The emergence and strategy of tech hubs in Africa: Implications for knowledge production and value creation

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Abstract

Do-it-Yourself tech hubs in Africa are challenging the dominance of traditional universities as sites of knowledge production. We adopt the theory of the new production of knowledge to explore how these hubs' transdisciplinary, heterarchical and boundary-spanning approach enables them to more efficiently generate innovative solutions in direct response to specific industry needs and critical societal challenges. We draw on five case studies of tech hubs in Nigeria, South Africa, Kenya and Uganda. While traditional universities are struggling with resource constraints, inadequate industry engagement, and the limitations imposed by the institutional organisation of disciplinary knowledge, our study shows that tech hubs are leading the way in generating new knowledge and innovative solutions particularly for those at the bottom of the pyramid. They are also more effective in economic and social value creation by generating new jobs, stimulating the entrepreneurial ecosystem and improving the quality of life through technology. We develop a conceptual model to show the constraints underlying hub formation, the strategies used to achieve hub motives and the contingent impact of hub strategies.

Keywords:

Africa; Bricolage; DiY, Mode 2 knowledge; Tech hubs

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1. Introduction

Following Gibbons et al's (1994) influential book- *The New Production of Knowledge*, many scholars continue to grapple with the global implications of the rapidly changing landscape of knowledge production. Consequently, there has been an emerging area of study questioning the role of universities as the principal source of knowledge and its ability to remain useful to society and industry. The current trend of knowledge production point to the fact that traditional universities are no longer the principal knowledge producers as non-university actors such as government-owned laboratories, industrial labs, innovation hubs, tech hubs, DiY labs and think tanks assert their influence in a more diverse and heterogeneous knowledge production space (Godin and Gingras, 2000; Hessels and Van Lente, 2008). This presents a challenge for universities to reinvent themselves by transforming from knowledge factories to boundary-spanning hubs connecting academia to local businesses community groups and the industry in stimulating innovation and economic development in a much more dynamic and robust manner (Youtie and Shapira, 2008; Mosey, Wright and Clarysse, 2012).

More importantly, this changing landscape of knowledge production provides auspicious opportunities for non-university actors to create new spaces and inject the much-needed dynamism, local resources, and agility into the system of knowledge production in communities as well as creating a conducive environment for co-creation of knowledge (Hessels and Van Lente, 2008). This is especially relevant in Sub-Saharan Africa, where universities are struggling to keep pace with the changing needs in the labour market and the increasing nature of graduate unemployment. Despite this realisation, current research on the non-university actors in knowledge production in Africa is less apparent. (Youtie & Shapira, 2008; Amankwah-Amoah, 2016). More importantly, the model of establishment, management strategy and financing of the non-university knowledge hubs remain under-researched (Fox 2012). It is in the light of the above changing landscape and the need to explore the role and contribution of other non-university actors in the knowledge production space that this paper investigates the emergence of Do-It-Yourself (DiY) tech hubs in Africa and the implication of this for knowledge production, job creation and value creation.

Extant research has examined several knowledge economy themes in Africa, such as the impact of globalisation, peace and stability on innovation (Amavilah et al. 2017), the knowledge

economy performance and trajectory of African countries (Asongu 2017a; Asongu et al. 2018; Vadra 2017), and the policy syndromes and strategies for building knowledge-based economies (Asongu 2017b; Asongu and Odhiambo 2019; Obamba 2013). While we acknowledge the importance of these studies for illuminating our understanding of the dynamics and issues pertaining to knowledge management in the African region, we also note some gaps. First, the literature dominantly dwells on aggregate country-level analyses with a strong focus on national policy bordering on education, ICT and institutional conditions (e.g. Asongu and Odhiambo 2019; Jowi 2012). This leads to limited knowledge of how the other stakeholders of Africa's knowledge economy systems such as firms and technology hubs navigate precarious institutional and constraint regimes to instigate innovation, engage in knowledge transfers and drive solutions at the bottom of the pyramid.

Second, research on technological advancements in Africa has similarly focused on the contextual evolution of emerging technologies as well as the opportunities and challenges they pose to businesses on the continent (Amankwah-Amoah et al. 2018; Amankwah-Amoah and Sarpong 2016). However, there is a paucity of works about how nascent African technologies emerge, the role of tech hubs in this evolutionary process, or the adoption, adaptation and diffusion of these technologies.

Third, over the past few years, sub-Saharan Africa has witnessed a proliferation of tech hubs (Kelly, John, & Firestone, 2016; Giuliani et al., 2019). However, research on these hubs has not kept pace with the phenomenon. It is widely believed that these hubs generate scientific knowledge and socio-economic impacts, but there is a limited exploration of the intricate mechanics and strategies through which they create value and how they work differently from traditional research institutions.

We address the aforementioned gaps by examining the evolution, operations and impact generation activities of five tech hubs in four sub-Saharan African countries. In doing this, our study makes important contributions to the knowledge economy and DiY literature. We provide a proximate understanding of how tech hubs emerge and their impacts on the knowledge-based economic transitions currently sweeping across Africa. Our work unpacks normative suggestions for ICT development and institutional regime strengthening (Asongu 2017b; Asongu and Odhiambo 2019) to facilitate a deeper understanding of how DiY laboratories present platforms for grassroots technological innovation and scientific democratization. Specifically, we develop a conceptual model to map the strategies used by

DiY tech hubs, starting from the constraints that motivate their formation, the interventions used to achieve their motives and the contingent impact of their strategies. Beyond theoretical value, this knowledge is also important for policymakers to address the policy syndromes that hold back the promise of DiY tech hubs as important sources of innovation (Fox 2012; Meyer 2013; Seyfried et al. 2014). We argue for the importance of community engagement in DiY tech hubs in contributing to "below the radar" innovations that are cost-effective, localised and community-oriented. We also argue for local financing schemes through crowdsourcing whereby DiY labs could be used to serve multiple purposes for communities in fostering local economic development, bootstrapping and bricolage initiatives particularly for start-ups (Petrushenko & Dudkin, 2014).

The remainder of the paper is structured as follows. Next, we discuss DiY tech hubs with specific reference to their presence in Africa. Thereafter, we present our theoretical framework where we explore the literature on knowledge production in African universities and tech hubs. We also discuss our methodology, particularly justifying our approach and the case selections. Finally, we present and discuss the findings and their implications for practice, policy and future research.

2. DiY Laboratories

DiY labs come in various forms and shapes with varying degrees of focus. From the likes of SpaceX in 2002 and OSSI-X in 2013, DiY labs are known to harness local talent particularly for start-ups who are constantly in search for space in trying new ideas amidst scarce financial resources. A DiY laboratory refers to those projects in which communities themselves exert a great deal of interest in financing, ownership, control and management (Seyfang, Pank, & Smith, 2013). Sarpong, Ofosu, Botchie, & Clear, (2020) also describe a DIY laboratory as a community-based hub which is independently managed by scientists, science enthusiasts or volunteers with the desire to acquire experimental knowledge. UNICEF (2012) also indicate that a community DiY Lab could simply be a space of creativity which is aimed at solving local problems through the use of local resources, collaboration, openness and experimentation.

In its design, DiY labs, therefore, provide an inclusive technological platform by which communities in low-income countries become major stakeholders in local technology development (Botchie, Sarpong, & Bi, 2017). DiY labs, therefore, ensure global interoperability in the sense that it creates the space for collaborations among a host of stakeholders in designing solutions for business and local challenges (UNICEF, 2012).

Traditionally, universities are known to be at the forefront of research (Datta, Saad, & Sarpong, 2019). However, these research institutions are usually hindered by funding and protracted publication delays and have therefore failed to engage communities effectively in undertaking important research which serves local needs (Kaplinsky, et al., 2009). Comparatively, DiY labs being designed around open source principles where individuals undertake personal research without formal qualifications provides both complementary and alternative research outlets for communities to access training, tools and technical 'know how'. This alternative research space also reduces the mysticism associated with research and possesses the potential to become the game-changer in community research and local technology development in shaping national strategic foresight (Sarpong, Eyres, & Batsakis, 2019).

Since the inaugural lecture of the 1st-Africa Living Lab Workshop in Gaborone, Botswana in June 2011, the need to establish DiY labs in Africa was intensively expressed and was supported by several international organisations such as UNICEF, the European Commission and the World Bank. Consequently, research on the establishment of community Labs in Africa to champion technological development has become more apparent than ever (Coetzee, Toit, & Herselman, 2012: Bell et al, 2014). However, the spread of DiY labs has not seen the kind of speed expected due to several factors including funding, community awareness, empowerment and other policy bottlenecks (Petrushenko & Dudkin, 2014).

DiY labs in Africa has provided distinct support for the growth of science Technology and Innovation (STI) over the past decade and this is expected to grow in size and relevance across various communities. Nevertheless, the search for an innovative technology that is sustainable and meets local conditions continues to dominate the African research agenda (Botchie, Sarpong, & Bi, 2017). Whether it is referred to as *below the radar*, *local*, *community* or *indigenous* innovations, there is a renewed consensus currently that local people need local innovations which serves their local needs (Kaplinsky et al., 2009). Unfortunately, much of the innovation research in Africa which is supposed to champion economic and technological development usually happens at controlled and designated laboratories, thus restricting community participation and usage of the local ordinary entrepreneur who would like to improve product designs and technical efficiency in business (Beeer et al, 2017). However, looking at the contingencies of resource constraints particular for start-ups in Africa, these secluded areas of research known as innovation centres, incubators and the likes, which are usually located within universities do not serve the needed community purposes and local needs (Landrain & Sussan, 2013; Southern et al., 2014).

While we acknowledge that DiY laboratories come in various shapes and forms, the focus of this paper is on tech hubs which have become one of the dominant knowledge production platforms in Africa (Kelly, John, & Firestone, 2016; International Trade Centre, 2019). Within the past five years alone, DiY tech hubs have expanded rapidly in the continent from 314 in 2016 to 643 in 2019. The number of tech hubs has doubled within the last three years from 314 in 2016 to 643 in 2019 (Kelly, John, & Firestone, 2016). This new era of research into DiY tech hubs, therefore, seeks to effectively engage many users and stakeholders in the knowledge co-creation process in fostering economic and technological development in Africa (West & Boger, 2014).

3. Theoretical Framework

3.1 The evolution of tech hubs in Africa

One of the contemporary challenges facing the African continent is the significant technological gap between African countries and the rest of the world. Bridging this gap is critical to the success of poverty alleviation agenda in sub-Saharan Africa (You, Dal Bianco, Lin, & Amankwah-Amoah, 2019). The rate of technological progress accounts for differences in total factor productivity among African countries (You, Dal Bianco, & Amankwah-Amoah 2020). Over the past four decades, the total Research and Development (R&D) output from low-income countries including Africa has increased from 2% to over 20% (Kaplinsky et al., 2009). Despite this growth, it has been observed that current knowledge generated in the developing world and Africa particularly, do not often meet the needs of low low-income consumers and communities. The African populace especially those found at the bottom of the pyramid are therefore faced with an avalanche of challenges ranging from health, agriculture, housing and infrastructure (Prahalad and Hammond 2002; Kaplinsky et al., 2009). Kaplinsky et al., (2009) argued that the reason for this knowledge gap is the fact the innovation value chains are often disconnected from the realities and peculiarities of those at the bottom of the pyramid.

Tech hubs in Africa have attracted significant attention within the last five years, and they constitute the most dominant form of DiY labs in the continent. A 2015 World Bank survey reported the existence of 117 tech hubs in Africa. Of the total number, only nine of them are led by academic institutions and 10 of them are government-led. The vast majority-79 out of 117 hubs- are led by civil society/private sector, whilst the remaining 19 are hybrid of public-owned and private-led organisations (Kelly, John, & Firestone, 2016). These figures paint a

picture of the key drivers of the new model of knowledge production. Between 2016 and 2019, African countries witnessed a significant expansion of tech hubs, from 314 in 2016 to 442 in 2018 and 643 as of October 2019 (Giuliani et al., 2019). In other words, African tech hubs have more than doubled within the last three years leading to 2019. This number does not include the 110 hubs that have close down their operations within the last few years "due to pivoting, bankruptcy, or the expiration of their mandate" (Giuliani *et al.*, 2019, p.5). Reports indicate that 90 of these tech hubs are located in Nigeria, 78 in South Africa, 56 in Egypt, and 50 in Kenya.

Tech hubs in Africa can be classified as cluster hubs, company hubs, or country hubs. Whilst a cluster hub refers to distinct entities located in close proximities to one another and are therefore often in regular contact and close interaction with each other, a company hub is a single entity which defines its own community and interacts with the outside world as a company. A country hub refers to an operational definition of hubs in terms of their national identity and core characteristics (Beer et al., 2017). Tech hubs in Africa also take a variety of legal structures including NGO/non-profit, private/for-profit, academic institution and associations. Tech hubs also engage in different activities with varying degrees of specialism as incubators, accelerators, co-working spaces, technology parks and corporate ventures (Giuliani et al, 2019). Alternatively, tech hubs can be fabrication labs, co-working spaces, hackerspaces, and makerspaces (David-West, Umukoro and Onuoha, 2018). Majority of tech hubs in Africa rely on some form of external funding. Aside donor funding, their revenue streams include membership fees and consulting, the latter being the largest revenue stream for many hubs. There has also been a surge in venture capital funding in the last five years. In 2018, 148 African tech hubs raised a total of $1.163 billion in equity through 164 rounds. This compares with $277 million in 2015 (Collon and Dème, 2018). One of the modern methods of financing community tech hubs in Africa is to adopt a crowdfunding model where communities are engaged in harnessing local financial resources in establishing tech hubs in contributing to economic development and pursuing local innovations in their respective localities (Brem, Bilgram, & Marchuk, 2019). Thus, public participation is a dynamic way of raising funds for research, local growth and innovation labs (Petrushenko & Dudkin, 2014).

The functions of the tech hubs can be categorised into three main broad categories: knowledge production, employment generation, and value creation. Tech hubs achieve this by providing communal spaces where people with different ideas and varying levels of skills and expertise

can collaborate to catalyse innovation and create new forms of knowledge. They facilitate skill development through training and workshops and the use of virtual learning platforms, among others. These broaden and deepen the pool of the much needed highly skilled entrepreneurs in Africa (David-West, Umukoro and Onuoha, 2018; International Trade Centre, 2019). Because of their agility, flexibility and adaptability relative to traditional universities, they are better able to respond to new challenges and opportunities precipitated by rapid changes in the knowledge economy.

Furthermore, African tech hubs are better positioned to create economic and social value. Because of their proximity to industry and active engagement with the public sector, they are better able to align their activities and interventions with specific industry requirements and societal needs. In the process, they create social value, stimulate the market, and enliven the entire entrepreneurial ecosystem. Their impact is not only in terms of support programmes for start-ups, but also in terms of creating communities with a shared identity where inexperienced founders can interact with more experienced members (International Trade Centre, 2019). They can also have significant positive impacts on the university system, by co-opting universities as partners in the process of generating market-driven technological innovations (Kelly, John, & Firestone, 2016). By so doing, they can stimulate universities to upgrade their facilities and update their curricula to create more value.

African tech hubs provide an avenue through which ICT-related solutions are generated locally in addressing local challenges. The study of tech hubs in the context of Africa presents a new area of emphasis in the development of Science Technology and Innovation (STI) serving as a catalyst to meet capacity development and community empowerment in the continent (Amankwah-Amoah, 2016). The hubs create employment opportunities through their direct activities supporting start-ups and scale-ups (David-West, Umukoro and Onuoha, 2018). However, they also contribute by generating new opportunities in the supply and value chains (Segal, et al., 2016) by raising the productivity in other sectors (Banga and Velde, 2018) and through their overall impact on the entrepreneurial ecosystems (OC &C Strategy Consultants, 2018).

3.2 Below the radar theory of innovation: The role of tech hubs in knowledge production

Before the emergence of universities in Africa, knowledge was produced by communities to suit their specific environment and needs. Undoubtedly, universities have complimented this

role by directing knowledge production focusing mainly on mode 1 knowledge production. However, the typical rigid institutional structures and disciplinary boundary that characterise the approach of universities tend to alienate local communities and other stakeholders' from knowledge generation. This is especially the case of model 2 knowledge category, produced in the context of application (Holland, 2009). Therefore, the production of mode 2 knowledge through tech hubs has become an important dimension that needs to be explored looking at the current knowledge gap and unemployment crisis in developing countries, including African countries (Childe, 2010).

Hubs, whether described as technology or creative, are conceptualized at national, city, and industry levels. At the national level, countries are treated as hubs (Li and Bakht 2009), particularly when they are centres of excellence (e.g. the U.S for computer technology, Denmark for wind turbine technology, etc.). Within countries, some cities are designated as hubs for creativity and innovation in specific fields (Currid 2006), for instance, Milan, Paris and New York for fashion. At the industry level, several studies and practitioner reports have explored the clustering of innovation along product or service lines (Lampel and Germain 2016), a phenomenon similar to agglomeration.

Studies about hubs in Africa usually dwell on industry-level conceptualization, with most of them examining technology and diary hubs (De Beer et al. 2017; Friederici 2018; Littlewood and Kiyumbu 2018; Omondi et al. 2017; Rao et al. 2016). The merits of these studies are unequivocal, but their dominant focus on the benefits of hubs requires further research on how these organizations strategize for knowledge creation and impact as well as the challenges they face.

Globally, India and China have made significant progress in adapting the structure of knowledge production to meet the needs of those at the bottom of the pyramid. However, many developing countries, especially those in Africa, are struggling to respond to the challenges and opportunities posed by a fast-paced knowledge economy (Osabutey & Jackson, 2019). However, there is a growing awareness of a new approach that recognises and co-opts those at the bottom of the pyramid as the drivers of innovations defining their own needs, designing their own innovative techniques, and allocating and managing their resources (Hicks & Ison, 2018). It is also realised that innovation driven from the bottom of the pyramid could be less expensive since local resources could be best used to drive innovation at the grassroots (Adejuwon, 2018). One other argument for refocusing on the below the radar innovations lies in the fact that global resources are depleting very quickly and there is a need to reconsider the intensity at which local resources are put to good use in meeting local demands. Chandwani,

De, & Dwivedi (2018) argue that sustainable consumption practices exist at the bottom of the pyramid where most individuals practice social consumption in the sense that purchased goods such a television are consumed by groups or families rather than individuals and this has a tremendous impact on resources utilisation and sustainability at this level. More so the bottom of the pyramid represents a major source of market for transnational companies since this represents a large group of low-income consumers (Pansera & Owen, 2015). Nevertheless, the bottom of the pyramid faces several challenges including low and seasonal income, a high need for formal education and poor infrastructural levels. These challenges discourage effective engagement with STI. The above account of the bottom of the pyramid point to a renewed thinking regarding the redefinition of innovation for the bottom of the pyramid, resource identification, location resource utilisation and much more demand-driven STI through community tech hubs and projects. In providing a development-oriented agenda for Africa, it has been advocated that technologies must be locally built and should be designed to meet the local and fiscal needs of the community (Botchie, Sarpong, & Bi, 2017; Kaplinsky, et al., 2009).

In developing technology hubs and research for development, rural communities have a major role in its establishment, management and sustainability (Sianipar, Yudoko, Adhiutamaa, & Dowaki, 2013). This is essential because local communities have indigenous innovation which can only be harnessed within the community by critically examining the available local conditions. Having the appropriate technology for businesses in a local community essentially becomes the fulcrum for community innovation through tech hubs (Sianipar, Yudoko, Adhiutamaa, & Dowaki, 2013). Therefore, empowering communities to engage in providing solutions to their local challenges has become the most sustainable method of local development of which university research more often than not has failed to achieve. Examples of community renewable energy (CRE) projects set up and run by communities themselves are observed in Australia, Scotland, Germany and Denmark where communities are provided with opportunities to establish, manage and regulate their resources in contributing to regional development (Hicks & Ison, 2018).

3.3 African universities and the new frontiers of knowledge production

Universities and other higher education institutions, for a long time, have been at the forefront of innovation and knowledge production. Besides funding research and hosting scientific laboratories (Moreton 2018), universities also hone entrepreneurial intentions, shape enterprise

orientations and spur creativity (Sandroto et al. 2018). Moreover, universities are core components of the complex interactions between academia, industry and government that consequently foster economic and social development through human capital development, innovation and technology transfers, as depicted by the Triple Helix model (Comunian et al. 2014, 2015; Comunian and Faggian 2014; Etzkowitz and Leydesdorff 2000; Leydesdorff and Etzkowitz 1996, 1998).

In Africa, extant research recognizes the importance of universities for knowledge creation and technology transfers. Dedicated technical universities and polytechnics exist in many African countries such as South Africa, Nigeria and Ghana, mainly for advancing vocational and scientific education, promoting knowledge ecosystems, and raising living standards (Fongwa 2018; Grobbelaar 2018; Jacobs et al. 2019; Kruss et al. 2012; Shambare and Nekati 2010). However, in recent decades, the role of universities in knowledge production has come under increasing scrutiny. Consequently, Gibbons *et al.* (1994) argued that, as the system of knowledge production expands to take in new actors from the public and private sectors, universities will decline in their pre-eminence as the locus of knowledge production. The authors distinguished between mode 1 and mode 2 knowledge production (see Figure 1). Whilst Mode 1 knowledge production is located within traditional scientific institutions and structured within disciplinary boundaries, mode 2 knowledge is more heterogeneous in terms of its location, principles and practices; and is usually found within the context of application (Gibbons *et al.*, 1994; Hessels and Van Lente, 2008).

Contrary to the above view, other scholars have suggested that the contribution and impact of universities will not necessarily decline, but universities would have to re-invent themselves by engaging new actors in the knowledge production process to supplement, rather than supplant, the contributions of traditional universities in the new system of knowledge production (Godin and Gingras, 2000). Drawing on a remark by the 19th-century biologist Thomas Huxley, Youtie and Shapira (2008) noted that universities have historically undergone epochal transformations. Thus, the medieval university was seen as the storehouse of old knowledge, while the modern university became the factory of "new" knowledge.

The 21st-century university, it is argued, needs to further transform into an innovation hub spanning boundaries to mediate the interaction between the academia and the industry. Traditional universities face historic limitations due to their organisational structures around single-discipline departments, and the stifling impact of the regulatory environment in which

they operate (Mosey, Wright and Clarysse, 2012). Multi-disciplinary collaborations and multi-sectoral partnerships therefore offer better prospects for universities as they embrace the third mission of economic development along with research and teaching (Etzkowitz *et al.*, 2000). The transformation of universities from traditional to "entrepreneurial" model is especially important in developing countries and latecomer contexts, where universities exercise much less autonomy compared with their European counterparts. More so, the innovation system in these universities is oriented more towards the diffusion of knowledge and innovation from advanced countries rather than active stimulation of indigenous knowledge to serve local needs (Wong, Ho and Singh, 2007).

However, while universities in developed countries are seeking to adjust and re-invent themselves in response to rapid changes in the knowledge economy, African universities are still struggling to respond to this call due to the constraints of bureaucratic controls, lack of sufficient integration within the global system of knowledge production, and limited linkages and synergies with local industries (Mutula and Jacobs, 2010; Cloete, Maassen and Bailey, 2015). In many African countries, while enrolment has significantly increased, graduate unemployment has also worsened, and there are significant challenges associated with inequitable access to university education, decline in quality, and turnout of graduate with limited technical and transferrable skills required in the job market (British Council, 2014). Furthermore, it is estimated that, between 2015 and 2030, about 29 million people will enter Africa's labour market each year. This signifies an increase in the African labour force from 750 million in 2018 to nearly 1 billion people in 2030 (International Trade Centre, 2019). Despite this huge labour force yearly, only three million out of the thirteen million youth entering the labour market can secure gainful employment, leading to high levels of graduate unemployment (Graham et al. 2019; Oluwajodu et al. 2015) To overcome this challenge, about 12 million new employment opportunities need to be created annually. These are big challenges, but they also present a good opportunity for non-university stakeholders to enter the space with bold new ideas that can inject dynamism into the entire system, precipitating transformative impacts towards new knowledge production and economic growth.

4. Methodological Note

Following previous research on hubs (Friederici 2018; Littlewood and Kiyumbu 2018), a case study methodology was used in this study whereby multiple bounded systems of tech hubs in Africa were explored based on available literature (Fouche & Delport, 2002). The authors used

desk-based research in investigating the existence and performance of African tech hubs. Following Yin (2013), we drew relevant data from various documents, reports, innovation hub websites, websites of international NGOs, multilateral agencies, and journal articles. As Rowley (2002) noted, a multiple case study approach is often preferred, as it enables the researcher to identify and use similarities and contrasts across the cases to establish robust evidence linking a set of theoretical propositions with field data. In line with this, we adopted a multiple case study approach by exploring cases in Nigeria, South Africa, Kenya and Uganda. Following a review of the extant literature and an outline of the empirical context, we selected five case studies as indicated in Table I below to explore the potentials and impacts of tech hubs, focusing on their strategies for knowledge production, employment generation and value creation.

The choice of the case studies is based on the information from the literature review showing Nigeria, South Africa and Kenya having the highest number of tech hubs in sub-Saharan Africa, with 90, 78, and 50 tech hubs respectively. Secondly, we selected tech-hubs that have communities as dominant stakeholders in their establishment and management. This criterion is very important because the authors believe community participation is an important factor in knowledge transfer and community development in Africa. Finally, we selected cases that have received financial and technical support from external partners including UNICEF, World Bank, CSIR, Makerere and Aalto Universities. In addition to the three leading countries, we also included Uganda as an example of a country in the second tier- representing dozens of other countries catching up with the digital "awakening" sweeping through the continent. Egypt, which has 56 hubs, is excluded from our sample given the focus of the study on sub-Saharan Africa.

5. Case Studies

5.1 Co-creation Hub, Lagos, Nigeria

History and background

Co-creation Hub was launched in 2013, with support from Indigo Trust and the Omidyar Network. It generated more than $1million in its first year, achieving financial sustainability in a very short space of time, and establishing itself as one of the leading tech hubs in Nigeria (The Indigo Trust, 2017). The organisation describes itself as a "shared working space for technologists, entrepreneurs, government, tech companies, impact investors and hackers in and around Lagos to co-create new solutions to the many social problems in Nigeria" (Co-creation

Hub, 2016). Since inception, CcHub has supported more than 100 companies, including more than 50 start-ups which graduated from their incubation programme (Co-creation Hub, 2019b). In addition, they have created a vibrant community of more than 14,000 tech entrepreneurs interested in using smart technological solutions to address societal problems (Co-creation Hub, 2016).

Operational and management structure

Co-creation Hub employs a three-tiered curriculum in their start-up programme: pre-incubation, incubation, and acceleration. The pre-incubation module is a 6-month programme aimed at supporting aspiring entrepreneurs to launch initial prototypes of their tech-enabled solutions. The 6-month programme also supports the project team to acquire new skills while they validate their products in the market. The pre-incubation programme comes with a cash investment of $5,000. This is followed by a more intense and structured 12-month incubation module, which helps the start-ups to build strong revenue and business model that enables them to scale up and grow into "globally sustainable companies" (Co-creation Hub, 2019a). This component comes with an initial $25,000 funding and access to a further $250,000; free office space for the team; and access to the hub's extensive network of partners. The acceleration module builds on this with a further 12-week curriculum that includes a one-to-one session with internal experts at the hub and coaching sessions with selected leading industry experts.

Along with its core start-up programme, Co-creation Hub outlines six key activity areas on their website: smart infrastructure; governance; health and well-being; fin-tech; education; and digital security. These partly inform the type of proposals they accept into their start-up programme (Co-Creation Hub, 2019). The smart infrastructure element is in recognition of the fact that the huge infrastructure challenges in a country Nigeria also presents tech entrepreneurs with the opportunities to create sustainable smart solutions. In pursuance of this, therefore, CcHub launched the i-HQ project, bringing together more than 30 tech companies in Lagos and other key stakeholders from the academia and the government including the government of Nigeria's commercial capital, Lagos State. CcHub carries out its work on governance through GovLab, a multi-faceted intervention designed to enhance the works of government agencies and other public sector stakeholders around "civic engagement, social accountability and public service delivery. BudgIT- one of the graduates from CcHub's start-up programme- has made a significant impact, making budget and governance data readily accessible to Nigerian citizens.

With regard to the health sector, the organisation is working with public sector and industry stakeholders to develop innovative solutions that enhance the quality and accessibility of healthcare delivery. One of such is NIMCURE, a collaborative research and development project launched in partnership with the Nigerian Institute of Medical Research (NIMR). The intervention aimed to improve the quality of tuberculosis treatment. In addition, they have graduated two health-care start-ups, Life Bank and Truppr- focusing on healthcare logistics and fitness and healthy lifestyle respectively. Finally, they also launched Health Meet Tech, a three-day hackathon bringing together "health professionals, software developers, investors, patients, health maintenance organisations (HMOs) and hospital administrators" to generate innovative solutions to key challenges in the health care sector. With regard to the Fin-Tech component of the organisation's activities, they have worked with international and local stakeholders to improve financial literacy and make financial services cheaper, more efficient and more accessible to more people, especially under-served groups in society. On Education, they are providing schools with customised technological solutions to enhance learning, in addition to setting up an educators' network and building a community of practice. They are also actively involved with Go-Lab Goes Africa (GOGA) which is European-funded research with the core objective of enriching learning and improving outcomes in Science Technology Engineering and Mathematics (STEM) across secondary schools in Africa. Finally, their work on digital security is in response to the increased vulnerability of people in a highly connected digitised world. As such, they have set up a digital security guide for professionals and citizens actively using web-based platforms for various activities.

Knowledge production, employment generation and value creation

It can be seen from the foregoing that Co-creation Hub has employed a range of innovative and complementary approaches to knowledge production, outside of the traditional classroom model typically employed in universities. One important feature is that the knowledge production process begins with the learners in the sense that they had to come up with a proposal comprising a specific challenge and their proposed solution. This is at the heart of the co-creation logic, affirming the critical agency of the learner as a co-producer of - and not merely a receptacle for- knowledge. All the subsequent support and training programme is based around the learners' original idea. Thus, the one-to-one sessions the mentees have with internal and industry experts are more focused and more productive, and the mentors also benefit from the interaction. Furthermore, the co-working space provides an auspicious opportunity for peer learning among mentees coming with different ideas in the start-up

programme. Furthermore, the hackathon model used in the Health Meet Tech event is in line with what Gibbons et al. (1994) describe as the transdisciplinary character of mode 2 types of knowledge. By bringing together a whole spectrum of health professionals, tech practitioners and public sector stakeholders in one place, they can create a space in which the actors can bring together distinct disciplinary and sectoral ideas together to generate an integrated solution that efficiently incorporates the sum of the parts.

Co-Creation Hub has been able to create social and economic values across the whole spectrum of public and private sectors. For example, they have directly enabled the creation of 600 jobs through the start-ups they have supported in the five years leading to 2018, and many more indirect jobs through their impact on the entrepreneurial ecosystem. Furthermore, their activities in the education and other public sector are having a significant social impact in terms of human capital development and improved access to healthcare, financial services and other public services. These are often through their graduates, such as BudgIT's impact on citizens access to budget and governance data in Nigeria.

While CcHub has had significant impact, especially in the high-tech entrepreneurship landscape, it is grappling with the challenge of scalability. Most of its start-ups are clustered around the Lagos metropolis, where it launched its operations in 2010. More recently, in September 2019, CcHub acquired iHub, one of East Africa's leading tech hubs based in Nairobi. The limited scalability of CcHub's operations underlines the need for Africa's tech hubs to reach beyond the continent's main commercial centres to harness and create new opportunities in the hinterland. Furthermore, while significant progress has been made in the past decade, tech hubs like CcHub need to be better integrated and more competitive at the global market. There are rooms for Africa's highly skilled tech entrepreneurs to harness their factor advantages to expand their operations, create value and new opportunities. Finally, CcHub is limited in its focus on high-tech enterprises, mainly programmers, in a country where significant impact can be achieved, and new opportunities created through the use of low-tech innovations to tackle pressing economic and social problems.

5.2 Siyakhula Living Lab in South Africa

Historical background

The Living Lab concept in South Africa which began during the 1990s emphasises the idea of creating an open innovation environment which offers users and stakeholders the opportunity to participate actively in co-creation projects (Coetzee, Toit, & Herselman, 2012). In 2006 Siyakula LL (SiLL) started its operations in the Eastern Cape province of South Africa as a

project kind of activity but later developed into a Living Lab (LL) with a multifunctional community communication platform to create e-commerce and e-government websites and a provision of information and communication technology (ICT) training for the local community (Khane et al.2011; Coetzee, Toit, & Herselman, 2012). However, in 2007, SiLL became a community DiY project through a multi-stakeholder input including, the government of South Africa, universities of Rhodes and Fort Hare with the Dwesa community serving an integral position using its localised innovation potential (Khane et al.2011). One of the major focus of SiLL was to provide capacity building for schools (Coetzee, Toit, & Herselman, 2012). Therefore in 2008, SiLL hosted the Nokia wireless Village project to connect various surrounding villages and schools to enhance education and communication.

In 2009, SiLL commenced Pre-ACE-certified training programme for teachers which metamorphosed into the establishment of the software factory known as ESTIMA. ESTIMA is instrumental in developing various software to serve the needs of small businesses in Dwesa community and beyond (Khane et al.2011; Coetzee, Toit, & Herselman, 2012). Currently, SiLL has 24 sub-projects which has created various knowledge platforms in the areas of sustainability, e-services, networking and ICT4D which all have generated countless jobs.

Operational and management structure

The management structure adopted at SiLL consist of multi-stakeholders consisting of academic institutions, industry, government and the local community who collaborated in developing and testing e-business and telecommunication platforms (Coetzee, Toit, & Herselman, 2012).The premise behind this approach sterns from the fact that the development of Information and Communications Technology for Development (ICT4D) requires a multi-stakeholder and multi-disciplinary input to be successful. In this regard, the Dwesa community becomes an integral part of the project and is always consulted before any critical decisions are made c to the project (Khane et al.2011; Coetzee, Toit, & Herselman, 2012). Currently, SiLL has twenty-four separate projects relating to technical and cultural sustainability, e-services provisioning, networking and ICT4D and has published a lot of its research in various publication outlets highlighting the contribution of SiLL to community development and contribution to business growth, job creation and value addition (Dwesa, 2013). Operationally, SiLL usually uses scrum agile project management software in running its daily operations with most training being conducted in schools. Moreso, a train to train approach was adopted

whereby teachers were trained to later train students in developing digital and ICT skills (Khane et al.2011; Coetzee, Toit, & Herselman, 2012).

Knowledge production, employment generation and value creation

Practical knowledge production is the focus of the establishment and operation of SiLL. Small businesses, teachers, students, the Dwesa community and the surrounding communities are provided with an opportunity to generate local and practical knowledge which meet their needs and add value to their business operations (Khane et al.2011; Coetzee, Toit, & Herselman, 2012). In this regard, the Dwesa community is considered an important partner and co-creator of knowledge at SiLL. The informal training approach adopted by the project team enabled the development of the appropriate and relevant knowledge to serve specific business needs. The academia being one of the major stakeholders in this project, is responsible for designing the research framework, literacy training and e-service creation (Coetzee, Toit, & Herselman, 2012). Whereas the industry was responsible for producing products for experimentation, the community members provide local knowledge about themselves and the market in which they operate to support the design of technologies that meet their needs.

5.3 MLab Southern Africa

Historical background

Mobile Applications Laboratory NPC also known as MLab Southern Africa is a registered non-profit organisation which came into inception in 2012 with the sole aim of creating a mobile technology which would provide innovative ways of accelerating start-ups through the use of mobile apps (WorldBank,2017; Mlab, 2019). MLab with labs located in Gauteng, Cape town, northern Cape and Limpopo is also focused on providing the youth with the right skills to innovate and create solutions in unlocking various opportunities in the Southern African region (WorldBank, 2017). Since its inception, mLab has become an open innovation lab by partnering with a host of stakeholders including various code academies, the industry, the World Bank, the Ministry of Foreign Affairs, Finland and, the *Council for Scientific and Industrial Research (*CSIR) and the Departments of Science and Technology to co-create innovations that meet the needs of businesses (WorldBank, 2017; Mlab, 2019).

Operational and management Structure

The operation of Mlab Southern Africa cuts across the Guaten, CapeTown, Northern Cape and Limpopo provinces. It has a management board which focuses on Skills, Enterprise and Supplier Development (ESD) programmes to companies to achieve digital skills (WorldBank,

2017; Mlab, 2019). Particularly, programmes are designed to support new enterprises to be able to scale-up to generate jobs and contribute to the economy (Mlab, 2019. Usually, these programmes are targeted at the specific needs of the enterprises which reduces the time spent on addressing business challenges. These dedicated spaces or hubs are usually equipped with resources, technology, digital services, and workshops through which partners can choose to run mlab facilitated activities with entrepreneurs (WorldBank, 2017; Mlab, 2019). Mlabs also provide coaching and entrepreneurial eco-system consulting services to the public. Usually, these venues are free, and partners or users do not have to pay for its use.

Knowledge production, employment generation and value creation

Over the years, MLab has had an impact on digital start-ups and the development of the Southern African economy (WorldBank, 2017; Mlab, 2019). Start-ups have gained higher survival rates through the activities of MLab. In terms of digital education, over 1.7 million students have been provided with digital skills which prepares them to be able to enter into the venture creation process (WorldBank, 2017). Regarding the growth of agriculture in the Southern African region, the capacity of local farmers has been increased through the activities of mlab to monitor their yields and this has been assessed to have generated an income of $2.7m per annum. Hands-on training has been provided to countless existing entrepreneurs in using the opportunities provided by mlab digital training programmes (WorldBank, 2017; Mlab, 2019). Mlab activities have also supported the reduction of road accidents. Through an app developed by Mlab road accident deaths have been reduced by 30%. Mlab has supported the creation of at least 70 digital start-ups since its inception and in 2016 more than US$750,000 has been raised as an external investment to support new venture creation (WorldBank, 2017; Mlab, 2019).

5.4 Uganda Innovation Lab

Historical background

Globally, the concept of innovative labs is not new. Pioneers like INSTED in South East Asia, the Global Pulse in Jakarta, and Un Techo para mi Pais in Chile show the demand for methodologies of openness, collaboration, and experimentation in developing and organising an innovative lab (UNICEF, 2012). This approach is not different in the African case. The Ugandan Innovation Lab through the support of UNICEF was launched in 2010 (UNICEF, 2012). The Innovation Lab located in Mbuya, Uganda began as a strategy to invest in scaling-up business innovation throughout the whole of Uganda. The project was therefore focused on

implementing Technology for Development implementations by providing a prototyping workshop, a Rapid SMS service development hub, an electronics workshop, a video production unit, a venue for workshops and informal co-creation activities. Through partners such as the Council for Scientific and Industrial Research (CSIR), Makerere University, Aalto University, Thought Works, UNICEF, WHO and the Global Pulse, various research activities were initiated for product and service innovations particularly in focusing on community and small business development (UNICEF, 2012). The lab has so far worked with over 3,600 youths and has hosted a series of innovative workshops to enhance training in various technology for development (UNICEF, 2012; Bloom and Faulker, 2015).

Operational and management structure

The organisation of UNICEF's model of the innovation lab is technically focused on bringing innovation to products, services and processes (UNICEF, 2012). This has been the focus of the Ugandan Innovation lab in fostering economic development. In each country that UNICEF initiates these labs, it engages a host of collaborators or partners including the private sector, NGOs, academia, government and civil society. Therefore, the central management team is made up of members drawn from all the stakeholders (UNICEF, 2012). Thus, a multi-stakeholder approach to management is unique to UNICEF innovation labs. More so, all the labs in the UNICEF Innovation network are encouraged to share experiences, resources and models generated by labs. More importantly, these models could be adapted by others in the network. The management team ensures that all projects implemented provide potential solutions to national problems through the optimised innovation network. It is expected that all UNICEF initiated labs recognise the best practice applications necessary based on a comprehensive understanding of local challenges (Bloom and Faulker, 2015).

Knowledge production, employment generation and value creation

The Ugandan Innovation Lab has over the years developed technology in the form of physical products, mobile services and the provision of real-time feedback loops for data collection. Several kinds of training are provided through the lab to students in developing electronic items and technological solutions (Bloom and Faulker, 2015). The Ugandan Technology for Development (Tech4Dev) project is, therefore, one of the major projects which have accelerated technological development in Uganda. Through the use of local talent, cost-effective technology has been produced in addressing local challenges which are reliant and tailored to the local environment and economic conditions (UNICEF, 2012; Bloom and

Faulker, 2015). In 2011, Uganda Innovation Lab developed the Digital Drum which was voted by the Time Magazine as one of the best inventions. The lab has also facilitated the deployment and development of the RapidSMS projects including mTrac which is disease surveillance and tracking system for the Ugandan health sector. Also, apart from the impact at the country level, the innovation Lab has initiated other projects which have led to greater interventions in the local community.

While the Ugandan Innovation Lab has made a significant contribution to the development of the Ugandan economy, questions remain about its self-sufficiency, efficiency and agility of the lab. First, the lab relied heavily on donor funding for take-off, and also for continuous operations. To achieve its potentials, the lab needs to move away from donor-based funding to more sustainable models. With self-reliance and financial independence, the lab will be better positioned to expand its technical competencies, sets its agenda and sharpen its strategic focus in meeting the needs of the local environment. Finally, the lab needs to ensure greater access to its lab and resources by the community and other interested parties. This will ensure greater interoperability.

5.5 Innovation Hub (iHub) Kenya

Historical background

IHub Kenya is an ICT focused support system for entrepreneurs in facilitating start-ups in Kenya. The iHub project emerged from the ICTD 2010 discussions and became one of the initiatives of the Network for African Researchers (NAR). The iHub project therefore became a reality in March 2010 (iHub Kenya, 2014; Chirchietti, 2017) with a focus on forging collaborations among various stakeholders. Located in Nairobi, iHub, is an innovative and hackerspace for technology entrepreneurs who endeavour to collaborate, share, co-create and produce knowledge for a mutual benefit (iHub Kenya, 2019; Chirchietti, 2017). Nairobi's iHub is an innovative community of entrepreneurs, technologists, investors, tech companies and hackers. It is an open community workspace which focuses on web and mobile phone programmers, designers and researchers. The hub facilitates local research capacity building in East Africa in support of decision-making processes of entrepreneurs (iHub Kenya, 2019).

Operational and Management Structure

The entire structure of iHub is based on co-creation and cross-disciplinary research where young entrepreneurs are provided with the opportunity to receive training from experienced

researchers in the IHub.The management structure of the iHub, therefore, consists of research associates and fellows with a group of mentors who are responsible for reviewing all technical works and providing the necessary training to new researchers (Chirchietti, 2017). In terms of funding, iHub Kenya is partly self-funded and partly through grants from companies such as Google, Oracle, Chase Bank and IBM. IHub also enjoys funding from other projects awarded to the hub for execution. Currently, iHub Kenya has about 14,000 members and 50 employees in charge of various projects (Chirchietti, 2017). Three kinds of membership exist in iHub. First, there is the white membership which is basically through online participation and free. Secondly, there is the green membership which is free and consists of businesses at the pre-incubation stage. Finally, there is the red membership which needs to be paid for and consist of established start-ups who are offered permanent office space in the hub (iHub, 2014; Chirchietti, 2017).

Knowledge production, employment generation and value creation

IHub mainly produces knowledge and researches in the areas of mobile and web applications, business governance, innovation and entrepreneurship. Most of the knowledge in the East African country is generated through increasing the visibility of African ICT researchers, improving the quality of ICT research in Africa and encouraging effective collaboration and knowledge networks among African researchers in a cross-disciplinary manner. Young researchers are therefore linked with senior researchers for appropriate training and mentorship. Through the iHub project, several ICT start-ups have been created which results in 90% of start-ups created in the ICT sector, 73% in the finance sector, 52% in retail services, 44% in the tourism industry and 40% in social work domain (iHub, 2014). Whilst these ICT start-ups employed four persons on the average, growth private enterprises employed 13 on the average. IHubs through their ICT hubs and training institutes play a significant role in providing digital skills (iHub, 2014). Essentially, iHub provides adequate space for technology entrepreneurs whereby they can receive mentorship, business support services, product development services and access to venture funding connections both locally and internationally. The actual benefit, therefore, goes to mobile phone programmers, designers and researchers working in an open community workspace. Table I below provides a summary of the activities of the various African tech hubs explored in this study.

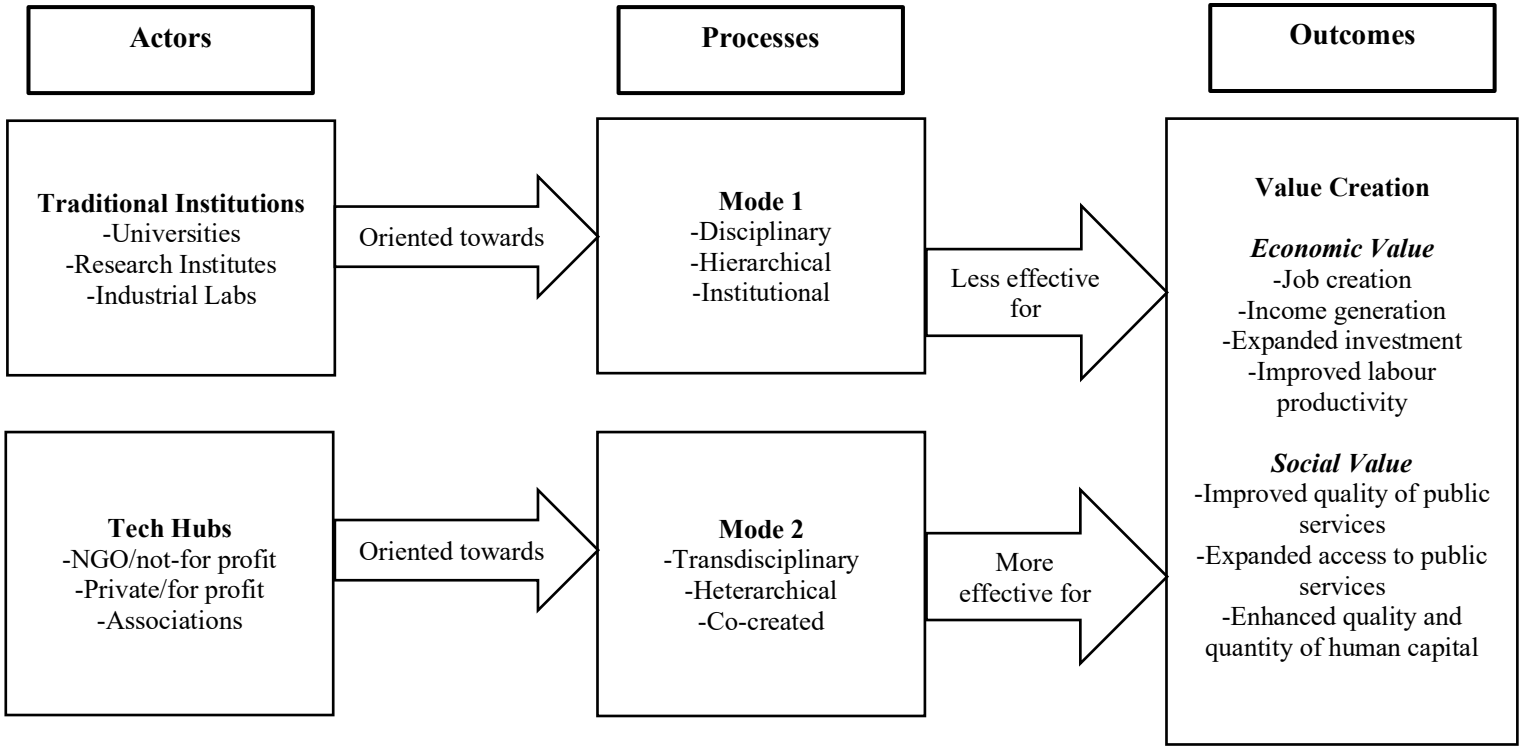

Figure 1. Differences between tech hubs and traditional research institutions

6. Findings and discussion

As table 1 summarises, the cases explored in this paper show that African tech hubs are asserting themselves as important actors and key sites of knowledge production on the continent. They have stepped in and making significant impacts where traditional universities have struggled, that is in producing knowledge and generating innovative solutions that meet specific industry needs and address important societal challenges. In other words, they have been especially effective and efficient in producing "mode 2" type of knowledge. Gibbons et al (1994) identified five key attributes of this type of knowledge: knowledge produced in the context of application; transdisciplinary; heterogeneity and organisational diversity; social accountability and reflexivity; and quality control. We employ this model in the present discussion.

First, all the cases discussed are characterised by knowledge production in the context of the application. All the tech hubs were set up to address specific, or at least specific types of, societal and industry challenges. In the case of Co-Creation Hub, for example, the starting point of the knowledge production process is the proposal submitted by the aspiring entrepreneur. This proposal focuses on a specific industry or societal challenge, and all the subsequent training and mentorship programme are organised around this. Thus, in line with Gibbons et al (1994)'s model, the imperative of utility is present from the outset of the knowledge production process. This approach brings a different level of focus, clarity and efficiency to the knowledge production process. Second, while the use of ICT is broadly visible across the operational structures of the tech hubs, knowledge production is not defined by any disciplinary boundary or sectoral limits. Thus, Siykhula lab co-opts participants and partners from academic institutions, industry, government, the local community- each of them bringing unique contributions to the pool of co-created knowledge.

Third, the transdisciplinary character of the tech hubs is also reinforced by organisational diversity and flexibility For example, when Co-Creation Hub organised a Hackathon, contributors are brought together from a whole spectrum of disciplinary and professional backgrounds and sectors to create technological solutions for specific needs. Many of the participants were probably meeting for the first time. They were all unlikely to meet again for similar or new projects. However, from this initial meeting, there would likely be new combinations of partnerships for different projects in the future, and participants would also be able to carry new knowledge, skills and ideas acquired into future new networks and projects.

Table 1. Operational structure, knowledge production and value creation among selected African tech hubs

Cases	Operational/programme structure	Knowledge production	Value creation
Co-Creation Hub, Nigeria	Three-tiered curriculum for start-ups: pre-incubation, incubation and acceleration programme	Learner-initiated, expert-directed, co-creation approach.	Economic: employment generation through start-ups; ecosystem stimulation; indirect job opportunities across the supply and value
	Six key activity areas: smart infrastructure; governance; health and well-being; fin-tech; education; and digital security.	Multi-sectoral, multi-stakeholder approach to problem identification and solutions development.	Social: Improved quality of, and better access to, public services; enhancement of human capital through skill development and
Siyakhula Living Lab, South Africa	Twenty-four individual projects relating to technical and cultural sustainability, e-services provisioning, networking and	Collaborative multi-stakeholder approach comprising academic institutions, industry, government and the local community.	Economic: improved efficiency and productivity for participating businesses
		Informal training approach tailored to specific business needs	Social: co-option of indigenous in developing innovative and relevant solutions
		Training the trainers model	
Mlab, South Africa	Focus on Skills, Enterprise and Supplier Development (ESD) programmes for small businesses and open consulting services for	Bespoke training for businesses	Economic: job creation through 70 start-ups; capacity building for local farmers have generated $2.7million per annum; investment
			Social: Mass digital education reaching 1.7 million; reduction of road accidents through the app developed by Mlab
iHub, Nairobi Kenya	Management structure comprises research associates, fellows and mentors.	Cross-disciplinary, collaborative approach involving African researchers.	Economic: job creation through ICT start-ups
	Membership in three levels: white membership online only and free for the public; green membership free for	Mentorship and training programmes for junior researchers and aspiring tech entrepreneurs.	Social: diffusion of digital skills across the entrepreneurial ecosystem.
Ugandan Innovation Hub	Collaborative networking approach involving the private sector, NGOs, academia, government and civil society	Capacity building workshops to empower tech developers	Economic: enhancing private sector productivity through the development and diffusion of technological innovations

In effect, as Gibbons et al (1994) noted, the research groups are less institutionalised in tech hubs, as participants often come together as temporary work teams and dissolve when the problem is solved or re-defined. Fourth, social accountability is a key consideration in the activities of the hubs. In the Ugandan case, for example, civil society actors are an important part of the network. This is to ensure that solutions are better tailored and more responsive to local needs. In a similar vein, the Kenyan iHub provides an opportunity for interested ordinary citizens to be part of the tech community through online membership. This provides an important channel from which the tech hub can access important feedback from community members, thereby enhancing the relevance and impact of the tech solutions launched or supported by the hub. Fifth, and in line with the social accountable process of knowledge production, the quality control process in the hubs is characterised by market competitiveness, cost-effectiveness and social acceptability. Furthermore, this is a dynamic and ongoing negotiated process in which the tech hubs actors have to respond to the forces of demand and supply in the market. This enhances the quality of the outputs.

Finally, the cases also underline the efficiency of the hubs in creating both economic and social value. In all the cases, the hubs have contributed in varying degrees to new job creation, increase in household income, and expansion of investment funds in the respective countries. The employment impact is not only in terms of direct jobs created by start-up but even more so in terms of the stimulating impact on the entrepreneurial ecosystem. This enables new jobs to be created across the supply and value chains, not only in the tech sector but also in sectors that have been influenced by new solutions developed by the tech hubs.

The hubs have also had a significant social impact on governance, education, health care, financial services, and other public sectors. The hubs appear to be having greater social impact compared with traditional universities, viewed in terms of their proportionate resources. In terms of impact on human capital development, the mass digital education spearheaded by MLab in South Africa is noteworthy, not least with regard to its reach of 1.7 million. Similarly, one of Co-Creation Hub's start-ups, BudgIT, has had a major impact in the Nigerian public sphere, in terms of empowering citizens with budgetary information they needed to engage better with the process of governance. There are also impact stories of expansion of access to financial services through technological solutions.

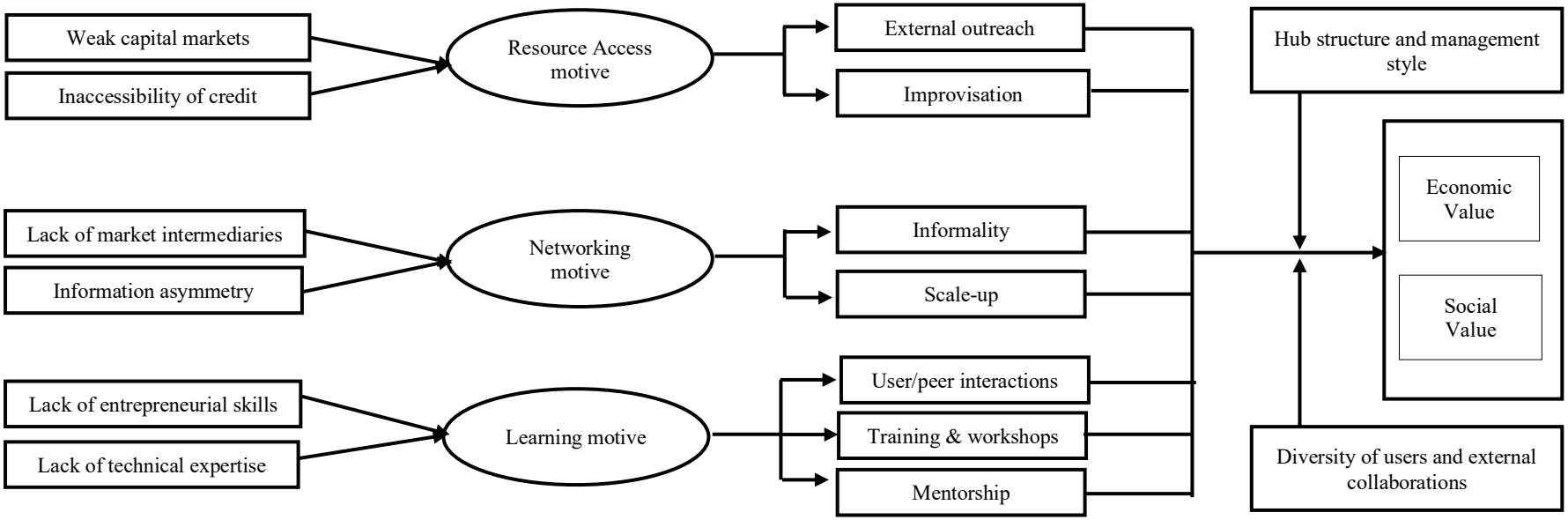

Figure 2. Tech hub formation strategy

6.1 African tech hub strategy

The main motives for the creation and existence of tech hubs are; 1) bricolage and resource access; 2) networking, and 3) learning and capacity development. First, hubs create access to critical resources for informal experiments and innovations through various channels including angel investments, venture capital and even public funding. As seen in the case studies, some of the hubs benefited funding from external agencies and other large corporations such as the World Bank, UNICEF and CSRI, which was subsequently disbursed to support their users. Importantly, the hubs facilitated bricolage (Baker and Nelson 2005) whereby their users are supported to recombine existing resources to overcome resource constraints. In this sense, the hubs offer a platform for unorthodox application of resources beyond their initial intended usage. Second, the hubs aim to promote and facilitate networking among tech entrepreneurs and create opportunities for sharing ideas and bridging access to diverse support for innovation (Sarpong and Rawal, 2020). Networking is particularly crucial in Africa where due to institutional voids, social capital serves as a substitute for inefficient and non-existent market intermediaries (Acquaah 2007; Liedong et al. 2020). Finally, the hubs are created to provide learning opportunities for budding entrepreneurs to develop their product and service ideas. They enhance entrepreneurial and technical skills through formal training and informal knowledge exchange initiatives.

To achieve these motives amidst constraints, the hubs deploy various strategies and tactics. To promote learning for instance, hubs increase user interactions and use mentorship and training. For networking, they adopt an informal culture to break down barriers and siloed clusters while scaling up to increase the number of users/members and the networking nodes. For resource access, hubs intensify their external outreach to attract and mobilize funding (Atiase et al. 2018). They also encourage active improvisation and experimentation with existing resources. These strategies impact economic and social value creation, but the extent of this impact is moderated by the diversity of hub users or collaborators and the hub management style. A diverse user base enriches knowledge production while a flat structure increases information flow and supports faster decision making. We leverage these findings to develop an integrative model (figure 2) to map the drivers of tech hub formation, the strategies used by tech hubs, and the contingent effects of tech hub strategies.

6.2 The challenges of hub formation in Africa

While tech hubs' benefits are undisputed, their formation can be difficult. They face three main challenges. The first is funding. The capital required to keep hubs open is not readily accessible. Africa's capital markets tend to cater to the needs to large firms whose credit ratings are

unquestionable. Investments in hubs, the home of start-ups, DiY ventures and small enterprises, does not seem to be an attractive market proposition for banks. Essentially, there is intense competition for credit in African countries, with stronger contenders and established businesses receiving more favourable treatment. African governments, saddled with numerous developmental problems and fraught with policy syndromes, do not prioritize tech hubs. Charging fees to users is one way to plug the funding gap, but doing so defeats the hubs' purpose of serving as low-cost alternative homes for local talent. Seeking international donor funding could also address the funding constraints, but this option is farfetched especially when hubs have low international visibility and poor evidence to demonstrate their social impact. Overall, hubs struggle to find a business model that works.

The second challenge is attracting users. Hubs are as good as the number of users and collaborators they have. The more people use a hub, the more the hub can serve as a learning and networking platform. Similarly, the larger a hub, the better its chances of attracting external funding. Unfortunately, STI education in African countries has not yet reached a point where individual curiosity pushes enough critical mass of enthusiasts to use hubs for honing their innovative ideas.

Similar to the point above, hubs struggle to develop linkages to external collaborators and other resource persons. This makes it cumbersome for them to create the bridges that will connect users to external resources, information and expertise, thus inhibiting their ability to create socio-economic value. Linkages to government agencies avail institutional support for commercializing the innovations of tech hubs. However, hub-government engagements appear to be limited. In addition, Africa's tech hubs are not yet sufficiently integrated with, and competitive in, the global tech landscape.

7. Conclusion

The development challenges confronting Africa currently does not seem to be surmounted in the immediate future. One of these challenges is how to generate localised innovations which address local challenges targeting those at the bottom of the pyramid without necessarily adopting foreign technologies which might be costly and incompatible to localised conditions and technical know-how (Kaplinsky, et al., 2009; Botchie, Sarpong, & Bi, 2017). With the resource contingencies of the local economy in Africa, these hubs have provided distinct support particularly for start-ups for the growth of Science Technology and Innovation (STI). African universities are grappling with resource constraint and struggling to keep pace with the changing needs in the labour market and the worsening rate of graduate unemployment. Our present study examines how and why DiY tech hubs could provide alternative channels of research and knowledge production. DiY tech hubs provide global

interoperability in creating the space for collaborations among a host of stakeholders in designing solutions for local business challenges through community collaborations, empowerment, openness and experimentation. DiY tech hubs being an open-source resource could impact on knowledge production, employment generation and value creation in Africa. DiY tech hubs could also help invigorate the ailing African economy through community participation in knowledge production.

This study, therefore, provides a unique opportunity for a renewed research effort in investigating the impact of DiY tech hubs in Africa. The five case studies explored across Africa, despite the limited generalizability of the findings and the limitations of case study methodology (Yin 2003), highlight the impact of tech hubs in knowledge production, employment generation and social value creation. Tech hubs have therefore become an alternative source of local knowledge production among communities which seek to foster high tech entrepreneurship, inclusive growth and the expansion of knowledge and innovation ecosystem in Africa. However, the drive to generate localised technical knowledge also requires initiation of the appropriate institutional change in public policy. These include interventions regarding the direction of educational funds to support the creation of local expertise and knowledge which in turn can resolve local challenges. More so, in developing the appropriate local technology for economic development in Africa, the three connected stages of participation, empowerment and sustainability are crucial. It is also recommended that since funding is a major challenge facing the establishment and management of tech-hubs in Africa, crowdfunding could be harnessed in the establishment of tech-hubs to facilitate knowledge production and transfers. Is this case, communities would become major stakeholders in the establishment of tech-hubs.

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