasons why (see Figure 4.). We are cognisant of the fact that the history of innovation and a different knowledge paradigm in Africa predates 1885; however, for the purpose of this discussion we are focusing on the advent of colonialism and the genesis of the scientific method in research and innovation. The advent of colonialism saw the development of enclave economies that were set up to serve the centre and hence it is not surprising that key research efforts were put into tropical and international health; the predecessors of global health, and agricultural research. Production expansionist policies and strategies post-Second World War mimicked the trajectories at the centre and drove investment, especially agricultural research in the 1950s. Agricultural research supported the development of local commodities such as cocoa and was augmented with the establishment of state run boards (Kolavalli and Vigneri, 2017). This example is revealing as it demonstrates the need to fund the whole value chain of a commodity, which in the case of cocoa in Ghana included road construction, variety improvement, local manufacture of spraying chemicals and creation of market conditions that allowed expansion of the sector.

The end of the colonial period - Ghana the first in 1957 and nearly 40 years later, South Africa, - coincided with successive geo-political and economic shocks; the 1973/9 oil/energy crisis, and the 1980s-1990s economic structural adjustment programmes. ESAPs advocated for two approaches (which turned out to be damaging to economies); first the

removal of subsidies and state funding for research institutions, and second the de-emphasis of tertiary education critical for developing and sustaining scientific and innovation capabilities in favour of investment in primary education (Kolavalli and Vigneri, 2017). It is pertinent to raise these issues as key contextual issues of political analysis in understanding the agents/actors at play, the structural factors and the institutions in place. Underfunding of these sectors had an impact on national, sectoral, regional and technological innovation systems (Lundvall, 1985; Cooke, 1998; Malerba, 2002) both from an institutional perspective and in drying up the pipeline of innovators and researchers through brain drain and weakening of tertiary education.

Economic structural adjustment programmes caused massive de-industrialisation, and a reduction in technological competencies. When African countries design research and innovation strategies there are pertinent historical issues to consider see Figure 4 below, in addition to the contemporary issues that are a normal part of strategic and tactical planning.

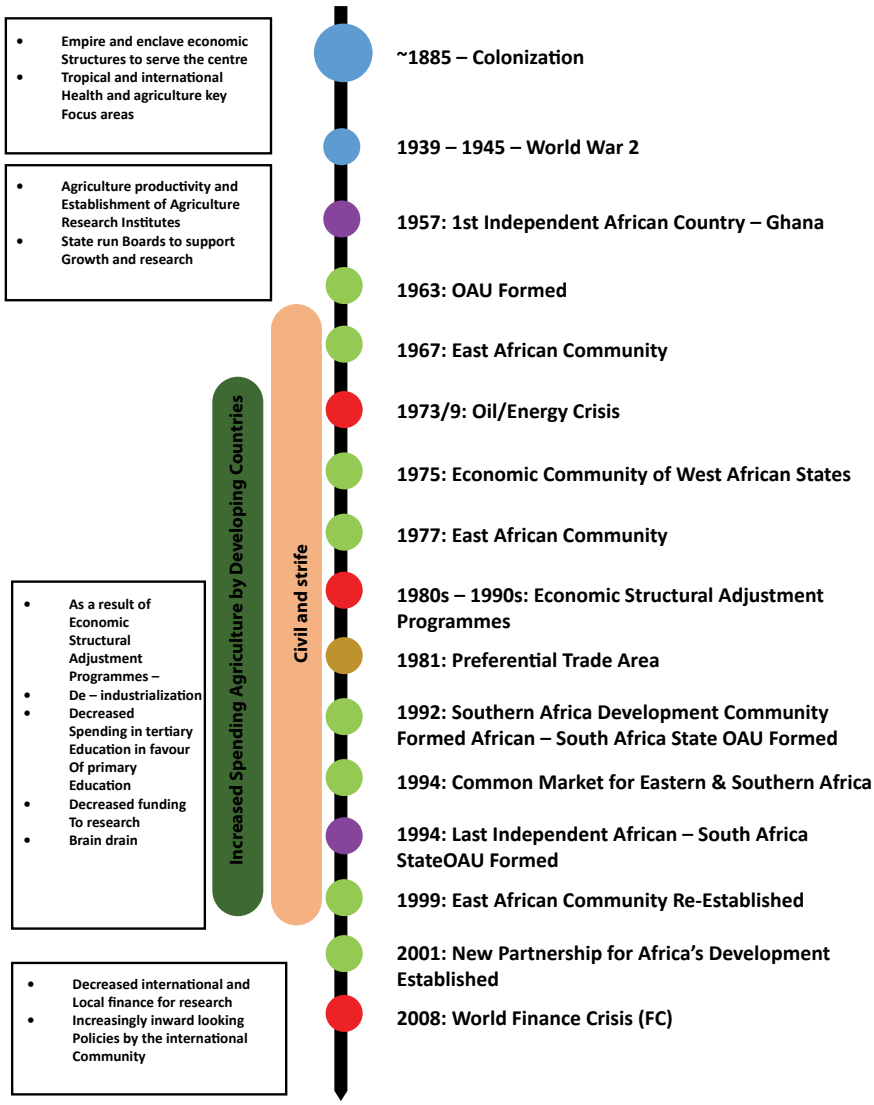

Figure 4: An illustration of key political, regional integration, economic shocks and social events important in the political economy of funding Africa research and innovation

Source: Developed by authors using various sources including Mouton (2008), Waast and Krishna (2003) and government and regional economic communities' websites.

3.0 Methodology

To meet the multifaceted research objective of identifying and analysing "new approaches for funding research and innovation in Africa'' and ensuring the consistency, rigour and validity necessary for such a comprehensive study, four stages of research activity were designed and carried out iteratively by researchers between July and December 2018. Stage one involved collecting and analysing published and grey academic, policy and practice literature on research and innovation in Africa broadly, and funding models in particular. This informed stage two of the research, which covered two related aspects – development of a semi-structured research questionnaire/instrument with clustered questions and sub-questions; and drawing up of a participants' list. A total of 60 participants were targeted, 15 of them being officials in science granting councils from SGCI countries (list provided by ATPS), 28 were from the UK regenerative medicine network, while 17 were from research organisations, funding agencies or policy bodies in Africa or elsewhere (key informants purposively targeted based on researchers' experience and literature reviews). A breakdown of respondents is given in Fig 2. In stage three, the research instrument was administered via email in all the cases, with varying response rates among the respondent clusters; 73.3% (11/15) for SGC respondents; 64.3% (18/28) for UK regenerative medicines respondents; and 35.3% (6/17) for academic, policy and practitioner, including private sector, respondents in Africa and elsewhere. Besides the relatively low response rate among the third category respondents, there were no other significant constraints or limitations to the research process.

In stage 4, data from the research instrument was collated, anonymised, aggregated and analysed using Thematic Analysis (Boyatzis, 1998) using a combination of themes drawn from literature and from the research findings.

Respondent details

Study respondents were drawn from within SGCs and from academic, policy and research bodies. Figures 5 below shows respondent proportions by area of function.

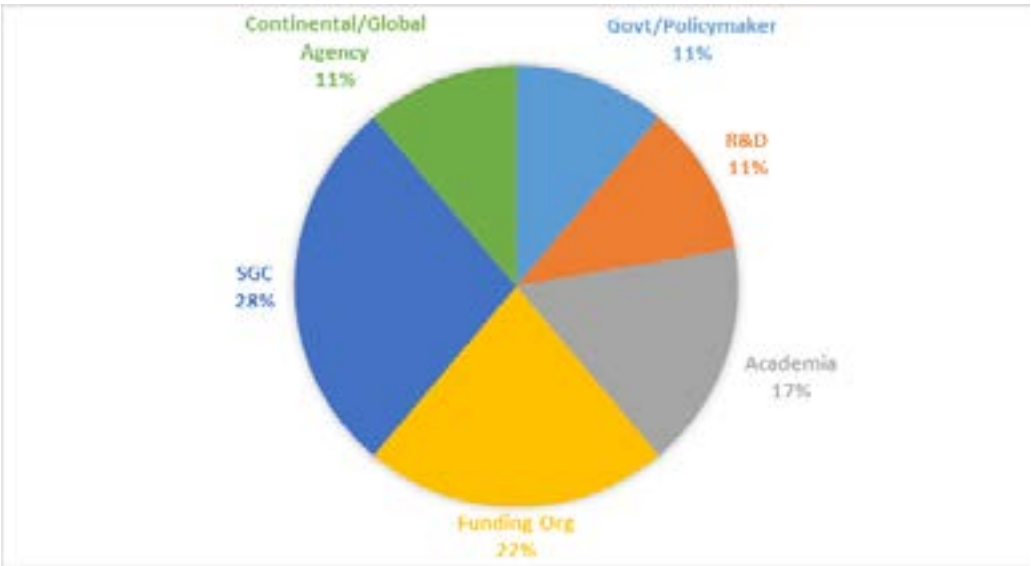

Figure 5: Respondents by area of function innovation (Source: compiled from respondents' input)

The respondents with different functional areas represented in the chart above also showed a diverse spread over, and engagement with research and innovation activities in different countries, sectors and time periods, allowing for a nuanced and diverse understanding of the role and contribution of the research and innovation. This diverse range of respondents was important for eliciting and cross-checking the diverse set of reflections on the issues being investigated.

4.0 Findings

4.1 How Important Is Funding of Research and Innovation Among African Countries and What Is the Evidence to Demonstrate the Level of Importance?

In answering the above question, we draw attention to the historical and current momentum in Africa towards funding research and innovation as elaborated in numerous literature sources and in the primary evidence that we gathered in which respondents highlighted a number of commitments that national governments and other stakeholders have made towards funding research and innovation.

African countries have explicitly committed themselves to raising their domestic research expenditure to at least the equivalent of '1% of their gross domestic product' (Lagos Plan of Action, 1980). However, almost all the countries are failing to fulfil this commitment and calls for increased funding have grown. For health, governments agreed in the Algiers Declaration to allocate 5% of the National Health Budget to health research and few are meeting this target (Nabyonga et al, 2018). Yet, overall, commitment towards deploying STI to strengthen economies is not lacking, for example, the AU Agenda 2063 'The Africa We Want' aspires for a prosperous Africa imbued with means and resources to drive its own sustainable development and long-term stewardship of its resources, where African people have a high standard of living, quality of life, sound health and well-being, and assured health security (AUC, 2015). More specifically, in order to deliver on Agenda 2063, the Science, Technology and Innovation Strategy for Africa, STISA-2024 was developed, and it identifies research and innovation as enablers for achieving Africa's sustained growth, competitiveness and economic transformation (AUC, 2014). STISA-2024 calls for continuous embedding of STI in six priority

areas namely: eradicating hunger and ensuring nutrition and food security; prevention and control of diseases and ensuring wellbeing; communication (physical and intellectual mobility); protecting our space; living together; and wealth creation. A major recognition in STISA is that the continent needs to apply existing and emerging technologies in order to accelerate Africa's desired transition into an innovation-led, knowledge-based economy.

That the place of science, technology and innovation on the national, regional and continental policy agendas in sub-Saharan Africa (SSA) has become markedly more prominent in recent years is not only reflected through initiatives such as STISA, but also through policy and institutional developments at various levels (UNESCO, 2016). At continental level, the New Partnership for Africa's Development (NEPAD) is now well established institutionally and continues to evolve in its role of implementing African Union policies. Recently transformed into the African Union Development Agency, NEPAD has an Industrialisation, Science, Technology and Innovation Hub with a number of thematic programme areas[4], including: African Biosafety Network of Expertise (ABNE) Biosciences eastern and central Africa - International Livestock Research Institute (BecA - ILRI) Hub; African Institute for Mathematical Science (AIMS) – Next Einstein Initiative; Bio-Innovate; African Medicines Regulatory Harmonisation (AMRH); NEPAD Water Centres of Excellence; African Science Technology and Innovation Indicators (ASTII); Southern African Network for Biosciences (SANBio); Alliance for Accelerating Excellence in Science in Africa (AESA). NEPAD also works alongside other AU science-related arms, such as the Scientific and Technical Research Commission (AU-STRC).

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[4]http://www.nepad.org/rec/industrialisation-science-technology-and-innovation

Although various surveys on countries having S&T or STI policies show a gradual increase from none between 1960 and 1980, to about 13 out of 17 surveyed by Mouton et al (2014) in 2010; there is now widespread adoption of STI policies and institutional developments in support of these initiatives at the sub-regional level (UNESCO 2016) and by many SSA countries (AOSTI 2013). These developments are happening in the context of the adoption by the international community of the Sustainable Development Goals (SDGs), which include specific reference to STI within SDG 17 (UNGA 2015).

This is in contrast to the absence of explicit reference to STI in the Millennium Development Goals, which some argue may have hampered efforts to pursue STI capacity building (HOC-STC 2012).

Accompanying these policy developments there has been an increase in the number of donors interested, or active, in supporting STI in Africa compared with the support of just a few during the 1990s (AOSTI 2013).

4.1.1 Importance placed on funding research and innovation

Embedding the innovation principle in government policies, strategies and programmes demonstrates the importance that a country places on science, technology and innovation as key drivers of economic

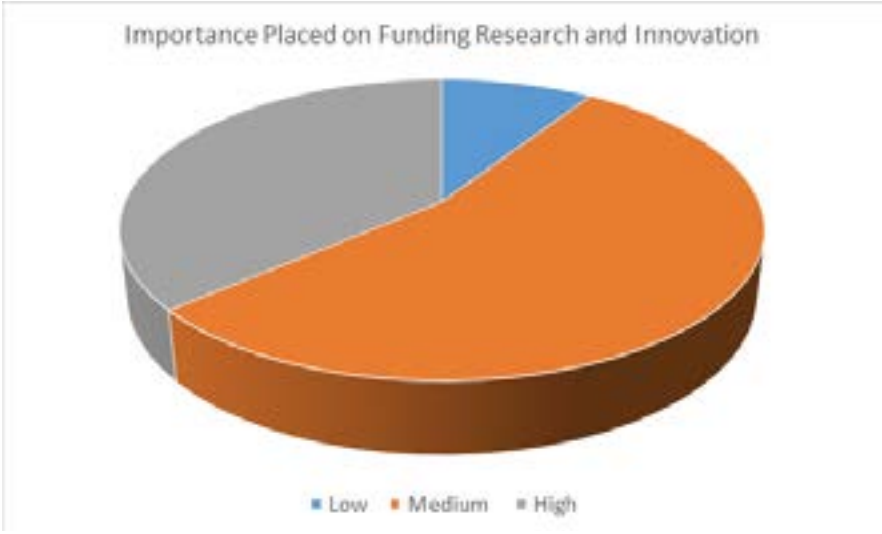

Figure 6: Importance placed on funding research and innovation by countries

development. This is important because researchers, innovators and funders tend to take a cue from government's position on research and innovation and associated resources allocation.

Our study shows that of the targeted 15 Science Granting Councils, of which 11 responded, one country reported that their country placed low importance on funding for research and innovation, whilst six countries scored this attribute at medium and four at high importance (Fig 6). The respondents attributed the rational for funding research and innovation to the developmental needs of their countries, among them; leapfrogging and home-grown economic development (combined score of 57%), catching up (24%) and the balance following global trend (see Fig 7 below).

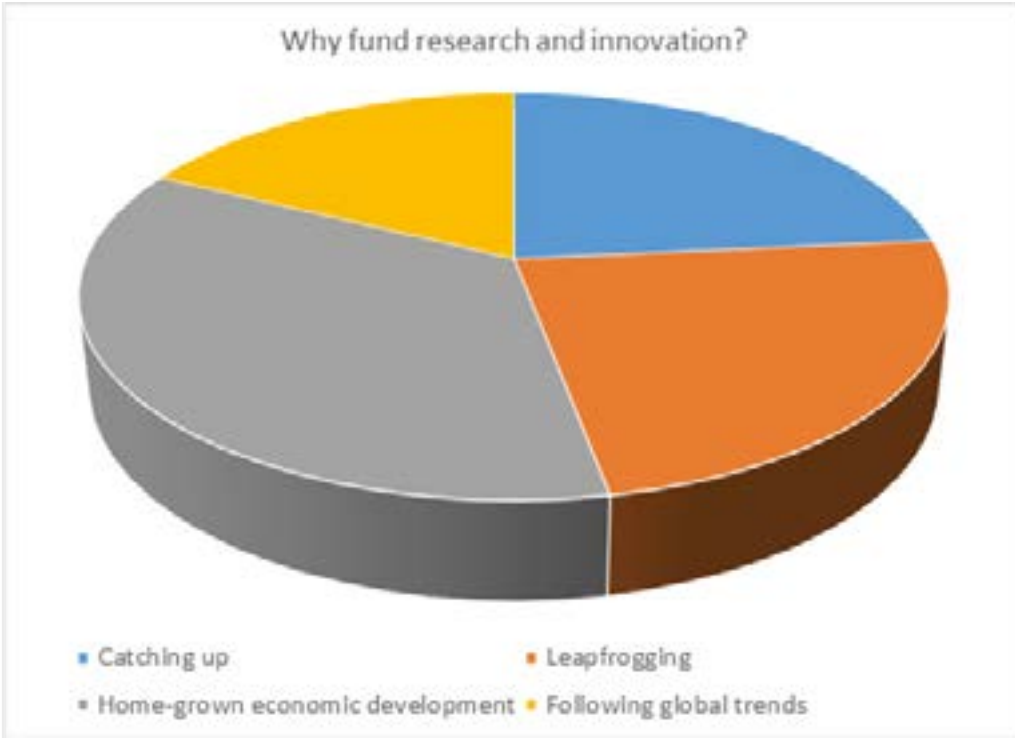

Figure 7: Reasons for funding research and innovation in African countries.

This data implies a growing importance placed on catching-up, leapfrogging and home-grown economic development as key drivers of new knowledge generation that should translate into positive economic activities. However, even with this realisation on the ground, few countries

are meeting the Abuja agreement to allocate at least 1% of their GDP to R&D. The respondents scored overwhelmingly in favour of locally derived funding models, and this is not surprising given the recent reduction in foreign funding sources which accentuated the risk of unsustainability of foreign sources of funding for research and innovation. As described in the introduction, the global financial crisis and the restructuring of funding models have resulted in a shrinking of foreign sources of funds, in addition to the increasing competition for the research funds in source countries. Although some respondents in interviews acknowledged the positive impact of GCRF (Global Challenge Research Fund) opportunities created by the UK government to channel some DFID funds into the UK Research Councils for collaborative research programmes with LMICs, most worried about the sustainability of such funds. In addition, they reported that the timeframes given were too short to form meaningful joint bids as networks generally took a long time to establish.

Other specific motivations identified for funding research and innovation included accelerating structural transformation; increasing international competitiveness and improving quality of lives. Demonstrations of commitment to research and innovation were not only seen through influential continental or supranational policy agendas such as Agenda2063 or SDGs which have a specific goal (Goal No. 17) and targets for science, technology and innovation, but also through national policy and resource provisions. Policy is a key component of generating interest and coalitions that support research and innovation as illustrated by the following national examples:

- In Kenya, the ST&I Act was enacted in 2013 to establish key institutions such as the National Commission for Science, Technology and Innovation (NACOSTI) to promote STI. In addition, the National Development Agenda which recognizes STI as the foundational pillar of elevating the country to a knowledge based economy was viewed as an important factor.

- Zambia, increased budgetary allocation to the government research and innovation Funds (e.g. the Strategic Research Fund (SRF), Science and Technology Innovation Youth Fund (STIYF), Technology Business Development Fund (TBDF); the country also introduced innovation programmes (e.g. multi facility economic zones, innovation incubators); as well as the national Intellectual Property Rights Policy (2010) and the national Industrial Policy (2018).

- In Mozambique, a Science and Technology Policy (2003) was developed, and there has also been establishment of a National Research Fund and a National Directorate for Science in the last 10 years, operating under the Ministry of Science and Technology, while in Ghana there is proposed establishment of a Research Fund; the Presidential Advisory Council for STI; and a National Innovation Agency.

The priorities that drive research and innovation in a country also reflect the importance that is placed on the contribution of research and innovation

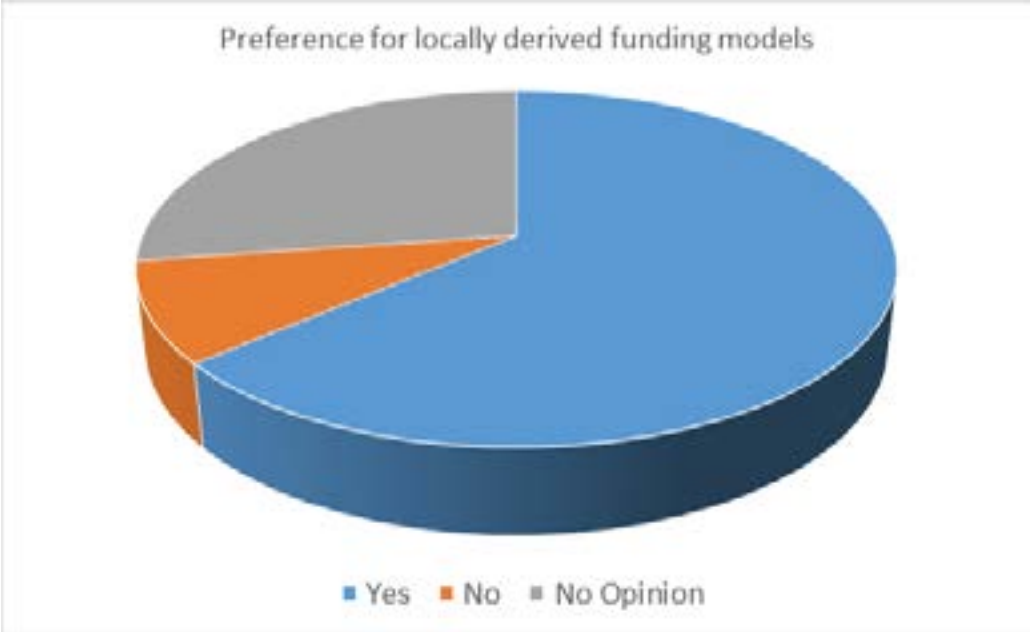

Figure 8: Preference for locally derived funding models for research and innovation.

in national development (Polanyi, 1962; Juma, 2016). However, sources of funding for research and innovation are increasingly coming under scrutiny by SGCs as they grapple with risk of sustainability and shifting the centre of gravity on research and innovation prioritisation.

From a long-term sustainability perspective, preference for locally derived funding models is not surprising given that in the last 5 years the greatest source of funding has been international donors with central government providing the smallest[5] portion in most instances for example in Ghana, Ivory Coast, Burkina Faso and Namibia. However, Uganda reported a greater contribution of government funds to research and innovation (see Fig 9 below). Local science councils contributed significant amounts for Ivory Coast and Burkina Faso, whilst in Namibia the local private sector contributed more than central government, international donors and local science councils.

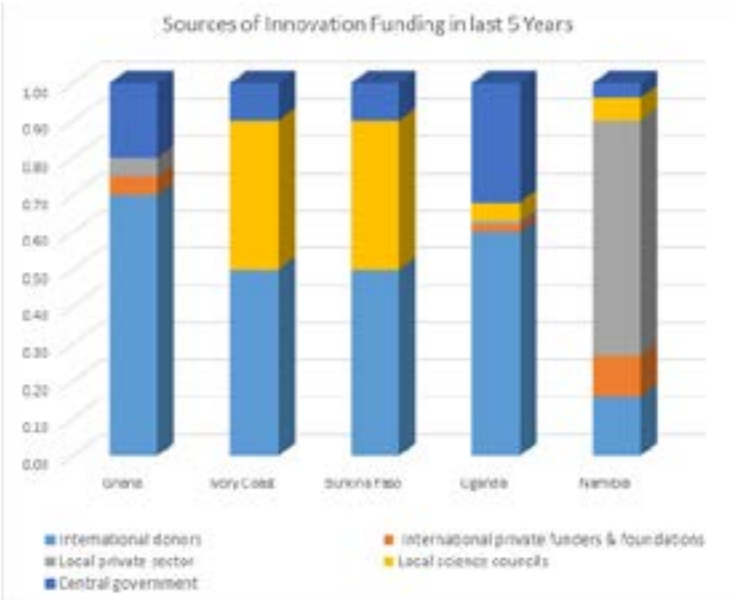

Figure 9: Sources of innovation funding in the last 5 years

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[5]Issue disputed by some informants who cite the fact that governments' contribution is often underestimated because contributions to staff salaries and other institutional overheads and running costs which governments take care of, are not factored in.

Countries attributed the shift in funds in the last five years to more funding opportunities (Ivory Coast, Burkina Faso, Rwanda and Uganda), a shift in research and innovation priorities (Ivory Coast, Burkina Faso, Rwanda and Uganda) and following local and external trends (Namibia). None of the countries that responded on this section of the survey attributed the shift in funding to problems with previous funders, in essence re-enforcing the fact that the shift relates more to scarcity.

Table 1: Reasons for a shift in funds in the last 5 years

Reasons for shift	Countries
More funding opportunities now available	Ivory Coast, Burkina Faso, Rwanda and Uganda
Shift in research and innovation priorities	Ivory Coast, Burkina Faso, Uganda and Namibia
Problems with previous funders	None
Following local and external trends	Namibia
Other (specify)	

Of the 11 SGCs that responded, 5 highlighted that there was a change in use of funds as a result of the shift in funding and the changes were in; more capacity building in terms of infrastructure (Ivory Coast, Burkina Faso, Rwanda, Uganda and Namibia) policy capacity building (Uganda and Rwanda) and research dissemination. None of the respondents, including the academic and practitioner respondents, reported any other changes in the use of funds.

Across the different countries, some of the challenges highlighted for the low ranking of research and innovation range from persistent inadequacy of funding (32%), difficulties with complying with funding requirements (16%), lack of timely availability of funding (28%) to lack of national research strategies, and sometimes, not seeing benefits from any available funding that has gone into research (24%). This could explain why institutional, policy and budgetary adjustments were implemented as a response in some countries.

Figure 10:Challenges faced by organisations funding research and innovation

In addition to the above, other challenges that were mentioned include lack of national R&D strategies, need to ensure stable and appropriate financing of the National Research Foundation (NRF) mandate to avoid gaps in research support, lack of planning and funding for impact evaluation of funded projects, delays in accelerating transformation of the research enterprise (in South Africa), and the lack of overall funding coordination.

4.1.2 Historical sources of funding for research and innovation

Before looking at new sources of funding for research and innovation, we explored historical sources of the same to lay a basis and rationale for the emerging innovative models. Among other aspects, the previous section has shown that that there were differences among the countries with respect to the importance and levels of contribution to research and innovation by different sources of funding. Literature shows a general trend of increasing central government and science councils' contribution, averaging around 80% and 58% for Ethiopia and Tanzania respectively, while international donors are still a major funder, averaging around 40% across many African countries (UNESCO, 2016). Our findings

confirm that indeed, historically, international donors were even more dominant, providing, for example, up to 60%, 70%, 75%, 80% and 90% of research funding in Malawi, Ghana, Kenya, Mozambique and Burkina Faso respectively in the 1990s and 2000s. International and local private sector funding was rated low historically and currently and both sectors were highlighted later as potential opportunities to be exploited, see Fig 11 below.

Figure 11: Historical sources of funding for research and innovation (beyond 5 years ago)

With respect to why historically international donors have been the main funders, respondents reported that there were limited options of funders and that some research institutions have on-going and sustained relations which kept them with particular funders. Additionally, because governments remain unable to allocate sufficient funds to research and innovation, international donors still play significant roles. Scarcity of resources for research causes different staged of the research-innovation-commercialisation continuum to compete for the limited resources.

Respondents indicated that over the years, shifts have been observed regarding what donors, central government, science councils and other players fund. In Ghana, for example, respondents indicated that central government funding is split into 80% for salaries, 10 % for research and 10% for research infrastructure; international donors – 70% for research activities and 30% for research infrastructure; private sector – 100% research activities; and international private funders -100% for research activities. Looking at the allocation from another perspective, and while no percentages were given, in Malawi, research funds were split between the following functions: research capacity building in health and agriculture; research granting in health and agriculture; promotion of STI; valorisation of research results; promotion of research ethics; and documentation services. Given the key development challenges facing many African countries, and the paradox of opportunities that arise from such challenges, it is not surprising that health and agriculture/food security re key targets of research and innovation funding.

Key: 1 is most important and 7 is least important. The closer to 1 the more important the source of finance

Figure 12: Current sources of finance for Research and Innovation

In Mozambique, the following sectoral split was given: agriculture (40%), health (20%), marine sciences (10%), social sciences (10%) and other (20%). Regarding who decides on sources of funding, the dominant position was that it was government and science councils with the councils assuming a more prominent role lately. One respondent from Southern Africa noted that …

> *'Government [decides], however, the institutions are allowed to find other sources by themselves'.*

Another respondent from the same region elaborated on how science councils help researchers and their organisations in this process:

> *''Researchers hugely take an initiative to source funding for themselves as such they are on the fore front to decide on sources of funding. Primarily, the SGC is by law required to finance national research priorities but funding from treasury is quite inadequate. In a case where the SGC disburses some grants, it decides for its own source of funding''.*

It is evident from the foregoing that historically, there has been a number of dynamic factors and actors shaping the funding of research and innovation in African countries. These actors and factors form both the background and foreground for new and innovative sources and uses of funds for research and innovation, which will be presented and analysed in the next section.

4.2 What Are the New and Innovative Funding Approaches (Schemes, Models and Mechanisms) That Have Been Applied Across the World and What Lessons Could Be Drawn for African Countries?

Faced with persistent constraints in prevailing models, options and levels of funding for research and innovation, countries in the developed world and elsewhere have experimented with, among others, institutional reforms, models and mechanisms for funding and financing research and innovation, delivering outstanding results in some cases. African countries have also undertaken the same efforts. This section does two things, first, we present and discuss a number of funding model case studies from different regions of the world, including Africa, and secondly, we draw from literature and our own primary data to look at specific cases

of innovative funding models in the countries that we studied. What we present is by no means an exhaustive list of case studies, but carefully selected exemplifiers of some innovative funding mechanisms.

In this section, we answer the second research question which focused on new sources of funding for research and innovation. In Table 2 below, we present the conventional (already in operation in Africa) in black against what we found in secondary evidence and primary evidence from this research and another similar research that focused on funding schemes for university spinouts and SMEs in Regenerative Medicine in the UK. Table 3 which follows, gives specific country examples of where some of the innovative approaches have been used and the impact realised, based on a critical synthesis and thematic analysis of respondents' feedback.

Table 2: Old and new (green) funding models for research and innovation

Funder	What is funded	Funding Mechanism	Rationale
Government	Basic Research Applied Research Translational Research Commercialisation Entrepreneurship (SMEs)	Grants and grand challenges Public institution co-funding on interdisciplinary and multidisciplinary programmes Innovation brokerage Formation of national research funding consortia Co-funding with SGCIs in the Region Investment in high-end research programmes, incl. Chairs (240 in SA) and Centres of Excellence, with 15-year funding horizons	Traditionally governments have funded basic, applied and translational research as investment in economic growth and development. These are deemed public goods.

As Table 2 above illustrates the new funding models that we identified from government-driven programmes were public institution co-funding of

Funder	What is funded		Funding Mechanism	Rationale
Private Sector	Applied Research Commercialisation		Retained profits and borrowing for capital markets Corporate Social Responsibility	Profit driven motives
Public Private Partnerships	Applied Research Commercialisation		Equity and project funding	Solving market failure issues
Impact Investors	Commercialisation		Equity or debt	Solving market failure with a focus on social goods
Non-Governmental Organisations	Commercialisation		Equity or debt	Solving market failure
Capital Markets	Commercialisation		Equity	Attractive return on investment in the venture
Crowdfunding	Research and commercialisation		Equity	Social investment because of market failure
Local and International collaborative research grants	Research		Grants	Scarcity of local funding for research in many African nations
Private sector	Take-over of applied research after proof of concept, safety and efficacy		Patent buyouts	Innovators either selling off patents to fund more innovation or researchers not interested in entrepreneurship
Charities	Basic and applied research as well as clinical trials		Grants and co-funding academia and SMEs working neglected areas	These tend to be niche areas such as rare diseases where market failure is common
Cities or regions	Land, labour and utilities		Grants given as incentives to firms that relocate to a city or region targeting industrial development	Attracting particular industrial activities to a particular city or region to boost economic activity and contribute to rejuvenation of de-industrialised places

interdisciplinary and multidisciplinary programmes, government funding of innovation brokers (see case studies 2 and 3), formation of national research funding consortia, co-funding with SGCs in the region as well as investment in high-end research programmes, including Chairs (240 in SA) and Centres of Excellence, with 15-year funding horizons.

Table 3: Respondents' examples of innovative funding models and areas of research and innovation targeted

S/n	Funding model/ mechanism	Features/ characteristics of model	Countries adopted	Impacts recorded so far
1	Patent buyouts		Zambia	Strengthening research programmes and research dissemination
2	Local and international collaborative research grants		Zambia, Ivory Coast, Malawi	Strengthening research dissemination
3	Rewards and incentives for specific outcomes		Zambia, Ghana	Enhancing research expertise and research dissemination
4	Research infrastructure fund	Fund for renewal, replacement and acquisition of essential national research infrastructure	South Africa	Improvement of research infrastructure
5	Public-Private Partnerships	Focused particularly supporting human capital development for R&I activities	Mozambique and South Africa	Strengthening of research and innovation expertise
6	Investment in high-end research programmes	15-year funding horizons for research chairs and centres of excellence	South Africa	240 research chairs in post

S/n	Funding model/ mechanism	Features/ characteristics of model	Countries adopted	Impacts recorded so far
7	Multi-institutional co-funding for inter- and multidisciplinary research		Kenya and Zambia	Strengthening research and innovation programmes
8	International strategic research partnerships		Kenya, South Africa	Strengthening research and innovation institutions and policy
9	Human capital development pipeline	Funding for emerging and established researchers	South Africa	Enhancement and retention of research and innovation expertise

What is innovative about these new funding models are the institutional arrangements where targeted sectors are purposively funded by public funds with a specific innovation focus to accelerate identified opportunities (case studies 2 and 3). We argue that adaptation of specific quasi-public institutions that provide specific funding, advisory services and co-working capabilities with SMEs for specific innovation target would benefit African countries. The UK, for example, has catapults which focus on the 8 great technologies the country aspires to be a world leader.

Turning specifically to Africa, the variety of types of initiatives to support scientific research in SSA has also grown over the last two decades (Hydén 2017). Among them are national level public or quasi-public organisations and the grant funding for science and/or research activities, known by various interchangeable names, including science granting councils (SGCs), funding agencies, science councils or research councils or commissions. They sit in an intermediary space between the state and the research community, where they define and execute a significant part of the state's science policy (Braun 1998). While their central role is making grants for science or research, Science Granting Councils are increasingly taking a

range of additional functions such as advocacy and communication roles, information gathering, analysis and dissemination. It is unsurprising therefore that SGCs play important roles in scouting for and shaping funding mechanisms for their countries.

In order to give exemplars on innovative funding models, we present below a selected number of case studies to contextualise our discussion.

Case Study 1: TIBA (Tackling Infection to Benefit Africa) Research Consortium

TIBA is a UK National Institute of Health Research (NIHR) £ 7.5 million 4-year research consortium led by the University of Edinburgh in collaboration with the University of Botswana, Uganda, KEMRI in Kenya, University of Kwazulu Natal in South Africa, University of Zimbabwe, Sudan, University of Rwanda and Tanzania.

The funding came from a UK funding institution – the NIHR, and had conditions that the consortium be led by a UK based institute, which should collaborate with research institutions from low to medium income countries (LMICs). TIBA was set up to focus research and innovation on tropical African diseases such as Schistosomiasis, Typanosomisasis, Lymphatic Filiasis, and Malaria, through activities ranging from mass drug administration, clinical trials, to basic research and drug and vaccine development. The ethos of TIBA resonates with those of the African Academy of Sciences on "shifting the centre of gravity to African researchers" and as a result, 80% of the funding will be used in African countries to fund research priorities identified by the local researchers. The research consortium encourages south-south collaborations and research programmes are based on 'rapid impact projects' and 'making a difference projects'.

Rapid Impact Projects

These are 1-year research projects of up to £100 000 each.

The funds operate as follows:

1. Participating countries identify a health challenge on the ground and they fill in a user-friendly TIBA Rapid Impact Project form. The form requests for the information of the health challenge, its impact on people, what the proposed intervention/research is and what the TIBA partner intends to achieve through scientific enquiry or interventions

2. The proposal is forwarded to the Steering Committee, which checks for rigour and alignment with TIBA initiatives. The process is meant to strengthen the proposal, so the Steering Committee proposes amendments to make the proposal fit for purpose

3. The proposal is returned to the participating partner and they are given an opportunity to strengthen it and answer queries raised by the SC.

4. Amended proposal is submitted to the Directorate who approve or decline

5. On approval, funds are transferred from the University of Edinburgh to the participating institution in Africa.

6. A report is required after 6 months as per the funders conditions

7. At the end of the 12 months the participating partner reports on the findings and impact of their research and/or innovation activities.

Making a difference projects

These are more ambitious research and innovation projects with a value of up to £500 000. The process of approval is the same as for Rapid Impact Projects; however, these projects require south-south collaborations and usually involve 2 to 3 partner countries working together on an infectious health challenge in their region. What is innovative for these approaches is how grant funds are also matched with private sector financing for example clinical trials for paediatric Praziquantel (anti-worm/schistosoma) medicines where TIBA is contributing some funding in collaboration with the pharmaceutical company Merck.

What is different about this research consortium?

1. The shift of prioritisation of research focus to African researchers in terms of identifying research projects, resource allocation and use as well as meeting local and international research ethics

2. Transfer of the full funds for Rapid Impact Projects (up to £100 000) or Making a Difference Projects (up to £500 000) of the funds to the research institutions carrying out the work

3. Reciprocal respect between participating partners and trust that they will use the funds for what they promised. At an institutional level, this is backed by agreements (Framework of Agreement) between the University of Edinburgh and each partner, as well as assurance of ethical and financial reporting compliance.

4. In addition, there are 22 PhD fellowships as well as post-doctoral fellowships with exchanges between African-African partners or African country with other countries and there is no requirement that the western partner be University of Edinburgh.

Case Study 2: UK Regenerative Medicine: Business Models and Financing Mechanisms

This case study focuses on how funding models shape emerging regenerative medicine business models and innovative technologies that are not yet on the market

Table 4: Types of funding and who uses them and why

Type of Funds	Who uses them and why
Grants	These funds are available to universities, research institutions and private firms. There are specific challenge funds that especially encourage collaborative partnerships between industry and academia
Innovation Challenge Funds	Firms at various stages of innovation translation compete for funds to move them to the next level on the value chain
Regional Regeneration Funds	Firms located in old industrial cities are promised to be paid a flat amount for each person they employ. One firm used this approach to raise over £100 000 to fund its early operations because it was not yet generating revenue
Equity Markets	Firms with promissory medical technologies to meet unmet needs such as cancer therapy. Investors fund the early stages based on the promise to be paid out when an initial private offering is made
Consultancy Income	Early movers who have become experts of the regulatory process or optimisation of production processes or assaying methods use their skills as consultants for latecomers. They then use the consultancy fees to finance innovation in their firms.
Contract Manufacturing	Firms that had invested in cGMP (current Good Manufacturing Practice) contract manufacture for firms which have not yet constructed their own manufacturing plants or are at the early stages of proof of concept. The income from contract manufacturing is used to finance research, development and translational activities.
Early stage exit through sell off of IP rights to large firms	These are usually researchers with no interest in entrepreneurship who exit by selling off IP rights after proof of concept, safety and efficacy for their therapies

This case study shows that various forms of funds varying from grants to contract manufacturing income can be used by emerging firms which do not as yet have any products on the market to fund research and innovation.

Case Study 3: Cell and Gene Therapy Catapult: De-Risking Early Stages of Innovative Technologies

Here we highlight how at institutional level the state can invest in an innovation broker that steps in to fill a value chain gap. We chose the UK's Cell and Gene Therapy Catapult's Stevenage Manufacturing plant as the case study. All the SMEs and university spinouts interviewed in a separate study but with similar focus as this paper highlighted the fact that at early stages capital is a limiting constraint especially in regulation intensive sectors such as medical technologies. Constructing of a cGMP plant is expensive and just maintaining the plant comes at a huge cost of up to hundreds of thousands of pounds (£s) per annum. Firms that are still in the cash burn rate stage (no income yet because they do not have products on the market), are keen to use as little cash as is possible and move their product development as close to approval as possible. The UK government realised this value chain gap and invested in the Stevenage Cell Manufacturing Plant, where under-resourced SMEs can book to optimise their manufacturing processes as well as manufacture therapies for clinical trials. We termed this investment by the state innovation brokerage (Banda et al, 2018), a role through which the state de-risks the translation processes for SMEs. The SMEs as a result delay investing in an expensive manufacturing plant until such a time as they have achieved proof of concept and also done clinical trials. The firms argued that it becomes easier to approach venture capitalists and other funders if they can prove that the efficacy, safety and potential of their therapy have been established.

Case Study 4: Innovative Procurement in The Pharmaceutical Sector

From an entrepreneurship perspective, this case study highlights how innovative procurement by the public sector can pull innovation in SMEs. The case study focuses on innovative procurement in the African pharmaceutical sector (for a more detailed discussion, please see Chataway et al, 2016). Procurement can be used as a potent industrial policy tool to support emerging SMEs. Ethiopia is a case in point, where when local firms win a tender to supply drugs to the public sector, the government pays them 75% of the costs in local currency upfront. This reduces the cost of finance for the firms, ensuring financial viability for the local firms. However, offering local currency requirements only is not sufficient as the bulk of active pharmaceutical ingredients and excipients are imported and require foreign currency. What is important though is that the Ethiopian government is using public health funds to support local industry through innovative procurement. If the company remains financially viable, then it can use retained profits to fund formulation and development activities for generic drugs. This demonstrates the importance of leveraging policy tools; in this case procurement as industry policy to support emerging SMEs critical to health security (see also West and Banda, 2016).

Zimbabwe was the first African country to locally produce anti-retrovirals (ARVs) in 2002. The country accelerated the local production of ARVs by local firms because they assured the firms that if they could formulate the drugs locally, they would procure them. The government used policy - compulsory licensing - to legally overcome intellectual property (IP) constraints as production of the ARVs was for local consumption only. The compulsory license was based on the fact that the country had declared a state of emergency on HIV/AIDS as the country recognised that it was dealing with an epidemic. Thus, health policy, was aligned with procurement policy as well as industry policy to support local innovation capabilities in the pharmaceutical sector. The country also institutionally set up a viable funding scheme for ARV management by converting what had been instated as a drought levy into an AIDS levy (Russo and Banda,

2013). The AIDS levy composed of 3% of the pay as you earn tax which was allocated to the National Aids Council through the National Aids Trust; and 50% of the funds were supposed to be used to procure medicines for HIV/AIDS (ibid). However, due to the economic challenges that the country later faced, local production encountered foreign currency shortages and a reduced demand from the public sector which then depended on imports from India. This was to an extent exacerbated by finance and industry policy incoherence. Imported drugs from India were imported duty free, whilst raw materials for local production were subjected to both duty and value-added tax (VAT). After local lobbying the duty on raw materials was taken away, however, VAT was left in place and firms had to claim for VAT refund after initially paying it. Firms complained that it took a long time to claim the VAT from the revenue authority (Banda, 2012).

Case Study 5: Chilecon Valley – Enhancing The Chilean Entrepreneurial and Start-Up Culture

As part of Chile's innovation agenda, the country has taken pivotal steps to encourage its start-up culture and foster what is now known as 'Chilecon Valley' (Larsson 2016). Beginning in 1998, the Production Development Corporation (CORFO) commenced to promote the formation of private venture-capital funds (OECD, 2016). Thereafter, in 2000, CORFO set up a fund to support incubators and, in 2004, it created a seed-capital fund to close early-stage funding gaps for new enterprises (OECD 2013). In 2010, the greatest start-up initiative was inarguably taken through the launch of Start-up Chile by the government, which has led to further policy reforms around start-ups and the formation of enterprises in the country (OECD, 2016). Start-Up Chile utilises a Silicon Valley-type foundation, based on the ideas of Nicolas She and Vivek Wadhwa, to attract foreign entrepreneurs and FDI and, thereby, to increase the global business networks of the country, while decreasing the reliance on commodities export and supporting economic diversification (Melo, 2012; Dube, 2015).

The programme came at an opportunistic time: Europe was recovering from a recession, PayPal had just acquired Chile's Multicaja, there were

increasing online consumer habits, and Microsoft set up an innovation centre together with CORFO for early-stage ICT companies (Tmf-group.com, 2016). By running a competition, entrepreneurs from all over the world can apply to the Start-up Chile programme and, if selected, would receive $15,000-60,000 equity-free on a reimbursement basis, as well as a one-year work visa to live in Chile for six months while developing their enterprise (Melo, 2012; Startupchile.org, 2018). The entrepreneurs are also helped with basic procedures such as opening a bank account and obtaining a local ID, as well as being equipped with free Wi-Fi-enabled office space in downtown Santiago (Melo, 2012).

Since its establishment, Start-up Chile has worked with more than 1,300 businesses and the programme has been replicated in over 50 countries (Larsson, 2016). Moreover, the programme has made Chile one of the five top countries in the world for start-ups, with the government investing USD 15 million. In comparison, the UK invests only USD 9.9 million (Larsson, 2016). Yet, it is not without its challenges. Firstly, despite the availability of initial seed money, there is a lack of investors and funding opportunities in the later stages of enterprise development; and, due to large funding availability in the early-stages, this may not necessarily drive the enterprises to produce self-sustaining models (Larsson, 2016). This has caused many of the enterprises to eventually venture abroad, along with the want to be close to their market demographic (Dube, 2015). Such was the case of the student-loan repayment service enterprise 'Student Loan Hero', which found success in the United States (Dube, 2015). There is therefore a definite need to encourage the estimated 80% of foreign programme-participants to stay, instead of leaving after the programme ends (Dube, 2015).

There has additionally been a call for improved regulation and bureaucracy to facilitate start-ups, as being audited and sorting payments can hinder further development (Larsson, 2016). Issues within this area include dealing with lengthy procedures to obtain construction permits and registering property and paying taxes (taking up on average 124 hours of employers'

time) (Tmf-group.com, 2016). As of 2018, the World Bank's Doing Business report had ranked Chile as number 55 in ease of doing business, down from 34 in 2014, which has been counteractive in attracting businesses and foreign direct investment (FDI) to the country (Larsson, 2016).

Lastly, there is also a need to find the balance between fostering new diversification and providing greater support for enterprises which makes use of Chile's sectoral strengths (Tmf-group.com, 2016). Those enterprises coming out of the programme which have had greatest success in Chile have their basis in the country's already developed sources, such as mining and agriculture (Dube, 2015). An example would include Biofiltro, which has created an organic wastewater-treatment technology implemented in Chilean dairy farms and wineries (Dube, 2015).

Broad lessons

There are many lessons here to draw for African countries with respect to leveraging existing national and sectoral opportunities; leveraging competitive advantage for leading roles in research and innovation; and ensuring a supportive business and socio-political environment. Further, in addition to the few highlighted above, there in an inexhaustible array of other research funders and mechanisms, among them the Global Health Investment Fund (GHIF) a social impact investment fund for late-stage innovations; the Gates Foundation Grant Challenges initiatives which seek to foster innovation to solve key health and development problems; other renowned Foundations, Trusts, development agencies and research funds such as the Gates Foundation, Wellcome Trust, Leverhulme Trust, IDRC, SIDA, UK Research and Innovation and Global Challenges Research Fund, UN agencies among others, which offer grant funding and awards to researchers and institutions to find solutions for global development challenges across the world. Global multi-actor partnerships such as the Vaccine Alliance (GAVI), the Consultative Group on International Agricultural Research (CGIAR), UNITAID (short-term finance for innovation, access

and scalability in global health). We did not explore many of these in detail in keeping with the focus of our paper, and there are different sources that would be useful for further insights. For example, the GFinder[6] Surveys conducted by Policy Cures Research are a tracker of global public, private, and philanthropic investments in neglected diseases research.

There are indeed further examples of a number of Africa-based and Africa-focused organisations and programmes deploying various approaches to support research and innovation in different thematic areas. A few examples are highlighted below, drawing out of each the key funding approaches in operation.

Case Study 6: Centres of Excellence, Pan-African Networking and Harnessing Global Resources - African Network for Drugs and Diagnostics Innovation (ANDI)

The African Network for Drugs and Diagnostics Innovation (ANDI) a pan-African organization hosted by the United Nations Office for Project Services (UNOPS). ANDI's Mission is "to promote and sustain African-led health product innovation to address African public health needs through efficient use of local knowledge, assembly of research networks, and building of capacity to support economic development." Born out of need for dedicated research and development for some of the health challenges that disproportionately affect Africa, ANDI's vision is to create a sustainable platform for health innovation in Africa to address the continent's health needs. The expected outcome is the discovery, development and delivery of affordable new health tools and technologies in support of healthcare delivery in Africa, as well as the development of capacity of Centres of Research Excellence. ANDI is an institutional innovation centred on an ethos of pan-African coordination and harnessing of global resources to fund development and deployment of home-grown R&D and innovation capabilities.

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[6] *https://gfinder.policycuresresearch.org/*

Case Study 7: Facilitating Public Private Partnerships, Harnessing Local and Global Intellectual and Technological Resources to Address Local Problems - African Agricultural Technology Foundation (AATF)

The African Agricultural Technology Foundation is a not-for-profit organisation that facilitates and promotes public/private partnerships for the access and delivery of appropriate agricultural technologies for sustainable use by smallholder farmers in Sub Saharan Africa (SSA) through innovative partnerships and effective stewardship along the entire value chain. The Foundation is a one-stop-shop that provides expertise and know-how that facilitates the identification, access, development, delivery and utilisation of agricultural technologies. AATF works towards food security and poverty reduction in Sub-Saharan Africa, and its structure and operations draw upon the best practices and resources of both the public and private sectors. It also contributes to capacity building in Africa by engaging African institutions in the execution of tasks that contribute to the Foundation's mission.

Case Study 8: Grant-Making for Transformative Agents – AGRA

The Alliance for a Green Revolution in Africa invests in projects that can have measurable impact and can create meaningful, transformative change in the agriculture sector. Through an Africa-led, farmer-centred and partnership driven approach, AGRA undertakes demand driven interventions that leverage donor, private sector, and government investments in agriculture. AGRA areas of intervention include seed supply, fertiliser value chains, farmer awareness, markets, finance and capacity building.

Case Study 9: Academia and Supranational Agency Partnership – AESA

AESA, an initiative of the African Academy of Sciences and the NEPAD Agency is committed to supporting the development of STI programmes in Africa, though supporting the best minds, working in conducive research environments, to design and implement programmes that produce quality, relevant data, and innovations that have the potential to impact health and developmental challenges on the continent and globally. Among

the initiatives programmes are (1) CIRCLE, the Climate Impact Research Capacity and Leadership Enhancement, a programme to develop the skills and research results for early career African researchers in the field of climate change (2) Grand Challenges Africa which promotes Africa-led scientific innovations to help countries better achieve the Sustainable Development Goals by awarding seed and full grants to the continent's most impressive innovators. Current priorities include maternal, neonatal and child health, anti-microbial resistance, biomedical engineering and key areas of infectious diseases and NCDs (3) the Developing Excellence in Leadership, Training and Science (DELTAS) Africa, a programme led by AESA to develop world-class researchers and scientific leaders in Africa who will conduct cutting-edge health research in infectious diseases, non-communicable diseases (NCDs), population and public health. AESA also has programmes in STEM, genomics, Africa-India science expertise mobility, science communication and good financial grant practice.

Case Study 10: Supporting Excellence in Individual and Collaborative Research - IFS

The International Foundation for Science (IFS) Programme aims to support excellent individual and collaborative research, to build the capability of early-career scientists in the developing world, and to contribute innovation to the sustainable management of biological, water and energy resources. In particular, through placement and research grants, the IFS enables young scientists to contribute to a global research community that is aiming to reduce poverty and supporting sustainable development.

Case Study 11: Local and Cross-National Collaborative Research and Innovation – NEPAD SANBIO

NEPAD Agency's Southern Africa Network for Biosciences (SANBio[7]) is a shared biosciences research, development and innovation platform for working collaboratively to address some of Southern Africa's

[7] *http://www.nepadsanbio.org/*

key biosciences issues in health, nutrition and health-related intervention areas such as agriculture and environment. Providing funding for research and skills development in these areas, SANBio is part of NEPAD Agency's Industrialisation, Science, Technology and Innovation Hub, together with the African Biosafety Network of Expertise (ABNE) Biosciences eastern and central Africa - International Livestock Research Institute (BecA - ILRI) Hub; African Institute for Mathematical Science (AIMS) – Next Einstein Initiative; Bio-Innovate; African Medicines Regulatory Harmonisation (AMRH); NEPAD Water Centres of Excellence; African Science Technology and Innovation Indicators (ASTII).

4.3 What Historical and Current Factors Facilitate or Constrain the Implementation of the Funding Approaches and How Have/Can The Gains Be Enhanced or The Challenges Re solved?

The different funding mechanisms highlighted in Tables 2 & 3, which encompass co-funding, partnerships and multi-disciplinary working, were deemed to be particularly important in the various countries at this point in time for different reasons which included relevance to local contexts, sufficiency of funding provided, more rapid application turnaround time, inclusion of new researchers and wider scope for cross-sectoral collaboration. Relevance to local contexts and scope for cross-sectoral collaboration were particularly viewed as key. In a majority of the countries, with the exception of Kenya, respondents said research and innovation would have suffered adversely without the new funding models. Among the reasons highlighted why this would have been the case were that with the new models there is more standardisation of research applications, there is better resource tracking and accountability among recipients, and there are stronger institutions. In South Africa, the new models were said to have led to:

> *'… continuous and consistent funding to support excellent research, increased international competitiveness of South African researchers and better science policy-linkages' (Respondent AS, Aug 2018).*

Across the countries, the different models were also seen as being in harmony with global, continental and sectoral development trajectories charted by among others, SDGs, continental development agendas such as Agenda-2063, STISA-2024, NEPAD and AU programmes such as ASTII, AMRH & CAADP, various national development agendas and programmes of multilateral agencies. Additionally, adoption of the new funding models was said to be benefitting from increasing access to knowledge resources, internationalisation of the research enterprise and increasing political and collective will towards research and innovation in various African countries.

Meanwhile, among different factors which influence choice of funding model for research and innovation, history of a particular model's use in developed and other developing countries. Even in this backdrop, there were several issues that were said to pause potential sustainability challenges for the new models, which for a majority of the countries could be summed up as perennial under-resourcing of research and innovation, 'the lack of an implementation plan and an uncoordinated approach to ST&I' (UNESCO, 2016). While political will was said to be on the increase, it still remained insufficient, and had not translated into 'political action'. The following challenges were also mentioned, and were said to be equally important and in need of urgent attention: limited government financial resources, unfavourable institutional traditions, policy incoherence across sectors, mismatch between research priorities and developmental challenges, lack of long-term policy planning, rapid technological changes and poor strategic partnership choices.

There were mixed views on whether funding models should be locally-derived or not, with 64% of respondents saying they preferred locally-derived models, 27% expressing no preference while 9% said, no, they should not be locally-derived, see Fig 13 below.

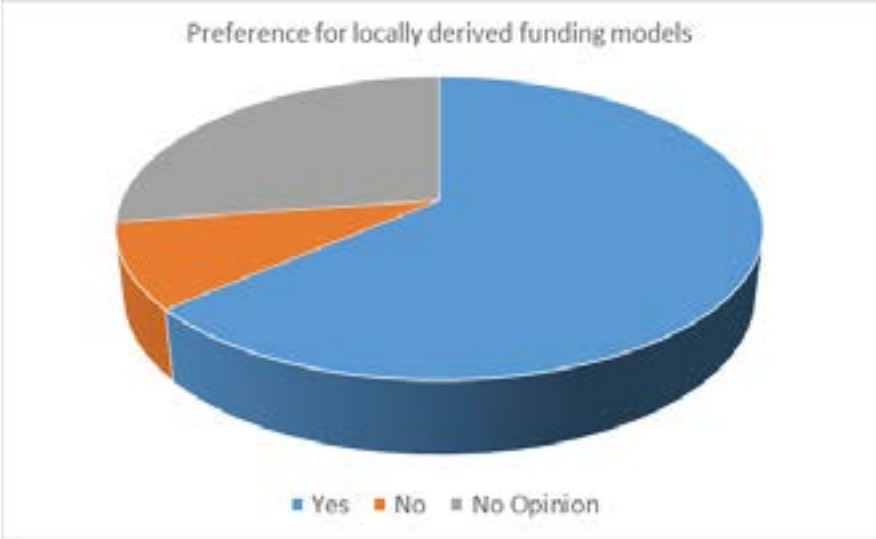

Figure 13: Preference for locally derived models

What was common across the responses was that the model of choice should be compatible with local contexts, as illustrated by some of the respondents below:

In favour of locally-derived models;

> *''It takes into context the entire national system of innovation that the research funding would address which includes research infrastructure, human resource as well as commercialization of research output'' (Respondent G, Aug 2018).*
>
> *''Implementation is based on our context. The models can leverage the limited resources to realize maximum output' (Respondent K, Aug 2018).*
>
> *''Because locally derived funding models would be more responsive to local needs and aspirations'' (Respondent M, August, 2018).*
>
> *''Because the local contextual factors/problems can determine and inform the relevant choice of a suitable funding model while learning from funding models of other countries'' (Respondent FB, August, 2018).*

And not in favour of locally-derived models only;

> *''A combination of options should be considered, informed by local context, that will best facilitate and impact the intent of the funding. There should therefore not be an exclusive preference for locally-derived funding models'' (Respondent AS, August, 2018)*

In relation to the above, some specific examples of locally-derived funding models for research and innovation that could be scaled up and adopted across the continent were suggested from Ghana and South Africa, as elaborated by respondent quotes below:

'Funding for the establishment of Technology Transfer Centres in R&D institutions will promote research collaboration with the private sector thereby increasing research funding from industry to the institutions';

'The NRF created and established an innovative academia-industry links programme for development of human capital. In addition, a dedicated and well-resourced chairs programme in-country contributed significantly to research output, research capacity development, and international collaboration'

Both models hinge on partnerships, co-funding and inter-disciplinary collaboration, which were key themes across the countries.

4.4 What Institutional Reforms Accompanied the New Approaches and How Could Africa Re-Position Its Own Institutional Architecture for Enhanced Research and Innovation Funding?

In seeking to understand institutional reforms that have accompanied the new funding approaches, we explored a number of issues with respondents, among them whether or not there had been changes in the drivers and priorities shaping decisions on funding research and innovation, changes that have been realised by institutions and researchers from use of new approaches, and the advantages accruing from use of the new approaches. This section summarises our findings on these and related aspects.

Figure 14: Important priorities driving funding for research and innovation; score of 1 means most important and score of 5 least important

According to the respondents, as shown in Fig 14 above, sectoral and national priorities are increasingly becoming key drivers of funding for research and innovation, compared to organisational, funder or researcher

priorities as was the dominant case in the past. The institutional adjustment noted here is that this shift is reflective of clearer articulation of national and sectoral priorities and development agendas which has taken place in most of the African countries in the last few years, and the role played by NEPAD and AU cannot be discounted.

Meanwhile, a number of advantages of new funding, again reflective of institutional adjustments at different levels, were highlighted, as shown below.

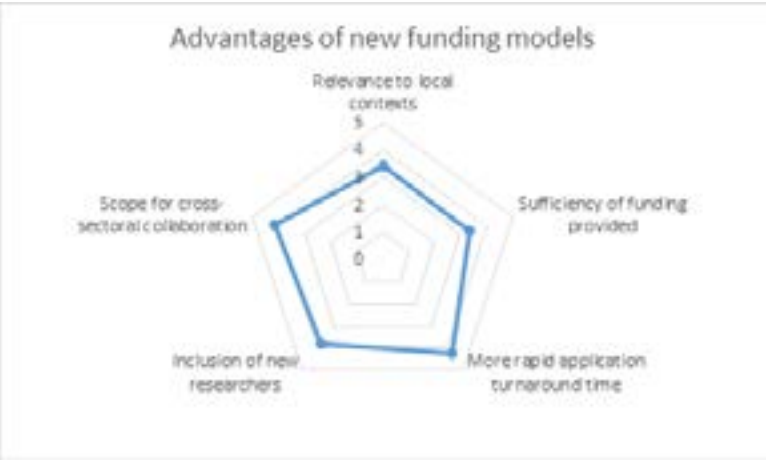

Figure 15: Advantages of new funding models

Other institutional adjustments and reflections in policy framing were also noted which resulted in the new approaches being advantageous, for example a focus on responsibility and assured output (Kenya), emphasis on international competitiveness, consideration of transdisciplinary, multidisciplinary and interdisciplinary approaches; and greater science-policy linkages (South Africa) and ensuring enhancement of human and societal benefits (Namibia).

Learning from past approaches to research and innovation funding

Other adjustments were related to the need to reflect on and embed lessons from approaches that have been used in the different countries before. It was highlighted that lesson drawing should not only focus on what comes from other countries, but also what can be learnt from what has been tried. In this regard, respondents referred to a number of

previous approaches which they said could be leveraged to enhance the new approaches. Malawi for example was looking at reviving government grant schemes for research and innovation based on the feeling that 'no donor can fund a country's national research priorities if the government itself does not prioritise funding them' (Respondent M, Aug 2018). Namibia was also rethinking

> *'allocation by the Central Government, because this is vital to ensure that research and innovation is targeting the solutions that enhance national research priorities and needs of the country as well as research and innovation infrastructure development' (Respondent AN, Jul 2018)*

while in South Africa there were efforts to focus again on specific disciplines to strengthen and support research. According to one respondent;

> *'A competitive, bottom-up research agenda has been useful during the past 10 years, but there is a need to re-focus on specific areas of advantage and disciplines to strengthen the research system (e.g. mathematics, engineering)' Respondent AS, Aug, 2018).*

Overall, there was a strong feeling that the multidisciplinary and partnership-based arrangement characterising the new funding approaches were benefitting from adjustments at multiple levels from the global to the national and sectoral which were increasingly in favour in such collaborative arrangements.

4.5 How Are Other Broader Issues Pertinent to Research and Innovation Broadly Being Taken into Consideration Towards More Efficient and Effective Funding for Research and Innovation?

Given the cross-cutting and pervasive nature of science, technology and innovation, it is not surprising that funding efforts for this sector are the centre of many dominant factors, forces and voices. Respondents highlighted that among the dominant voices in the debates on research and innovation were international donors, NGOs and developed country aid programmes, especially those focused on health and agriculture. Regional economic communities, AU and NEPAD were also said to be dominant, as well as international philanthropists, venture capitalists and multinational companies. Stakeholders that were said to be missing or less visible in the debates included civil society organisations at local and stakeholder level; appropriately resourced African research and innovation think tanks;

local private sector, banks, venture capitalists and philanthropists; active parliamentary committees on STI lobbying for funding; and local small and medium enterprises.

As a result of or related to the stakeholder participation scenario above, some issues were said not to be adequately addressed or attended to in the debates on research and innovation. These included the issue of compliance with continental declarations e.g. raising funding to at least 1 % GDP. One respondent had this to say:

> *''National governments are not held accountable by appropriate regional economic communities such as AU/SADC and civil society bodies on their initiatives towards funding for research and innovation in their respective countries. As such, such governments do take a les affaire approach towards funding for research and innovation. Even when there are certain legal and administrative instruments in place for S&T Fund, some national governments have not prioritised to make such a fund operational'' (Respondent Z, Aug 2018).*

This further underscored the lack of translation of political will into political action, which has been observed by other studies of the research and innovation terrain in Africa (e.g. Amankwah-Amoah, 2016 and UNESCO, 2016).

Other key issues that were highlighted as missing in the debates were: how to reach out to non-formal researchers and innovators across the continent; creation of a deliberate policy environment for private sector participation in research and innovation funding; harnessing mutually beneficial local partnerships to support R&I; a basis of a common/similar model for funding that is unaffected by the political dimensions of the region and rather supports the priorities agreed; and risk mitigation from regime changes that affect policy and funding allocations approved by previous regimes.

It is clear from the foregoing that an understanding of the political economy for the funding of research and innovation in Africa is not only necessary (Chataway et al, 2018), but also that this serves as an informed basis for developing synergies within and across African countries and for lesson drawing from countries elsewhere with similar politico- and socio-economic histories and realities.

5.0 Conclusions and Recommendations

The aim of this commissioned paper was to inform current debates, reviews and re-organization of research and innovation funding in Africa, through identifying, unpacking and analysing "new approaches for funding research and innovation in Africa". Guided by five broad research questions, the paper sought to understand historical and current contexts of research and innovation in Africa, identify examples of, experiences and lessons from innovative models and mechanisms for funding research and innovation from across the world and in Africa and explore opportunities for ensuring context-driven, efficient and effective harnessing and utilisation of resources for research and innovation by African countries.

In order to accomplish the aim of the paper, a comprehensive study was conducted iteratively between July and December 2018 encompassing collection and analysis of published and grey academic, policy and practice literature on research and innovation in Africa broadly, and funding models in particular; development and administration of a semi-structured questionnaire/instrument with clustered questions and sub-questions targeting informants from science granting councils in 15 African countries, research organisations, funding agencies or policy bodies in Africa and elsewhere. Data from the research process was collated, anonymized, aggregated and analysed in a combination of themes drawn from literature and from the research findings. Linking back to the study aims and research questions, this paper broadly confirms that a wide range of capabilities is required for different stages of the research and innovation value chain.

Effective funding of research and innovation from basic research up to launch of products on markets will require context-relevant governance approaches which balance the needs and optimises the roles of different actors.

The following specific key messages and recommendations are drawn from the study:

5.1 How Important Is the Funding of Research and Innovation Among African Countries and What Is the Evidence To Demonstrate The Level Of Importance?

Key messages

We conclude that while generally still rated as low to medium, the importance of research and innovation is increasing in most of African countries. This is demonstrated by institutional and policy provisions for STI which have been instituted in the last few years.

Recommendation 1: Beyond tactical addressing of current socio-economic challenges, African governments need to develop unifying long-range, yet operable national ideologies on the role of research and innovation, modelled around the impending demographic dividend and leveraging the continent's unique resource endowment for economic progress. An example is how Japan attained universal health coverage in the early 1960s, way ahead of the rest of the world by defining access to health as a 'nation building' imperative.

Recommendation 2: As part of their mandate to support and manage research programmes, SGCs should assist researchers to generate research and innovation impact evidence and sustained relevance which will result in political will and commitment to funding research and innovation. There is a lot of data generated by various agencies, e.g. ASTII, which can be utilized more for decision-making at national and sectoral levels.

Recommendation 3: For the purposes of defining research and innovation policy objectives and identifying appropriate approaches for funding research and innovation, it is important for the different stages of the research and innovation value to be mapped out (by sector where possible), from basic research to products. This will enable identification of entry points for different funding options. SGCs should lead this as part of their objective of strengthening research and evidence-based policies.

5.2 What Are the New and Innovative Funding Approaches (Schemes, Models and Mechanisms) That Have Been Applied Across the World and What Lessons Could Be Drawn for African Countries?

Key messages

A number of dynamic new funding models have been developed, adopted and deployed in countries and sectors to deal with realities of decreasing funding for research and innovation from traditional sources. These models, which encompass partnerships, co-funding and multi-disciplinary approaches, seek to ensure context-driven, efficient and effective utilisation of resources.

Recommendation 4: In light of the reality that different countries and sectors may work best with particular funding approaches, there is need for accommodation of diverse funding models and means of optimising and assessing their impact. SGCs and line ministries should work closely to come up with robust procedures for identifying and consolidating desired sector outcomes upon which policymaking should focus.

Recommendation 5: Access to and deployment of effective approaches for funding research and innovation require strong leadership and oversight from governments and SGCs, especially with respect to respect to identifying and balancing the disparate requirements of different sectors and areas of application with their points of commonality.

5.3 What Historical and Current Factors Facilitate or Constrain the Implementation of the Funding Approaches and How Have/Can The Gains Be Enhanced or The Challenges Re solved?

Key messages

A number of challenges stalk the expansion and sustainable deployment of the new funding models. For instance, political will remains insufficient and not acted upon, while urgent attention also needs to be paid to persistent limited government financial resources, unfavourable institutional traditions, policy incoherence across sectors, mismatch between research priorities and developmental challenges, lack of long-term policy planning, rapid technological changes and poor strategic partnership choices.

Recommendation 6: SGCs should commission an on-going review of best practice at sectoral, national and international levels to consolidate knowledge about how deployment and implementation of STI policies and research and innovation approaches can be optimised. The review should include the use of existing and new funding approaches, and should include details about how a specific industry or component of the research and innovation value chain can engage with upstream or downstream processes.

5.4 What Institutional Reforms Accompanied the New Approaches and How Could Africa Re-Position Its Own Institutional Architecture for Enhanced Research and Innovation Funding?

Key messages

New funding approaches were said to have brought more standardisation of research applications, better resource tracking and accountability among recipients and stronger research-policy institutions.

Recommendation 7: Leveraging their access to global knowledge resources, SGCs should help countries develop or reconfigure their STI policies to be not only forward-looking and agile, but also how they influence funding approaches and other interventions towards strategic

goals. Strategies for funding research and innovation should align with key policies such as national industrial, health, agricultural and education strategies and other national developmental visions.

Recommendation 8: SGCs should serve as, or help countries establish, consolidated national knowledge platforms on research and innovation. Generation and sharing of knowledge is integral to research and innovation processes, and the more cohesively and efficiently these can be done within the research and innovation ecosystems, the greater the benefit that will accrue to SGCs, researchers, decision-makers as well as entrepreneurs and other adopters of innovations.

5.5 How Are Other Broader Issues Pertinent to Research and Innovation Broadly Being Taken into Consideration Towards More Efficient and Effective Funding for Research and Innovation?

Key messages

It is undoubted that African countries' goals of economic development driven by research and innovation are in line with trends elsewhere. There are numerous context-specific and context-transcending technical, social, political and economic issues that stakeholders in the research and innovation ecosystem need to be aware of and to take into consideration in order to optimise use of research and innovation resources.

Recommendation 9: STI policies and attendant research and innovation funding models will be more effective when underpinned by an understanding of the interdependent political, social, technical and economic factors that affect them. SGCs and governments should use their considerable convening power to regularly bring together research, business, regulator, user and different other communities at national level to explore funding approaches that best promote the values and interests of African countries in a global context.

ANNEXES

ANNEX 1: STUDY QUESTIONNAIRE

New Approaches for Financing Research and Innovation in Africa
On behalf of ATPS and SCINNOVENT Centre

Summary

This questionnaire is part of a study commissioned by the African Technology Policy Studies Network (ATPS) working in partnership with The Scinnovent Centre under the Science Granting Councils Initiative (SGCI). The SGCs Initiative is 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) with a mandate to strengthen the capacities of Science Granting Councils in sub-Saharan Africa in order to support research and evidence-based policies that will contribute to economic and social development. Countries in the developed world and the newly industrialized countries have experimented with various approaches including through institutional reforms, models and mechanisms for funding and financing research and innovation that have delivered some outstanding results. The aim of this study is to identify, analyse and document evidence on new and innovative approaches to the financing of research and innovation in Africa across different thematic, sectoral and time scales.

Purpose

This questionnaire seeks to gather key stakeholder expert views to identify context-specific insights on how African countries can innovatively and sustainably finance research and innovation, and any constraining factors that need to be resolved. The results will be used to produce a Policy Brief

and peer reviewed paper, which will inform policy, debates and potentially lead to reviews and re-organization of research and innovation funding in African countries. As an expert in research and innovation in your country and beyond, we seek your contribution to this endeavour through responding to this questionnaire. All responses will be anonymised in the analysis and project publications. You will however be included in the distribution lists for final project outputs in the first quarter of 2019.

Respondent details

1.1 Name (optional): ……..

1.2 Organisation: ……

1.3 Position in organisation: ……

1.4 Years in position: ……

1.5 Stakeholder category:

Government/Policymaker	☐
R&D organisation	☐
Academic institution	☐
Funding organisation	☐
National science council	☐
Continental/global agency	☐
Other (please specify)	☐

2.0 Importance of funding for research and innovation in African countries

2.1 What are your current key sources of finance for research and innovation (please rank from 1 to 7 each of the sources below, with 1 being most important and 7 least important)?

Science granting councils

Government programmes

Multinational and Bilateral Donors

International NGOs

Local Private Sector

Local NGOs

Other (Please specifiy)……

2.2 In your own opinion, how much importance is placed on funding for research and innovation by your country?

High

Medium

Low

No opinion

2.3 What are the 3 key policy or strategic changes that have occurred in the last 10 years to demonstrate importance of funding for research and innovation in your country?

……

……

……

……

2.4 How important are these priorities in driving funding for research and innovation in your country? Please rank the priorities in order of their importance - 1 being highest priority and 7 lowest priority]

National priorities ……

Regional economic group priorities……

Sectoral priorities……

Organisational priorities……

Researcher priorities……

Funder priorities……

Other: Please elaborate……

2.5 What are the specific challenges that your organisation faces on funding research and innovation?

Adequacy of funding

Compliance with funding requirements

Timely availability of funding

Seeing benefits of funding

Other _____

3.0 Historical Sources of funding for research and innovations

3.1 Historically what has been the contribution in percentage terms by each of the actors listed below to funding research and innovation in your country?

International donors……..

International private funders & foundations……..

Local private sector……..

Local science councils……..

Central government……..

Other (specify)……..

3.2. Who decides on sources of funding for research and innovation in your country?

……

……

……

3.3 From the options below please select relevant explanations for the percentage contributions in 3.2

Government could not allocate funds for research and innovation

These were the preferred funders

There was a limited choice of funders

Local research is not competitive for other potential funders

Other (specify)……..

3.4 Giving examples of specific sectors and indicative proportions (%), please highlight what the main uses of the funds were

……

……

……

……

……

4.0 Current sources and uses of funds for research and innovation

4.1 Has there been a shift in sources of funding in the last 5 years? Please elaborate wherever possible

Yes ……

No……

I don't know……

4.2 In percentage terms, what were the sources of funding for research and innovation 5 years ago?

International donors……

International private funders & foundations……

Local private sector……

Local science councils……

Central government……

Other (specify)……

4.3 Why has there been a shift in sources of funding?

More funding opportunities now available……

Shift in research and innovation priorities……

Problems with previous funders……

Following local and external trends……

Other (specify)……

4.4 As a result of the shift in sources of funding, has there been a change in the uses of the funds? Please indicate proportions in percentage

Capacity building - Infrastructure

Capacity building – research expertise

Capacity building – policy

Research dissemination

Other (specify).....

5.0 New or Innovative Funding models or schemes

5.2 What are the three most important new (or innovative) funding models for research and innovation in your country. – List in decreasing order of importance; 1 being most important and 3 the least important

1. 2. 3.

5.3 In your view, what are the advantages of the new funding models? (Score 5 for most positive and 1 for least positive)

Relevance to local contexts

Sufficiency of funding provided

More rapid application turnaround time

Inclusion of new researchers

Scope for cross-sectoral collaboration

Others(specify).....

5.4 Would research and innovation have suffered adversely without the new funding models?

Very likely

Likely

Neutral

Unlikely

Very unlikely

5.5 What positive changes have occurred since you started using new models?

More standardisation of research applications

Better resource tracking and accountability among recipients

Stronger institutions

Nothing

Not Applicable

5.6 Which aspects of research and innovation would have suffered the most without the funding new models?

Capacity building - Infrastructure

Capacity building – research expertise

Capacity building – policy

Research dissemination

Other (specify).....

5.8 Given a choice, which old models would you resuscitate and why?

……

……

……

……

5.9 Please rank as high, moderate or low which continental agencies/programmes on science, technology and innovation have been most influential in your decisions on models to use

Nepad ASTII

AU STISA (Science Technology and Innovation Strategy for Africa)

AU/NEPAD CAADP

NEPAD AMRH

Others (specify)……

5.9 Rank as high, moderate or low how the following factors are important in access to funding model for research and innovation

Clarity of model implementation

History of use in developing countries

History of use in advanced countries

History of use locally

Others (specify)……

5.10 What are the main drivers for emergence of new or innovative funding models for research and innovation?

Political will

Collective will

Increase in access to knowledge resources

National development imperatives

Global trends

Others (specify)……

5.11 What are the key constraints to sustainability for the new funding models for research and innovation?

Limited government financial resources

Unfavourable institutional traditions

Limited political will

Policy incoherence across sectors

Mismatch between research priorities and developmental challenges

Lack of long term policy planning

Rapid technological changes

Others (specify)……

5.12 What are the opportunities for the use of new funding for research and innovation?

Sustainable Development Goals

National development agendas

Continental development agendas

Programmes of multilateral agencies

6.0 Other important issues on research and innovation

6.1 What is the rationale behind your country's funding of research and innovation?

Catching up

Leapfrogging

Home-grown economic development

Following global trends

Other (specify)

6.2 Do you agree with the suggestion that there should be a preference for locally-derived funding models for research and innovation?

Yes

No

No opinion

6.3 What's the reason for your opinion?

……

……

……

6.4 Related to 6.2 the above, do you have examples of key locally-derived funding models for research and innovation that should be scaled up and adopted across the continent? Please elaborate

……

……

……

6.5 In your opinion who are the key missing actors in mobilisation and allocation of innovative funding for research and innovation?

DOMINANT REGIONAL AND INTERNATIONAL ACTORS/STAKEHOLDERS	MISSING AFRICAN/LOCAL ACTORS/STAKEHOLDERS

6.6 Finally, what issues do you think have not being adequately attended to in the agendas on funding research and innovation in Africa?

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