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ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/riad20

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To cite this article: Glenda Kruss, Il-haam Petersen, Maruf Sanni, David Adeyeye & Abiodun Egbetokun (27 Mar 2025): Do we measure what should be measured? Towards a research and theoretical agenda for STI measurement in Africa, Innovation and Development, DOI: 10.1080/2157930X.2025.2481749

To link to this article: https://doi.org/10.1080/2157930X.2025.2481749

Published online: 27 Mar 2025.

INNOVATION AND DEVELOPMENT
https://doi.org/10.1080/2157930X.2025.2481749

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Do we measure what should be measured? Towards a research and theoretical agenda for STI measurement in Africa

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ABSTRACT

A persistent critique of standard science, technology and innovation (STI) indicators is that they remain reliant on concepts and theories transposed from the literature on STI in high-income countries. It is widely recognized that their relevance for African countries is limited, so we may not be measuring what we should be measuring, to promote development goals. To inform a shift from critique to building meaningful alternatives, the paper conducts a systematic review of the literature on STI measurement in Africa. The analysis highlights that STI measurement in Africa is under-researched, but the knowledge base is growing. The strongest trends relate to the adoption and extension of traditional standard STI indicators. More recent is a focus on environmental sustainability, digitalization and the informal sector, with most scholars based in South Africa and Nigeria. The main contribution is a research agenda to facilitate theory building as a foundation for designing contextually relevant STI indicators.

ARTICLE HISTORY
Received 29 February 2024
Accepted 14 March 2025

KEYWORDS
Science, technology and innovation indicators; measurement; Africa; bibliometric analysis; systematic review; developing countries

1. Introduction

A decade ago, Lorentzen (2011, 80) identified a critical problem for innovation measurement: despite some progress in theory development, there is little certainty that 'what we aim to measure in Africa is what should indeed be measured'. He questioned the extent to which emerging new indicators were able to capture the kinds of technological change, knowledge and capabilities characterizing innovation in the contexts of low and lower-middle-income countries.[1] One reason is that there is insufficient attention paid to the developmental challenges of low-income countries, in the field of innovation studies in general. Most of what did exist is country-specific empirical studies that did not theorize how the economic structures and dynamics of African low- and middle-income countries differ from those in the upper-middle- and high-income countries. Lorentzen surfaced a lacuna in the field – a dearth of theoretical and conceptual research exploring

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the nature and patterns of technological upgrading, learning and innovation in the context of the poorest economies.

Over the decade since, the emphasis in the field of innovation studies is shifted, from a conceptual focus on the contribution of innovation to economic growth, to interrogating how innovation drives inclusive and sustainable development (Pansera and Owen 2018; Park et al. 2017; Rodriguez, Pansera, and Lorenzo 2020). The volume and creativity of such research are so great that Godin, Gaglio, and Vinck (2021) recently were able to compile a substantial handbook on 'alternative innovation', responding to the need for new and different imaginaries. Despite this shift, ten years later, Diyamett (2021) echoed the challenge raised by Lorentzen, arguing that the field of innovation studies can in fact be detrimental to poor economies if it does not build 'empirically informed theoretical propositions' explaining how technological capabilities can be built. She emphasized how vital such conceptual foundations are for evidence-informed innovation policy. Indeed, a recent review using more sophisticated bibliometric techniques interrogated whether the gap identified by Lorentzen still persisted. Lema, Kraemer-Mbula, and Rakas (2021) found that there had been little change in the primary focus on middle-income emerging economies, increasingly China (see also Joseph et al. 2021). Even though the literature on innovation and development had increased four-fold over the decade, research on lower-income countries was fragmented and remained marginal (Lema, Kraemer-Mbula, and Rakas 2021).

How are these trends manifesting in the literature on innovation measurement in Africa? And what do these trends tell us about progress towards measuring what should be measured in Africa? Over the same decade, there has been mounting evidence and critique globally, that current measurement and analytical standards do not sufficiently capture how STI contributes to social and human development goals, and sustainable development (Boon and Edler 2018; Charmes, Gault, and Wunsch-Vincent 2018; Dziallas and Blind 2019; Gault 2020; Godin 2015; Godin, Gaglio, and Vinck 2021; Jauhiainen and Mugabe 2024; Kruss 2018; OECD 2012, 2022). Reflecting the trend in the field in general, much of the research undertaken to review and refine STI indicators aims to be of value to policymakers in high-income countries (Alhusen et al. 2021; Janger et al. 2017; Klarin 2019), and is heavily reliant on concepts and theories transposed from the literature on high-income countries. And, where there is a growing body of new indicators research focussed on and emanating from emerging economies of the global South (Cirera and Muzi 2020), few of the emerging alternative perspectives and new critical approaches emerge from Africa.

This paper therefore aims to catalyse research to ensure that by the next decade, there will no longer be such a wide gap in understanding the nature of innovation in Africa, as a foundation for creating contextually relevant measures and indicators. A critical starting point is to assess the current state of the art: How does the available literature on STI measurement in Africa provide an empirical and conceptual research base to inform shifting measurement objectives? Through a systematic review of the literature, we propose to identify the scale and trends of existing research, where research capabilities are situated, the main themes covered in the academic conversation, and how these change over time. On this basis, we can articulate a research agenda that can build on emergent networks of expertise and coordinate research efforts across the innovation indicators community of scholars in Africa.

The structure of the paper is articulated as follows: The next section discusses the importance of a contextualized knowledge base for innovation measurement in Africa that takes into account the structure and dynamics of their post-colonial economies and development challenges. The methodology used to conduct a bibliometric study of the existing literature on measurement in Africa follows. The fourth section identifies key topics, under-researched topics and the geographical structure of research networks, to highlight key focal issues, analytical trends, and potential research gaps. The fifth section articulates an agenda of six focus areas for theoretical and empirical research, which can inform the design of innovation measures reflecting progress towards development goals in African contexts.

2. Why it is important to build an African STI measurement knowledge base

In the STI measurement space, there have been significant shifts globally, reflected in a change to a more expanded definition of 'innovation' that can be applied to actors other than firms (Gault 2020; OECD 2018). Research is growing to problematize how to assess innovation in a range of settings, as enacted by a broader range of actors (Sutz 2012): in households (De Jong 2016; Von Hippel 2016), communities in informal settings (Cozzens and Sutz 2014), public sector agencies (Arundel and Huber 2013; Arundel, Casali, and Hollanders 2015) or informal enterprises (Charmes, Gault, and Wunsch-Vincent 2018; Kraemer-Mbula and Wunsch-Vincent 2016). One stream in this work stretches and adapts standard approaches to measure how and to what extent research and innovation outcomes are oriented to promote Sustainable Development Goals, or societal grand challenges (Confraria, Ciarli, and Noyons 2024; Iizuka and Hane 2021; Kahn and Koc 2016; Vélez-Cuartas and Romero-Goyeneche 2022). To monitor progress and measure the impact of these policy goals, a conceptual framework will be required that is based on understanding not only the science system or the outputs of science and innovation activity but also understanding of current innovation systems, competencies and capabilities, and flows of resources.

While the body of literature on innovation in African contexts is growing, it is not extensive. What exists tends to display a high degree of conceptual borrowing (Muchie, Lundvall, and Gammerltoft 2003) and often uncritical emulation of analytical frameworks; and there is insufficient strong empirical evidence as a foundation to inform new conceptual development. Over fifteen years ago, innovation measurement using the Oslo Manual (Eurostat/OECD 1992, 2018) was introduced and supported in African countries (Gault 2008; NEPAD 2006). The African Union and its partners[2] have been driving national efforts to build capacity on STI measurement, and continental efforts to produce internationally comparable indicators (AUDA-NEPAD 2019; Gault 2008, 2014; Gault, Ambali, and Mangwende 2016; UNU-INTECH 2004). From the outset, there was extensive debate on how the standard instruments could be adapted (Bartels and Koria 2014; Blankely et al. 2006; Manzini 2015) to contexts with low levels of technological capability and industrialization, and major human development challenges (Lorentzen 2011). Despite these concerns, the literature on African innovation measurement tends to be characterized by assessments of 'absence', of what does not exist, when measured against high-income countries. This is evident for instance, in attempts to

explain 'the failure to compete' (Lall, Pietrobelli, and Elgar 2002) or expressed in a call to understand the nature of 'innovation under the radar' in African systems (Fu 2020).

Such normative perspectives overlook the nature and antecedents of innovation in Africa's resource-constrained contexts, where innovation typically does not conform to traditional measurement and analytical standards (Jauhiainen and Mugabe 2024; Muchie, Lundvall, and Gammerltoft 2003). For instance, current innovation indicators tend to emphasize formal inputs such as R&D expenditure, number of researchers and patents. These measures overlook important aspects of innovation in resource-constrained environments, especially the crucial role of necessity and shop-floor serendipity as important inputs into the innovation process (Jensen et al. 2016). Moreover, as we argue later in the paper, much of the innovation in African economies occurs in the informal sector, driven by autochthonous knowledge systems which are typically underrepresented or ignored in traditional STI indicators. Consequently, in line with the general trend to take into account expanded actors, settings and forms of innovation in the new STI literature, there is a critical need for innovation metrics that are more appropriate to African economies.

Indeed, the structure of post-colonial African economies differs markedly from the high- and middle-income countries on which most of the innovation theory and literature is based. Their insertion into global value chains is constrained, and they are highly dependent on resource extraction to the benefit of multinational corporations and local elites (Mkandawire 2005). Large proportions of their populations remain dependent on informal livelihoods, whether in agriculture, manufacturing, trade, or services (Medina, Jonelis, and Cangul 2017). Moreover, strong systems of political patronage and elite capture constrain transformation (Gray and Whitfield 2014). However, African states now increasingly recognize the relevance of broader STI measurement – to monitor and communicate national STI policy achievements and to assess progress towards international development targets, including the SDGs and the STI Strategy for Africa (STISA). While most African countries have not built strong national technological capabilities over time, some are positioning themselves well to create opportunities through digital transformation (Beyene, Bedemo, and Gebremeskel 2024), and the potential of the African Free Trade Continental Agreement is being explored.

From this brief overview, we can distill three key reasons for growing a knowledge base to inform the design of STI measurement and indicators in Africa. First, for indicators to be of value and use to policy actors, they need to be informed by research that links the theorization of the attributes, determinants and outcomes of innovation, through an iterative process, with empirical testing (Borrás and Edquist 2019). Second, and closely related, is the need for a stronger research base on the capabilities of African countries. If policy mixes and instruments are borrowed from high-income countries into innovation system contexts with low capabilities, they are unlikely to succeed. Third, it is vital to identify and understand the societal grand challenges experienced in African countries. Measurement programmes need to be built on a strong base of literature on the nature, forms, and drivers of innovation in the economic growth and development pathways of low and middle-income countries in Africa. These dynamics stimulated the idea to conduct a bibliometric review, to ground and grow a new research agenda based on the current state of the art.

3. Methodology

The analysis and discussion are based on a bibliographic analysis of recently published scholarly outputs on STI measurement in Africa. A bibliographic analysis refers to a systematic literature review that analyses bibliographic data – including, amongst others, author names, journal names and article titles, keywords, abstracts and publication years – using bibliometric methods (Block and Fisch 2020). The value of such an analysis is to understand 'the current state of the academic conversation' (Park, Shin, and Choy 2020, 141), as a foundation to highlight key areas for further research and indicator development. The methodology followed is in line with the well-established Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach, which is an evidence-based guideline designed to improve the reporting quality of systematic reviews and meta-analyses (Moher et al. 2010) while ensuring clarity, rigour, and reproducibility in summarizing evidence from multiple studies.

3.1. Article selection process and data analysis

3.1.1. Inclusion and exclusion criteria

One of the first conditions for selecting an article for review was that it must be peer-reviewed but not limited to journal articles. It included journal articles, reviews, book chapters, editorials, books, conference proceedings and working papers. The Scopus database was used as the main source to identify relevant articles. Search terms with wider and broader degrees of specificity were used to identify relevant literature:

- Innovation measurement and Africa;
- Innovation measurement and developing countries/global South;
- Innovation and informal economy and Africa;
- Science, technology, innovation measurement and Africa; and
- Science, technology, innovation measurement and developing countries/global South

A second search was conducted to ensure that we have covered the literature on STI measurement in Africa:

- Science, technology, and innovation indicators + Africa/developing countries;
- Business innovation indicators;
- Innovation capabilities + indicators;
- Formalization of businesses + indicators; and
- Innovation indicators + informal economy.

We found overlaps in the literature sourced through the two searches and included relevant articles not covered by the first set of search terms.

The Scopus database is a useful resource for conducting a systematic literature review and includes a broader range of literature than many other databases. However, there are limitations to using Scopus such as the coverage being biased towards English sources (see Sanni and Verdolini 2022, for further discussion on the advantages and limitations). To reduce potential bias and widen coverage, the review includes 'grey literature' and

analysis of co-citations. The research team included African STI measurement experts who provided inputs into the database to consider coverage.

3.1.2. Searching, locating and identifying relevant literature

The Scopus database was used to identify and extract papers, and VOSviewer software[3] to identify and visualize key trends. After screening the paper titles and abstracts, a total of 42 papers were identified as relevant for analysis, the majority being journal articles. The earliest date of publication found is 2008. Within our corpus, we have identified only a handful of articles that delve into STI indicators within an African context specifically. In general, many of the articles were published in relevant and high-impact journals such as Research Policy and Technological Forecasting and Social Change. The African Journal of Science, Technology and Innovation Development is one of the few Africa-focussed journals that published articles in this field.

3.1.3. Data analysis

A team of researchers read the papers and recorded key information on an Excel spreadsheet template. The dataset was analysed using bibliometrics, complemented by a thematic analysis. The bibliometric analysis included the following commonly used techniques (see Park, Shin, and Choy 2020, 151):

1. 'Co-occurrence analysis: the greater the number of documents in which two keywords occur together, the higher the relatedness of these keywords'.
2. 'Citation analysis: the greater the number of times authors, journals, and papers cite each other, the higher the relatedness of these items'.
3. Analysis by publication year and geographical location of the authors' institutional affiliations.[4]

The analysis focussed on two main aspects. First, it assessed the topics covered in the research field, based on an analysis of the co-occurrence of subject terms. Second, it analysed the geographical scope of the papers, based on the institutional affiliation of the authors and citation analysis. Co-citation analysis was conducted to broaden the search to include articles citing the articles in our database. This is a way to overcome the limitation of using Scopus as the main source.

4. Contribution of the existing literature

4.1. Topics covered most frequently in the STI measurement in Africa literature

Co-occurrence analysis shows the frequency and relatedness of subject terms, revealing trends in the topics covered (Park, Shin, and Choy 2020). We first analysed the co-occurrence of indexed and author keywords (Figures 1 and 2). Second, to broaden the analysis to capture a wider array of topics, we analysed the co-occurrence of subject terms in the abstracts and titles (Figure 3).

Figure 2 shows the co-occurrence of keywords, revealing four major clusters:

(1) **STI measurement cluster (green)** focusssing on 'indicators' and 'metrics' of 'science', 'technology' and 'innovation'. Co-occurring with these topics is the

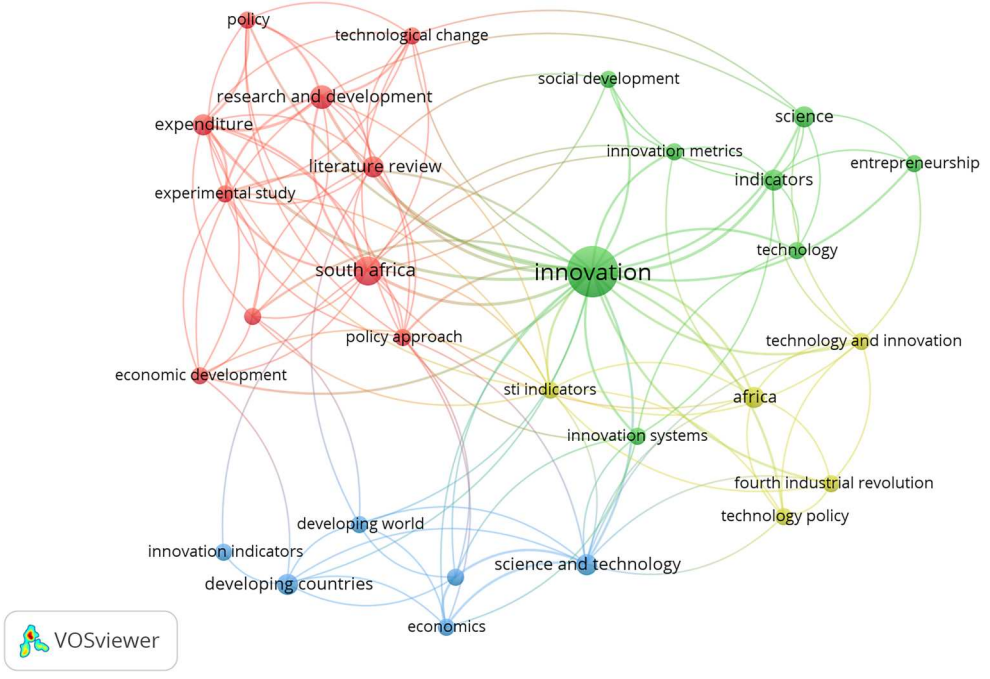

Figure 1. Map of co-occurrence of indexed and author keywords, indicating topic clusters. Source: Created in VOSviewer, by Frieda Billson and Shingirirai Muzondo (eRKC, HSRC).

'innovation systems' approach and more recent topics that are not well linked into this cluster include metrics of innovation and 'social development' and 'entrepreneurship'.

(2) **Science and technology in developing countries (blue)**, appearing more distant or weakly linked to the central cluster of keywords in the middle of the network. The specific topics covered in this cluster include 'developing countries' and 'innovation indicators', and 'science and technology' linked to 'innovation systems'.

(3) STI indicators and development cluster including **South Africa (red)**, centres on innovation measurement in 'South Africa' highlighting research on 'research and development', 'expenditure' and 'experimental study'. Also identified are 'policy' and 'technological change' and 'economic development'.

(4) **A smaller cluster (yellow) focussing on Africa**, highlighting the growing trend in research on STI indicators and the 4IR, as one focus for technology policy.

We also analysed the occurrence of keywords against publication year, to identify change over time (see Figure 2). Prior to 2017, the focus of the literature on Africa was on measuring performance using the more traditional and well-established STI measures and indicators such as R&D and innovation surveys. This period could be associated with the adoption of international guidelines for STI measurement promoted by the OECD, including the Frascati and Olso Manuals. From about 2017 onwards, it appears that the use of STI measures and indicators began to find relevance in innovation

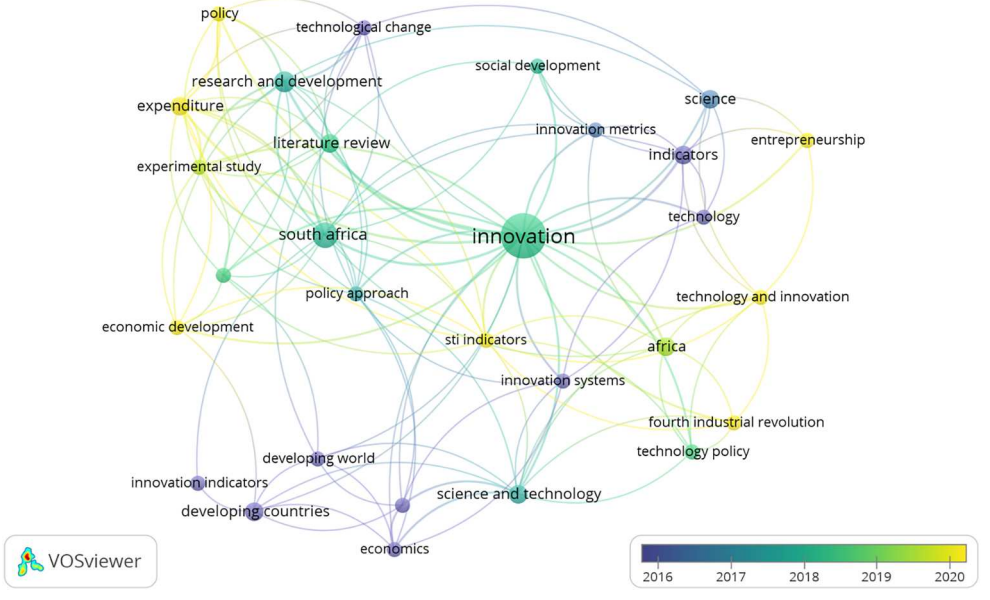

Figure 2. Map of co-occurrence of indexed and author keywords by average publication year. Source: Created in VOSviewer, by Frieda Billson and Shingirirai Muzondo (eRKC, HSRC).

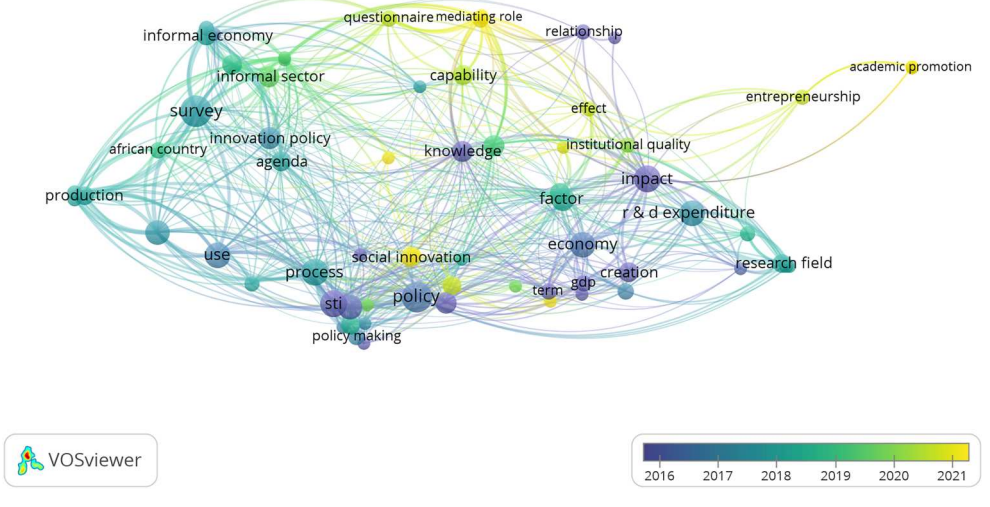

Figure 3. Map of co-occurrence of subject terms in the titles and abstracts, by publication date. Source: Created in VOSviewer, by Frieda Billson and Shingirirai Muzondo (eRKC, HSRC).

policy. The investigation of the association between STI indicators and economic development is linked to this trend but appears to be more recent. Linked to the focus on 'innovation metrics' and 'social development', is recent interest in 'social innovation'

in general and in relation to policy. The analysis of the citations indicates that the conversation around this cluster of topics is more well-established.

The focus of research on innovation measurement in 'Africa' as a region of interest is relatively more recent, from 2019 onwards. New trends relate to digitalization, spurred by growing interest in the Fourth Industrial Revolution and technological development (Figure 2). The expanded analysis, of subject terms in abstracts and titles, reflects research on the 'informal economy', which has been on the innovation measurement agenda for a while. Innovation measurement in the 'informal sector' appears as a more recent area of research, from 2020 onwards, reflecting new efforts to measure innovation in informal enterprises rather than innovation in the informal economy more broadly (Figure 3). Research on the innovation systems approach appears to be an older focus, prior to 2017. Related topics that are well-established in the literature include 'knowledge'. Other related topics that are not well-cited include more recent interest in 'institutional quality' and 'capabilities' (Figure 3). There is thus a basis for the kinds of empirically grounded indicators of change in innovation systems being called for in the broader innovation and development literature.

When it comes to Africa, South Africa appears prominently (Figure 2). The measurement of R&D and innovation is more established in South Africa than in any other African country. It is therefore not surprising that R&D and innovation measurement is well-researched as a policy focus and linked with technological change. Whereas the focus on R&D appears more strongly in 2017 and 2018, interest in the link between innovation measurement and economic development, expenditure as a policy focus, and experimental research is more recent, from 2019 and 2020 onwards. Although South Africa and R&D-related research in South Africa was also well-researched, this research did not appear to be frequently cited. The conversation seems to be limited in reach.

4.2. Main topics of interest in the academic conversation on STI measurement in Africa

We broadened the analysis to the co-occurrence of subject terms used in articles citing other articles in our database (Figure 4). The following topics were most highly cited: a recent trend related to 'sustainability' and included 'sustainable development' and the 'green economy' and 'alternative energy'; a trend related to 'technological innovation' and 'technology adoption', with some relation to 'manufacturing' and 'SMEs'; and a third strand related to 'innovation policy', 'industry' and 'engineering' (Figure 4). Research on China also appears prominently and interest in this country has grown in recent years. Africa and countries in Africa do not appear as frequently in the academic conversation.

4.3. Geographical structure of the STI measurement in Africa research network

The geographical location of the authors, based on their institutional affiliations, was analysed. We took this analysis further by analysing the geographical locations of the 527 papers that cited 27 of the papers in our sample (Figures 5 and 6). The network diagrams in Figures 5 and 6 reflect the dominance of scholars based in the United Kingdom, as well as the United States, Australia, and other European countries in the academic conversation. The same analysis by publication date shows an emerging trend growing around

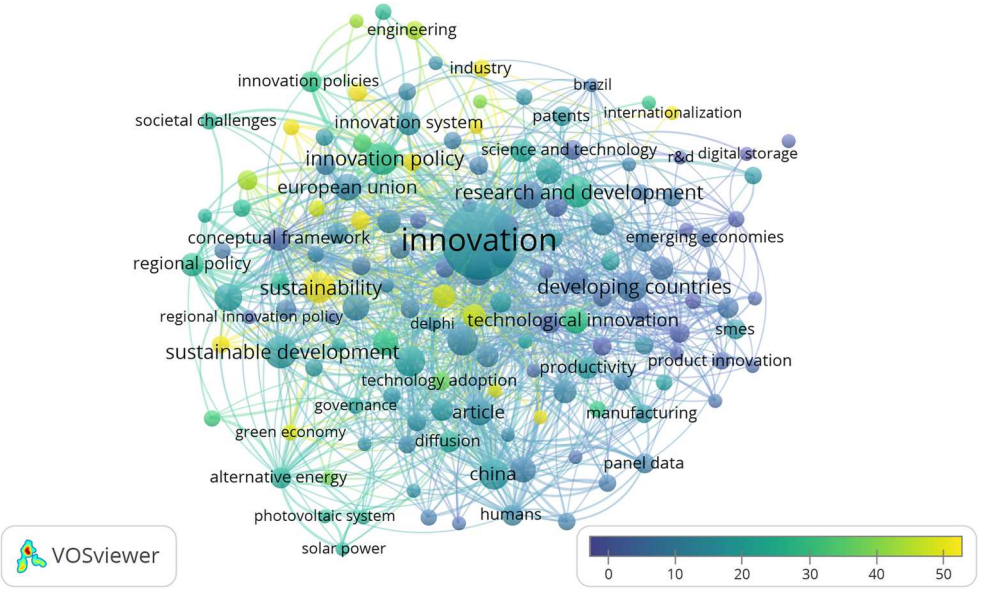

Figure 4. Map of citations of the STI measurement in African literature. Source: Created in VOSviewer, by Frieda Billson and Shingirirai Muzondo (eRKC, HSRC).

young economies in Asia and Latin American (Figure 6). In Africa, Nigeria and South Africa are the only two countries that are most visible on the STI measurement landscape. The two countries also seem to be conducting similar research as indicated by

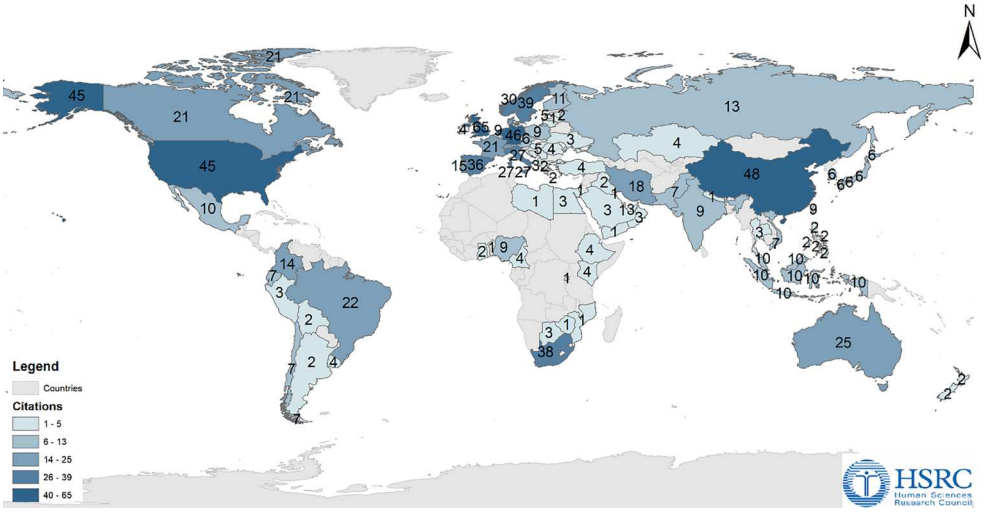

Figure 5. Map of the world indicating the geographical locations of authors citing papers on STI measurement in Africa. Source: HSRC.

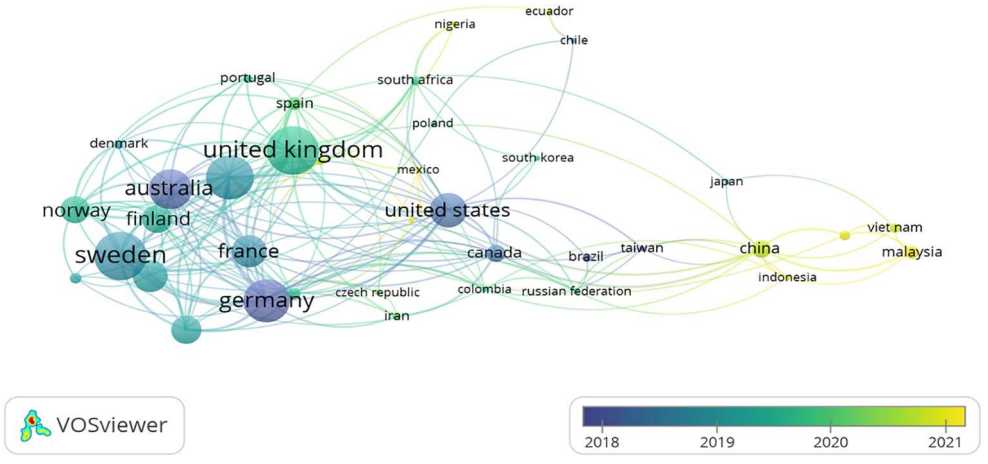

Figure 6. Map highlighting the geographical locations of authors citing papers on STI measurement in Africa, by publication dateSource: Created in VOSviewer, by Frieda Billson and Shingirirai Muzondo (eRKC, HSRC).

the proximity of the South African and Nigerian nodes (Figure 6). In comparison to other countries in the global South, researchers in South Africa are prolific (Figure 2) but are cited far less than research by authors in high-income countries (Figure 6). This is followed by Nigeria, which has developed STI measurement capacity in recent years (Siyanbola et al. 2016). The body of literature from these two countries is small and appears to be more recent, suggesting a relatively new area of focus. However, it will take time and effort for this picture to improve, even with the emerging research networks as shown in the bibliometric analysis.

4.4. Bibliometric analysis of the main topics and the location of research capabilities for STI measurement in Africa

In summary, the research on STI measurement in Africa, whether the focus is on specific countries or Africa as a region of interest, is under-researched, but the knowledge base is growing. 'Innovation indicators', as key to 'innovation policy', has been on the research agenda for several years and continues to be an area of interest. The strongest and oldest trends include well-established topics related to the more traditional STI measures and indicators. The focus has been on how international standards and existing approaches, led by the OECD, can be adopted by and extended for developing country contexts. A few papers by leading international scholars, including those from the global South, dominate the academic conversation.

More recent areas of interest with the potential to inform shifting policy objectives include a focus on environmental sustainability, digitalization and the informal sector. Research on these topics appears to be led by South African and Nigerian researchers, but, relative to other regions in the global South, the research base in Africa is nascent, and growing at a slower pace. Also, South Africa and Nigeria, as the largest economies in Africa, present different conditions, challenges and opportunities to most others

on the African continent. Research on STI measurement in low-income countries remains a notable gap.

Historically, researchers in high-income countries have led the research and academic conversation on STI measurement in Africa. In recent years, there has been rapid growth of research on the topic led by researchers in Asia, particularly China, and Latin America. Considering that measurement tends to lag behind the research, this trend suggests that it will take quite some time for African countries to develop measurement programmes underpinned by contextually informed conceptual frameworks, instruments and methodologies.

5. Research agenda towards the goal of creating contextually-relevant STI indicators in Africa

One of the strongest trends in the literature on science, technology and innovation (STI) measurement in Africa is the critique of standard STI indicators, and consensus around the need for contextualized STI measurement and indicators (Gault 2008; Iizuka and Hollanders 2017, 2020; Teng-Zeng 2009; Sutz 2012). New data and analysis, including multi-level analyses (Srholec 2011), can add value, to better understand the drivers of innovation and the link between innovation and economic growth and social development. In particular, the nature of 'enterprise' activity and organization in informal settings is a major research gap to close. Here, the need for suitable measures and indicators of incremental innovation, diffusion, and 'competence-extending rather than disruptive' innovation is highlighted (Zanello et al. 2015). Another under-researched area is the role of governance, including issues such as corruption and volatility, on innovation in African countries (Omidi, Shahabadi, and Mehregan 2020).

Based on our identification of changing trends over time, emergent trends and gaps, this section hones in on potentially fruitful areas to strengthen the emergent research base as a foundation for contextualized STI measurement and indicators. The analysis maps out key analytical issues, conceptual and methodological frameworks, and emerging empirical research.

5.1. STI measurement towards advancing the SDGs and understanding the impact

A strong trend is the concern that the standard STI indicators do not provide useful evidence for policy design, formulation and implementation (Igbinovia and Krupka 2019; Kahn 2022; Manzini 2015; Manyuchi 2018; Manyuchi and Mugabe 2018). The STI policy vision of most African countries is aligned with the commitment to contribute to achieving the United Nations' Sustainable Development Goals (SDGs), as a shared framework for transformation through innovation globally; and to the achievement of the six development priorities of the African Union's *STI Strategy for Africa* (STISA) 2024. Kruss (2018) proposes a new STI indicator framework aligned with the STISA goals and SDGs, contributing to an emerging literature arguing that assessing progress requires new STI measures and indicators oriented to societal challenges. New bibliometric methodologies are used to map research priorities and strengths relative to priority SDGs in a country, including in African countries (Confraria, Ciarli, and Noyons

2024; Vélez-Cuartas and Romero-Goyeneche 2022). The focus can be at a range of levels, from high-level societal grand challenges such as climate change and environmental sustainability to a specific priority such as innovating and diffusing affordable, appropriate technology and environmentally sustainable sanitation, energy or healthcare. Here, indicators of social innovation (Pigatto and Brunor 2021); public sector or more specifically, service delivery innovation (Nel and Masilela 2020); and human development (Kruss, Sithole, and Buchana 2021) may be important.

Despite its global importance, well-established measurement frameworks tracking the advancement of STI towards achieving the SDGs are a gap, but a recent focus in the literature that is slowly gaining traction. The major challenge is to conceptualize and define outcome and impact measures of STI activity, such as strengthened technological capabilities, more effective utilization of digitalization, improved sustainability, or wider inclusion of citizens in the opportunities and benefits of innovation. The inclusion of women and other traditionally marginalized social groups in STI remains a challenge. Two major challenges for the task assessing societal impact include: defining the system to be assessed, as some systems such as transport, energy and food overlap, and secondly, the kind of system change required may involve radical change of some system elements and at the same time, continuation of some other system elements (Laatsit, Grillitsch, and Fünfschilling 2025). Building an African knowledge base is vital, as research needs to focus on STIs oriented to the basic development challenges not as prevalent in high-income countries, such as eradicating hunger and ensuring food security, or access to health.

R&D surveys are now relatively established in many African countries. An emerging trend is to analyse R&D survey data in new ways to address development priorities important for African countries (Kruss 2018). For example, mapping and tracking investment in agriculture, health or green R&D, or R&D expenditure and collaboration related to indigenous knowledge. The extent and nature of collaboration between formal businesses, NPOs, higher education, science councils and informal sector actors such as indigenous knowledge holders and practitioners is a gap worth exploring. Taking this kind of R&D-related research further may contribute to evaluating progress towards the SDGs.

5.2. Creating quality data sets and data governance frameworks

A major challenge identified in the literature is the lack of quality data. Few countries in Africa collect innovation and R&D-related data on a regular basis. A promising recent trend led by African researchers as part of initiatives such as the Open AIR network, is the review of existing methodologies, datasets and surveys such as the World Bank Enterprise Survey and the Global Innovation Index to identify suitable data sources, and specific data gaps, towards improving innovation measurement in Africa (Alhassan and Girinsky 2020; Hassouna 2018; Rizk et al. 2018). Identifying ways to improve data quality, even for the well-established STI measures and indicators, is also emphasized (Cirera and Muzi 2020). While global indices help to fill the gap in the short term, a long-term strategy needs to include the development of capabilities for new surveys and datasets based on contextualized STI measurement frameworks and methodologies. The role of the African Science, Technology and Innovation Indicators (ASTII) initiative

in building local measurement capabilities has been highlighted (Gault, Ambali, and Mangwende 2016; Manyuchi and Mugabe 2018) but more needs to be done to strengthen institutional capabilities. An emerging trend is the recognition of the need for stronger data management systems, co-ordination and frameworks for the sustainability of data collection and management, at the national and regional levels (Atela et al. 2021).

5.3. New analytical perspectives and frameworks on firm innovation

The conceptual models underpinning current measurement paradigms, based on innovation patterns in high-income contexts, may steer STI policy in the wrong direction (Kahn 2022; Niosi 2010). Many African firms in low- and middle-income contexts are more likely to reflect modes of innovation activities that take the form of adoption, imitation or adaptation of new technologies acquired from elsewhere, rather than R&D or STI driven; or firms may not have the required capabilities to access and absorb new technologies. There may be contextually important emergent forms of innovation that are not typically measured nor supported in high-income countries, but which should be grown and nurtured in low and middle-income contexts. Moreover, while business innovation surveys typically cover manufacturing and services sectors, in African contexts, it is vital to also measure innovation in the agricultural sector (CeSTII 2024). The latter is of particular importance given its large contribution to employment and economic growth as well as its relevance to the process of structural transformation in Africa.

Appropriate and relevant indicators therefore need to be informed by context-specific evidence on the determinants and nature of technological learning and upgrading in the full range of local firms (Edler 2009; Freeman and Soete 2009; Lall 1993; Lorentzen 2009; Zanello et al. 2015). Unfortunately, there is only a small evidence base of the relative spread, importance, and intensity of innovation capabilities in specific clusters of firms in African economies. A stronger research focus to map and profile the modes of innovation found across local firms is vital.

Initially, in the late 1990s and early 2000s in the innovation research and policy literature, the definitions of innovation modes were simple, based on binary distinctions between degrees of novelty (radical or incremental) or high-level types of activity (product or process). The disaggregated analysis could examine the drivers, outcomes and barriers of types of innovation, across and between industrial sectors. These indicators are used for benchmarking progress over time, and to compare national progress relative to other countries.

Examples and models to define the specificity of African modes of innovation can be drawn from a range of attempts to define contextually specific classifications of modes of innovation, to track changes over time (Gokhberg and Roud 2016) or in specific countries (Hagen 2014; Peneder 2009) or regions (EUROSTAT 2025; Frenz and Lambert 2012; Vargas 2022). A potentially significant stream of research distinguishes Science, Technology and Innovation (STI) and Doing, Using and Interacting (DUI) modes of innovation, particularly in Small, Medium, and Micro Enterprises (SMMEs) (Alhusen et al. 2021; Jensen et al. 2016; Parrilli and Heras 2016) and is gaining traction as an analytical model in African contexts (Hansen-Addy 2021; Hooli et al. 2019; Lukhele and Soumonni 2021).

Indicators for modes of innovation in low and middle-income African countries should be able to capture activity across the full spectrum of innovation capabilities,

but particularly, to be fine-grained at the adoption, imitation, and modification end of the spectrum, to capture complexity along multiple dimensions.

5.4. Empirically grounded research on innovation measurement in the informal sector

The informal economy is significant and indigenous knowledge is highly valued in African countries. There is little international precedent for measuring innovation in informal enterprises. A foundation has been laid by experimental African attempts, including sectoral studies in Senegal (Konté and Ndong 2012); and a set of case studies and surveys (Kraemer-Mbula and Wunsch-Vincent 2016). A gap in this emerging literature is innovation measurement that is not industry or sector-specific but assesses scale and points to ways in which innovation differs from that in formal enterprises. Other potential areas include the need for measurement to capture the mainly non-technological and necessity-driven nature of innovation in the informal sector (Petersen and Kruss 2021); the importance of local embeddedness and innovation as 'every day activities' in 'every day settings' (Hoffecker 2018); and the prevalence of experiential forms of learning involving mainly imitative practice and learning by doing and using, rather than through interaction or R&D (Kraemer-Mbula et al. 2019). Some have questioned the significance of informal sector innovation, and whether the activities described in fact count as innovation. Others have pointed to the significance of informal sector innovation for building innovation ecosystems at the local level rather than for identifying and scaling up innovative products and solutions (Hoffecker 2018).

Charmes, Gault, and Wunsch-Vincent (2018), among others, have suggested approaches for measuring and understanding innovation in the informal sector. In grappling with the problem of the suitability of the conceptual foundations of existing measurement frameworks, there is experimentation with novel analytical frameworks for understanding innovation at the local level, drawing on and extending international standards (De Beer, Fu, and Wunsch-Vincent 2013; Mustapha et al. 2022). Some have attempted to leverage existing methodologies and surveys such as the Global Innovation Index and the Global Competitiveness Index to develop contextualized indicator frameworks but have found gaps (Hassouna 2018; Rizk et al. 2018). In South Africa, researchers have adapted and contextualized the standardized formal business innovation questionnaire for informal businesses, informed by in-depth qualitative research and cognitive testing with informal business owners (CeSTII 2020; Mustapha et al. 2022). The same questionnaire has been applied by counterparts in Nigeria (NACETEM 2020). The research methodology is participatory and involves a mix of methods to be able to build up a bottom-up understanding of innovation in the informal sector, and at the same time, use this understanding to inform and implement measurement. Such methodological approaches may be beneficial to increase the pace and base of research in Africa. This raises important questions for further research around Africa-focussed innovation measurement: What lessons can be learned from current efforts to put together a measurement framework that responds directly to the need to understand innovation activity in the informal sector on the continent, and how can these be linked to existing measurement programmes of formal sector innovation?

5.5. Measuring progress and the impact of digital technologies and the fourth industrial revolution

In developing countries, digitalization has proven to be an important driver of economic growth because of its potentially positive impact on raising capital and labour productivity, lowering transaction costs, and improving access to global markets (Dahlman, Mealy, and Wermelinger 2016). The main intent of digitalization in low and middle-income countries is to make a profit and to address societal grand challenges. Smart technologies in sub-Saharan Africa are beginning to play important roles in economic activities (Krammer 2017), such as giving citizens access to modern communication systems, financial inclusion for the poor through mobile banking, and increased participation of small businesses through e-commerce (Myovella, Karacuka, and Haucap 2020). Gaglio, Kraemer-Mbula, and Lorenz (2022) demonstrate that the use of digital communication technologies, such as social media and mobile phones, have a positive effect on innovation in SMMEs, and in turn, on labour productivity. Meanwhile, nations are currently confronting issues of technological advancement in digitalization and automation (de Man and Strandhagen 2017). The convergence, configuration and application of principles such as digitalization, automation, interoperability, virtual applications, decentralized systems, real-time capabilities, orientation for service and modular production, the model of 'Industry 4.0' (Ghobakhloo 2018; Lasi et al. 2014) need to be engaged actively. Digitalization is particularly significant for innovation in agriculture (Choruma et al. 2024), and in service delivery, to improve the quality of life (Nel and Masilela 2020).

Despite the deep interest in Industry 4.0 in Africa, an adequate understanding of this phenomenon is yet to be achieved (Castellani, Lamperti, and Lavoratori 2022). Some scholars have made efforts to track progress and deepen understanding by collecting data through surveys in specific countries (Gaglio, Kraemer-Mbula, and Lorenz 2022) or assessing specific technologies, or in-depth examination of innovation through case studies (Dachs, Kinkel, and Jäger 2019). Inadequate knowledge in this field has been linked to weak theoretical and conceptual frameworks, as well as a lack of reliable and accurate indicators to measure the development and utilization of digitalization on a large scale across countries and over time.

Stronger research efforts are required to improve our understanding of the magnitude of production, adoption, and barriers to the utilization of digital technologies and its evolution over time with appropriate theoretical and conceptual framings (Bogoviz et al. 2019; Kamble, Gunasekaran, and Sharma 2018). From a methodological point of view, tracking the growth and evolution of digital technologies is particularly complicated without reliable data, especially when the evolution is ongoing, and the technology is not mature. It is important to track the geographical spread across the continent and the presence of specialized clusters, through reliable indicators. Given the socio-economic realities within Africa, conceptualizing and developing reliable indicators of digitalization should become a priority.

5.6. Increasing priority to research on environmental sustainability

STI policy models and measurement frameworks centred on sustainable development, specifically, environmental sustainability, are a growing trend in the global South

(Kuzma et al. 2022). A recent systematic review of the literature on eco-innovation shows major growth in the volume of literature, led by European countries and the United States of America, with contributions by a few countries in the global South including China, Brazil, Malaysia and Mexico (Sanni and Verdolini 2022).

It is important to assess the directionality of innovations so that economic growth does not lead to further degradation and human suffering (Schot and Steinmueller 2018). This is not a strong trend in Africa, although our bibliometric analysis highlighted a recent trend that can be grown further. In Africa, in relation to sustainable development, research on poverty and inequalities tends to be prioritized above climate change, alternative energy sources, and so on. Given the current energy, water, and climate crises in African countries, and the impact on agriculture, livelihoods and food security, this should be raised as a priority. Research is needed to inform and track the progress of interventions on renewable energy, for example. This emphasis equally relates to the SDGS, to new challenge-led innovation policy approaches (Mazzucato, Kattel, and Ryan-Collins 2020; Schot and Steinmueller 2018) and new economic models, such as the Blue Economy (Madhou, Moosun, and Nagowah 2022). A promising development in the broader STI measurement literature is a set of guidelines for measuring eco-innovation (Kemp et al. 2019), as a basis for sound contextualization.

6. Conclusion

The paper began by pointing to what we know – that STI measurement in Africa may not be appropriate to context, so we may not be measuring what we should be measuring. More significantly, we proposed the need to break the prevailing cycle, which tends to stop at the critique of dominant measurement frameworks but does not build meaningful alternatives. We argue for scholars to move actively towards shifting the contours of the STI measurement and broader innovation studies knowledge base. No more should the innovation systems of African countries exist 'under the radar', but their specificities need to be foregrounded in the research literature.

The main conclusions of the bibliometric review are also not 'new', and largely confirm the 'normal functioning' of our unequal global economy of knowledge production (Connell et al. 2018). That is, research on developing countries authored in the global North tends to be more highly cited and more visible. The implication is that measurement informs policy intervention, which will continue to be skewed without a conceptually and empirically strong research base for STI measurement in low- and middle-income economies in Africa. We know that African countries are challenged by limited resources and weak institutional capabilities for STI measurement. Building capacity in resource-poor science and innovation systems is difficult, and there is much fragmentation and a lack of collaboration (Atela et al. 2021). Considering the limited funding available, research collaboration and comparative analysis across countries and within African country contexts is vital.

What the review highlights as noticeably absent in the African STI measurement and innovation policy literature is theory building. This is in contrast to Latin America, where the Bogota manual was an early attempt to contextualize innovation measurement and has enjoyed relative success with three waves of innovation surveys undertaken among some member countries between 1995 and 2010 (Bogliacino et al. 2012). Here too,

new indicator systems are emerging, grounded in sustainability transitions and transformative innovation policy conceptual frameworks (Vélez-Cuartas and Romero-Goyeneche 2022). The challenge, therefore, is to grow a research community.

Through the trends revealed by our bibliometric analysis, we provide a foundation and starting point from which to proceed. We identified areas that are well-researched such as R&D, and areas that are under-researched, but with emergent strengths, including STI for the SDGs, informal sector, agriculture, digitalization and firm innovation dynamics. Areas that are not yet given much attention are sustainability and environment, and gender equality and inclusivity.

A trend highlighted in the analysis that is both promising and concerning is the prominence of South Africa and Nigeria in the STI measurement field in Africa. The economic structures, firm capabilities and opportunities in these countries are very different from many low- and lower-middle-income African countries. It is important to prioritize empirical research in a wider spread of contexts, to avoid reinforcing inequalities in knowledge production.

Research on innovation in informal settings is arguably one of the most important research foci to drive, because of the significance of informal economic activity across middle- and low-income African countries. Also, because the informal sector is not high on the measurement agenda at the international level, it is an area where African researchers need to take the lead. It is an area where African researchers can contribute to extending measurement guidelines as these are contextualized for the informal enterprises in African countries. Current research on measuring innovation in informal enterprises uses mixed methods research. It proceeds with measurement and at the same time, builds a bottom-up understanding of informal sector innovation that is used to inform the research instruments and methodology (Mustapha et al. 2022; Petersen and Kruss 2021). The value of this approach, of conducting measurement alongside research, needs to be explored as a way to fast-track advances in measurement. It can be described as a more 'radical' approach to STI measurement and is more likely to 'disrupt' current knowledge production pathways in a way that can lead to much more progress in taking forward the research agenda in the next decade than was made in the past two.

Notes

1. There are 24 low income, 23 lower middle-income and 7 upper middle-income countries in Africa, each of which is characterized by high levels of inequality of opportunity and livelihoods, and primarily resource-based economies (for example, diamonds in Botswana, petroleum in Libya), exacerbated in some cases by repressive political regimes (https://worldpopulationreview.com/country-rankings/low-income-countries, accessed 6 November 2023).
2. Agencies like the African Observatory on STI (AOSTI) and the African Union's AUDA-NEPAD drive training and capacity building.
3. The advantages and limitations of VOSviewer are discussed by Park, Shin, and Choy (2020).
4. The analysis of geographical coverage only applies to peer-reviewed outputs as the country affiliation of authors is not available for outputs that were not available in Scopus.

Acknowledgements

This paper was produced as an activity of the AfricaLics Thematic Chair on Africa-Focussed Innovation Measurement, led by CeSTII in collaboration with NACETEM. The AfricaLics thematic

chair initiative has been a useful platform to contribute to building the knowledge base around STI measurement in Africa. The systematic review of the literature was a collaborative effort of research teams at CeSTII and NACETEM. A team of researchers at the two institutions reviewed the set of papers identified through a systematic literature search and recorded key information that would be the basis for the bibliometric and thematic analysis: Mbongeni Maziya, Setsoheng Mayeki and Nicole van Rheede at CeSTII, and Festa Ndutimi at NACETEM. Colleagues at the HSRC's eResearch Knowledge Centre, Shingi Muzondo and Frieda Billson, assisted with the systematic literature search and conducted the bibliometric analysis in VOSviewer. We also acknowledge the Department of Science, Technology and Innovation, South Africa, which provides funding support to CeSTII.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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