African Journal of Science, Technology, Innovation and Development

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rajs20

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To cite this article: Yasser Buchana & Moses M. Sithole (2022): Towards a conceptual framework for measuring innovation in the agricultural sector in sub-Saharan developing countries, African Journal of Science, Technology, Innovation and Development, DOI: 10.1080/20421338.2022.2072794

To link to this article: https://doi.org/10.1080/20421338.2022.2072794

Published online: 13 Jun 2022.

African Journal of Science, Technology, Innovation and Development, 2022
https://doi.org/10.1080/20421338.2022.2072794

Towards a conceptual framework for measuring innovation in the agricultural sector in sub-Saharan developing countries

Yasser Buchana* and Moses M. Sithole

Centre for Science Technology and Innovation Indicators (CESTII), Human Science Research Council, Cape Town, South Africa
**Corresponding author email: ybuchana@hsrc.ac.za*

Despite the importance and benefits of measuring innovation in businesses, standard methods for innovation measurement, such as the Oslo Manual, largely exclude the agricultural sector. As a result, innovation scholars in developing countries struggle to develop knowledge to understand innovation in agricultural businesses.

This paper proposes a conceptual framework to guide research on the measurement of innovation in the agricultural sector in developing countries, focusing initially on commercial agricultural businesses. The proposed framework provides an analytical reference point with detailed methodological guidelines for scholars and practitioners of innovation studies who wish to understand the complexities and dynamics of innovation in commercial agricultural businesses (including forestry and fishery businesses). A practical example, based on an empirical study that used this framework to measure innovation in South Africa's agricultural sector, illustrates how it can be put into practice.

Keywords: agricultural sector, conceptual framework, developing countries, innovation

Introduction

Innovation has long been recognized as an important vehicle for sustained competitive advantage and overall firm growth (Bilbao-Osorio and Rodriguez-Pose 2004; Hasan and Tucci 2010; Hirooka 2006). There is widespread realization internationally of the importance of research and innovation in addressing global challenges such as food security, poverty alleviation and livelihoods, environmental sustainability, biodiversity and climate change (Kallerud et al. 2013; OECD 2018). Most governments, especially in Africa, recognize the value of promoting public investments in agricultural knowledge systems to build capacity in core agricultural sciences to achieve developmental and sustainability goals (Mavhunga 2017; AUDA-NEPAD 2019).

The measurement of science, technology and innovation (STI) helps governments better understand the potential, capabilities and national innovation systems in their countries (Walsh, Murphy, and Horan 2020). The measurement of innovation through the African Science, Technology and Innovation Indicators (ASTII) initiative has shown that innovation (product, process, organizational and marketing) is pervasive in all African Union member countries participating in the first, second and third phases of the initiative. In all of these countries, goods and services resulting from innovations are sold both domestically and exported (AU-NEPAD 2010; NPCA 2014; AUDA-NEPAD 2019).

The data from STI measurement informs the provision of appropriate support to firms by governments, with a view to stimulate and encourage further innovation and, ultimately, increase productivity and competitiveness (Freeman and Soete 2009; Klerkx et al. 2013). This extends to the agriculture sector, as a strategic sector for most countries, that performs different roles and provides opportunities for the essential development of a nation. Examples include food quality and safety assurance, interdependence with other sectors of the economy and bioenergy production (Ariza et al. 2013).

However, innovation measurement in the agricultural sector is a recent development, with only some countries beginning theoretical reflection on what might be required to inform the design and implementation of surveys to measure innovation in the sector. This stands in contrast to the advance of innovation measurement for the industrial and services sectors, notwithstanding the general difficulties of the measurement task (Freeman and Soete 2009; Hipp and Grupp 2005; OECD 2018). Currently, there is a shortage of research work to provide systematic guidelines on the conceptualization and measurement of innovation in the agricultural sector in developing countries contexts. Moreover, there are also limited methodologies to identify and collect innovation data to inform research and policy on agricultural innovation for developing countries (Hall, Mytelka, and Oyelaran-Oyeyinka 2006; Van Mele 2008). This shortcoming is mainly attributed to two reasons: first, unlike other sectors of the economy (such as the manufacturing and services sectors), innovation in the agricultural sector involves multiple products and service groups that are difficult to unravel, and may intersect with other sectors of the economy (World Bank 2006, 2012). For example, a single farm can undertake animal breeding, dairy production and crop production. Within crop production alone, there may be a plethora of different crops and therefore, the innovations underway may be complex across a single farm. Hence, an approach to measure innovation tailored to the agricultural sector and able to capture the complex innovations within the agricultural sector is necessary.

Secondly, traditional innovation surveys framed by the Oslo Manual, largely exclude the agricultural sector (OECD/Eurostat 2005, 2018). This has made it difficult to obtain measurement data on key innovation indicators in the sector. Finally, agriculture in many developing countries, particularly in sub-Saharan Africa, is still largely based on informal or subsistence farming and not formal or commercial farming (Pant 2012; Van

Mele 2008). Given its unique challenges and complexities, the measurement of innovation in the agricultural sector necessitates new data identification and collection processes for the different types of innovations (product and process) taking place within the sector.

The purpose of this paper is to propose a conceptual framework to guide research on the measurement of innovation in the agricultural sector in developing countries. The aim of the conceptual framework is to provide an analytical reference point, with detailed methodological guidelines, for scholars of innovation studies and practitioners (mostly in developing countries) who wish to capture and understand the complexities and dynamics of innovations that occur within the agricultural sector (including forestry and fisheries). As such, the main research question is: ***How can innovation be measured at firm level in commercial agricultural businesses (including forestry and fishery businesses) in a developing country context?***

The remainder of the paper is structured as follows: Following the introduction, the next section presents a discussion on innovation measurement in developing countries. This compares some of the traditional innovation concepts and measurement approaches and highlights recent studies of relevance. In the section that follows, detailed descriptions are presented concerning existing perspectives on frameworks and methods to measure agricultural innovation in developing countries. Thereafter, a rationale for measuring agricultural business innovation in developing countries is discussed. Next, the conceptual framework for measuring innovation in the agricultural sector is provided, detailing how to operationalize a research project to measure innovation in the agricultural sector. A practical example based on a South African case study follows, and demonstrates how the measurement of innovation in the agricultural sector can be undertaken by following the guidelines described here. Finally, the contributions of this paper are discussed.

Innovation measurement in developing economies

Innovation measurement has, over the years, been strongly shaped by the need to inform evidence-based policymaking with respect to the contribution of innovation to economic growth, as well as the need for international comparability (Galindo-Rueda 2013; Gault 2018). Both developed and developing countries consider the measurement of innovation as an important policy tool that justifies the considerable investment required to implement innovation surveys (Blankley, Scerri, and Molotja 2006; AUDA-NEPAD 2019). Recently, however, there is a growing recognition that developing countries, particularly in sub-Saharan Africa, have distinctive economic contexts, as well as social development challenges. These require unique approaches which, in turn, shape innovation.

The 'subject' approach to measurement focuses on the innovating agency – namely the firm. This has been widely adopted globally, including by previous innovation surveys in some developing countries in sub-Saharan, like South Africa, which adopted the methodological recommendations for community innovation surveys (CIS) provided by Eurostat, the Statistical Office of the European Commission. This survey model has been used in more than 80 countries (Gault 2013; Arundel and Smith 2013).

According to Godin (2006), in the development of the Oslo Manual and subsequent surveys, there has been a conceptual shift from simply measuring the outputs of innovation to measuring the activities that facilitate innovation (see Table 1).

The Oslo Manual Innovation Survey Framework (OECD/Eurostat 2005, 2018) seeks to measure innovation activities and behaviour with respect to the following aspects:

1. Innovation in the firm;
2. Linkages with other firms and public research institutes;
3. The institutional framework in which the firm operates; and,
4. The role of demand.

Countries in Africa, however, face distinctive innovation measurement challenges due to their own unique innovation contexts, and processes that are dissimilar to those of European countries. One key difference in the structure of these economies is the substantial contribution of agriculture to GDP and employment in Africa. In the absence of frameworks to address the contextual issues presented by the STI measurement challenges in Africa, the representatives of African Union member states adopted the OECD frameworks of the Frascati and Oslo manuals as guidelines to measure R&D and innovation respectively ((NEPAD, 2014) African Innovation Outlook II (Second Edition). NCPA Pretoria.). However, these measurements are limited mostly to formal businesses and do not provide for the measurement

Table 1: Models of innovation.

Generation	Innovation model	Period	Essence of the model	Authors
1	Technology push	1950s–late 1960s	Linear process	Usher (1955)
2	Market (need) pull	Late 1960s–first half of 1970s	R&D based on customer wishes	Myers and Marquis (1969a, b)
3	Coupling model	Second half of 1970s–end of 1980s	Interaction of different functions.	Mowery and Rosenberg (1979)
	Interactive model		Interaction with research institutions and market	Rothwell and Zegveld (1985)
4	Integrated model	End of 1980s–early 1990s	Simultaneous process with feedback loops / 'Chain-linked model'	Kline and Rosenberg (1986)
5	Networking-model	1990s	System integration and networks (SIN)	Rothwell (1992)
6	Open innovation	2000s	Innovation collaboration and multiple exploitation path	Chesbrough (2003a, b)

***Source*:** Meissner and Kotsemir 2016

of innovation in the informal sector or the production side of the agricultural sector. The use of the Oslo Manual-based CIS-like instrument in these settings has therefore been criticized in recent years (OECD/Eurostat 2018). However, there is still no equivalent manual for these developing economies in Africa.

To address the contextual innovation processes that are unique to developing countries in Latin America, the Bogota Manual (Castellacci and Natera 2012) was included as an annexure to the third edition of the Oslo Manual (RICYT/OEA 2001). The Bogota Manual has been explored by some African countries for how it might contribute to addressing the innovation measurement challenges experienced on the continent. The lessons from Latin America, encapsulated in the Bogota Manual, are an attempt to focus more effectively on measuring innovation as a learning process, since this is a key driver of innovation capability and the absorptive capacity of firms in emerging economies (Castellacci and Natera 2012; Lugones 2006).

The persistent and major challenge is the identification of precedents to measure innovation that take into account the complexity of its measurement in agricultural settings in sub-Saharan Africa and build on the international measurement standards. In the next section, some of these approaches are reviewed.

Perspectives on existing frameworks and methods to measure agricultural innovation

A review of the literature reveals that research supporting the development of frameworks and methods to measure agricultural innovation is emergent. However, there is no holistic subjective approach or framework to measure agricultural innovation at the firm level in a way that enables survey results to reflect the agricultural innovation landscape of a country.

Proposing such a measurement framework is the purpose of this paper. Measurement frameworks that have been used and proposed in the literature use the objective approach that focuses on measuring specific crop or animal production innovations (e.g., Ariza et al. 2013), which are more suitable for in-depth case studies.

In South Africa, for example, the measurement of science, technology and innovation indicators has been underway for many years. Existing STI measurement has included studies that use empirical investigation to measure R&D and other STI indicators in the formal economy and, most recently, in informal settings as well. A survey of R&D and other science and technology (S&T) activities in the formal agricultural sector for the period 2010/11 was conducted by the Centre for Science, Technology and Innovation Indicators (CeSTII) on behalf of South Africa's Department of Agriculture, Forestry and Fisheries (DAFF 2014). It was based on a suite of indicators developed by DAFF to monitor R&D and other S&T activities as part of an initiative to close information and developmental gaps within the sector. The study was limited to public institutions.

A key contribution to the literature is a World Bank report based on the work of Spielman and Birner (2008), which explores the application of the innovation systems framework to the design and construction of national agricultural innovation indicators in developing countries. The authors propose indicators that could be used to gauge and benchmark national performance in dynamic, and innovative agricultural sectors in developing economies.

Similarly, Spielman and Kelemework (2009) demonstrate how to measure innovation in agriculture in developing country contexts. They achieve this by first identifying a set of indicators from secondary data sources that capture the key elements of an agricultural innovation system. They then aggregate these indicators into a unique agriculture, development and innovation index for 35 countries. This provides a toolkit to collect and analyze 'systems-oriented' indicators.

Alternatives to the Schumpeterian paradigm to innovation measurement have also been proposed (Howaldt, Domanski, and Kaletka 2016). The Global Innovation Index (GII) approach provides an alternative to measuring agricultural innovation (Dutta, Lanvin, and Wunsch-Vincent 2017). The 2017 GII report proposed a framework to measure agricultural innovation that provides a set of indicators which can 'be adapted to measuring innovation in specific systems and sectors'. However, the literature shows that this agricultural innovation framework has not been tested in an empirical context. The purpose of the GII report was to provide a ranking of world economies' innovation capabilities and results.

The most promising research in this area emerges from Colombia in Latin America. Here, Ariza et al. (2013) propose a framework to measure innovation, and apply this methodology in practice to four agricultural sub-sectors. Their method aims to measure innovation and its key determinants in agricultural firms, using three main tools: an innovation matrix (IM), an innovation index (II) and an econometric model (OLS estimation procedures). The IM provides an overview of the landscape of the current state of technology in a given agricultural sub-sector. It includes information about technological innovation levels, in terms of their place on the technological spectrum of the sub-sector. The IM also includes information about the frequency of innovation, which refers to the degree of adoption of a particular innovation by farmers.

The idea of using an innovation matrix based on a survey, to organize and sort the information gathered in order to identify innovations, was first introduced by Saavedra, Rugeles, and Guaitero (2012). These scholars proposed the design of a methodology to research innovation in the agriculture sector, both technological as well as non-technological.

Rationale for measurement of agricultural business innovation in developing countries

There are several reasons why it is appropriate to measure agricultural innovation separately from the other sectors covered by the main business innovation survey.

Firstly, agriculture extends beyond the farming sector, across multiple goods and services, making it difficult to measure using the standard approach and instruments. Agricultural activities follow an agricultural value chain

along which different types of innovations occur. These innovations may include:

1. Agricultural inputs such as seeds and fertilizers, with some coming from the biotechnology or chemical sector.
2. Product novelties from the capital goods sector.
3. Process or organizational innovations to improve efficiency in payments, distribution services and logistics from the banking, retail and transport sectors.

Secondly, as described, the first edition of the Oslo Manual focuses on the manufacturing sector, while the second and third editions include the manufacturing and services sectors, yet all these editions largely exclude the agricultural sector. It is yet to be seen in the implementation of the new Oslo Manual (OECD/Eurostat 2018) whether the reframing of business innovation into product innovation (goods, services and information products) and business process innovation (including production, distribution and logistics, information and communication technology services, administration and management, marketing, sales and aftercare services, and product and business process innovation) will adequately facilitate the measurement of the agricultural production sector within the main business survey.

The complexities outlined here, and the lack of robust methodologies to measure agricultural innovation, make it necessary to develop a conceptual framework to measure agricultural innovation in developing countries, particularly in sub-Saharan Africa. A discussion of the development of such a framework follows in the next section.

Developing a conceptual framework to measure innovation in the agricultural sector

As a result of the challenges and limitations of existing measurement frameworks, particularly the shortage of innovation measurement in the agricultural sector in developing countries, the proposed measurement framework set out in Figure 1 serves as a roadmap for researchers to use for their own explorations of innovation measurement in different contexts. The aim of the framework is to assist scholars through the entire measurement and research project.

Previous efforts to categorize innovations have been attempted in the innovation literature (Edquist 2010; Lundvall 2010). Although these conceptualizations of innovation may appear diverse, most share similar attributes (Edquist 1997). Over the last few decades, the definition of innovation used to measure innovation in firms has mainly been guided by the international standard definition of innovation in the Oslo Manual and has, over the years, undergone various revisions to broaden the general concept of innovation.

The definition of innovation is taken from the third edition of the Oslo Manual (OM3) (OECD 2005) which

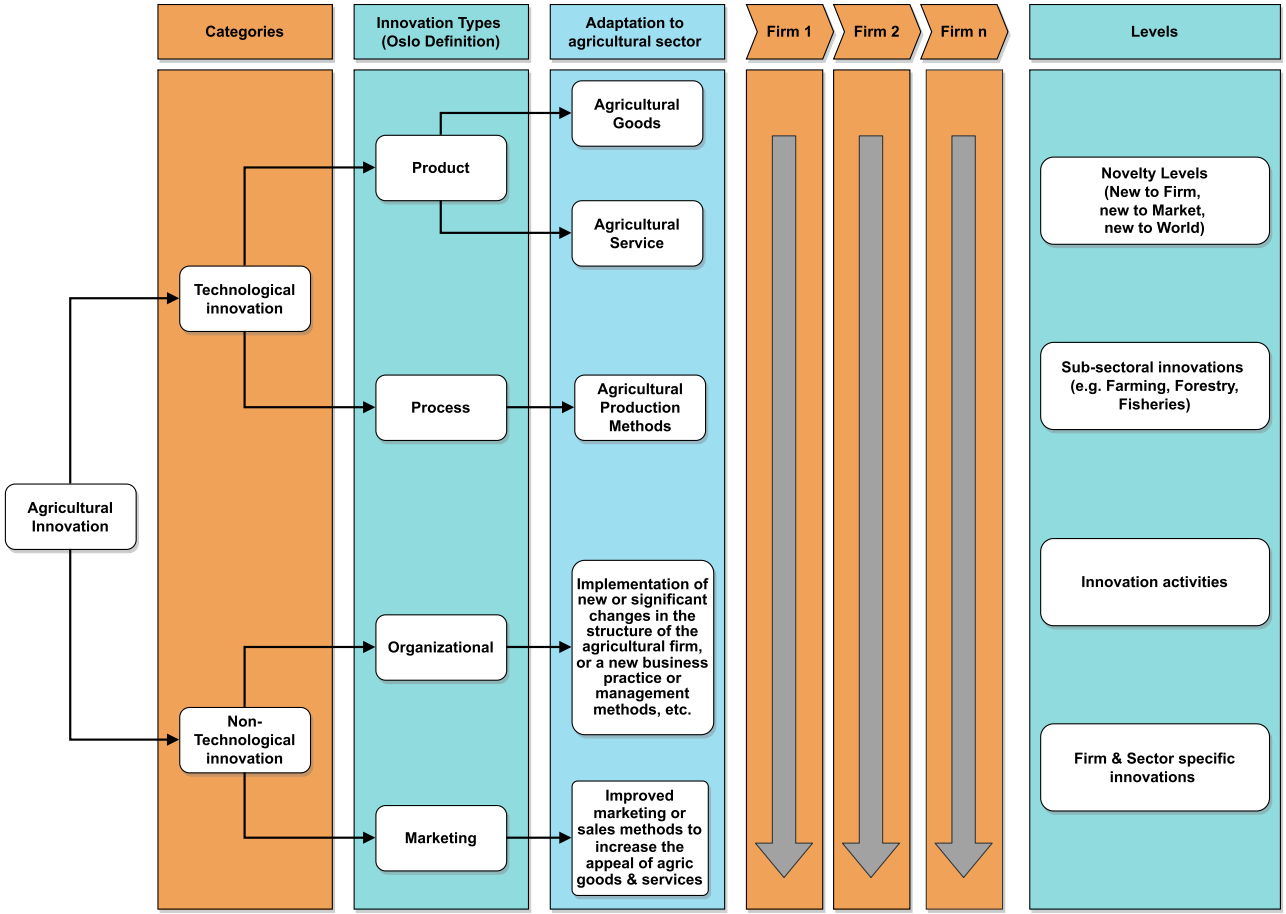

Figure 1: Conceptual framework for measurement of innovation in agricultural sector (based on the third and fourth edition of the Oslo Manual 2005, 2018).

defines innovation as: *'The implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations'*.

In the fourth version of the Oslo manual (OM4) (OECD/EuroStat 2018), the concept of innovation was updated to: *'a new or improved product or process (or combination thereof) that differs significantly from the units' previous products or process and that has been made available to potential users (product) or brought into use by the unit (process)'*. In contrast with previous definitions, the new definition is broader, illustrating that what counts as innovation activities are more than simply product and process innovations. This shift reflects an evolution in the models of how innovation occurs, from a technology push linear model, to more complex models of systems and networks. Meissner and Kotsemir (2016) reviewed and categorized models of innovation, their essence, and main proponents, from the 1950s to the present (summarized in Table 1).

Drawing insight from the existing OECD definition of innovation, as well as other conceptualizations and categorizations of innovation, and adapting for the agricultural sector enables us to propose two categories of innovation. These are: a) technological and b) non-technological innovations. These are further divided into four different types of innovation. Technological innovations consist of product and process innovation while non-technological innovation consists of organizational and marketing innovation. The adaptation of these types of innovation to the agricultural sector form the foundation of the conceptual framework for the measurement of innovation in this sector.

The fundamental tenets of the conceptual framework are illustrated in Figure 1.

Product innovation

An agricultural product innovation is defined as the introduction to market of a new or significantly improved good or service with respect to its capabilities. The innovation must be new to the agricultural firm, but does not need to be new to the agricultural sector or market. It does not matter if the innovation was originally developed by the concerned firm or by other firms. Given that the latest terminology from OM4 classifies 'products' as consisting of both 'goods' and 'services', an agricultural good is therefore conceptualized to include commodities or perishable goods such as drought-resistant seeds, new or improved grains, and other types of non-perishable goods such as animal products like milk and cheese or farming objects such as irrigation drones or harvesting robots. An agricultural service, on the other hand, is usually intangible, and may include educational courses or training methods and agricultural consulting.

Process innovation

An agricultural process innovation is the use of new or significantly improved methods for the production or supply of agricultural goods and services. These can include, for example, new or improved processes for animal production, or new farming methods to reduce time and resources, or approaches to reduce greenhouse gas emissions. The innovation (new or improved) must be new to the firm, but it does not need to be new to the agricultural sector or market. It does not matter if the innovation was originally developed by the enterprise in question or by other enterprises.

The primary distinction between Oslo Manual 3 (OECD 2005) and the current fourth edition (Oslo Manual 4) (OECD 2018), centres around the definition of process innovation.

In OM3, there were four types of innovation that businesses introduced namely (1) product (goods and/or services), (2) process innovation, (3) organizational and (4) marketing (Figure 2).

Whereas OM3 separated out process innovations, the current OM4 combines business process innovations to include both process innovations and organizational, as well as marketing innovations as illustrated in Figure 2.

Organizational innovation

An agricultural organizational innovation is the implementation of new or significant changes in the structure of the agricultural firm, a new business practice or management method that is intended to improve the firm's acquisition and use of knowledge, the quality of goods and services, or the efficiency of workflows. These may exclude mergers or acquisitions, even if for the first time.

Marketing innovation

An agricultural marketing innovation is the implementation of new or significantly improved marketing or sales methods to increase the appeal of agricultural goods and services or to enter new markets. Examples include changes in product design or packaging, product placement, product promotion and pricing, but excludes seasonal, regular and other routine changes in marketing methods.

Case study: the measurement of agricultural business innovation in South Africa

The South African case comprises five phases for conducting agricultural innovation measurement, as outlined here. First is the conceptualization phase, which includes identification of the need to measure agricultural innovation and the identification of agricultural indicators and data sources. This informs the second phase, which is the design of measures. This includes the survey design, the sampling process, and the development of the measurement instrument. The first and second phases feed into the third phase, which is the stakeholder consultation. This involves evaluation, assessment and feedback to improve the design of the measures. The fourth phase is the implementation of fieldwork which involves the collection of data. The fifth and final phase is the evaluation, analysis, reporting and dissemination of findings.

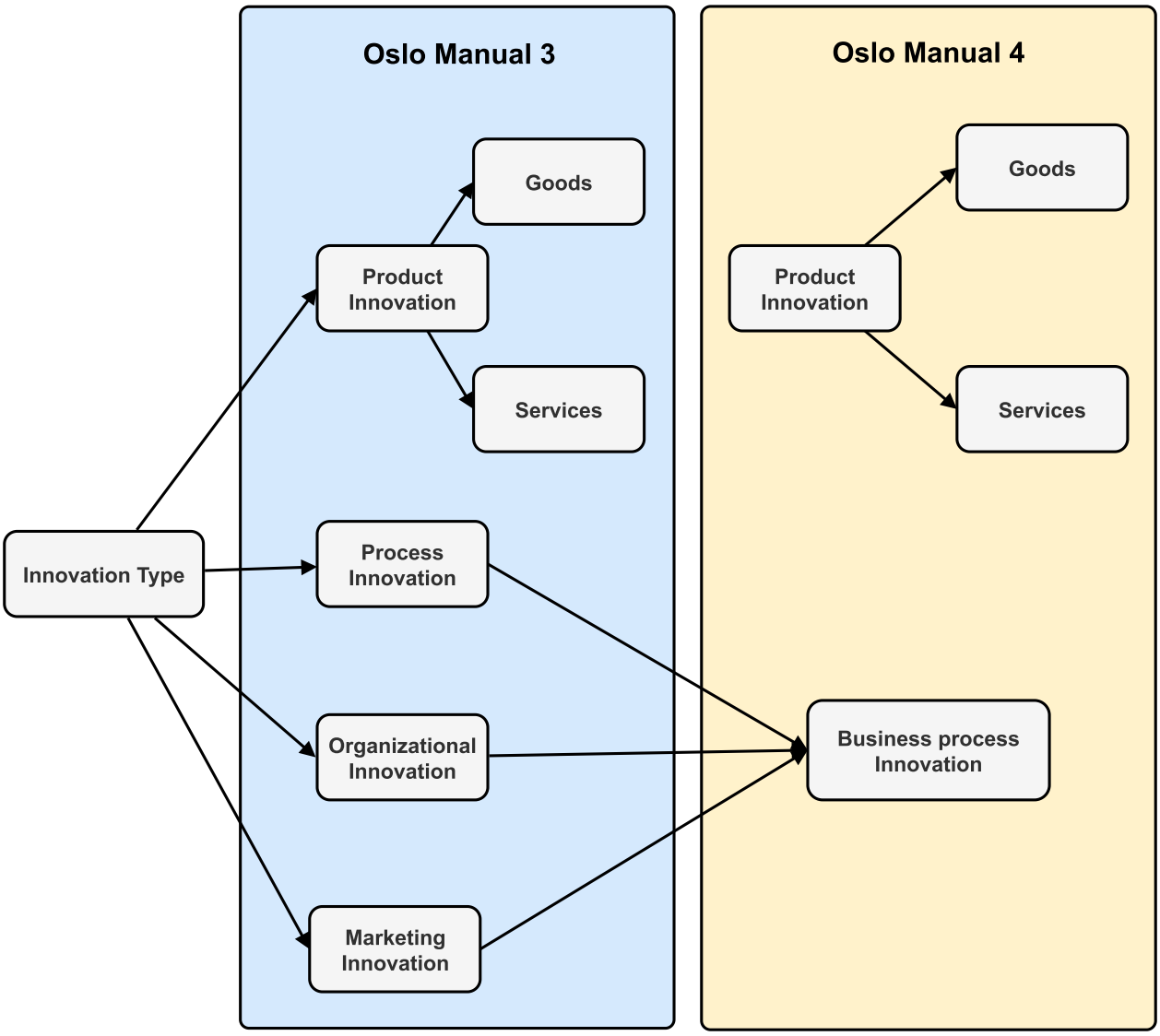

Figure 2: Simplification from four innovation types in OM3 to only two types in OM4.

Phase 1: Conceptualization of measures

The measurement of agricultural innovation in South Africa was conceptualized following the consideration of precedents to measure innovation in the agricultural sector in countries of the global south, particularly countries in Latin America (E.g. Ariza et al. (2013)).

The Colombian approach was developed based on the Oslo Manual classification of innovation by type as product, process, organizational and/or marketing. The purpose was to better understand the complex patterns of innovation behaviour by agricultural enterprises, given that agricultural goods or services and processes cut across multiple sectors. South Africa adopted and adapted some elements of the analytical framework developed by Ariza et al. (2013) which was largely based on the Oslo Manual (OECD/Eurostat 2005) that allowed for the profiling of agricultural innovations spread across multiple sub-sectors. The South African Business Innovation Survey has, so far, followed the methodological guidelines of the first edition of the Oslo Manual which focused on the manufacturing sector, and the second and third editions which added the manufacturing sector and the services sector, but which largely excluded the agriculture sector.

The study sought to answer these fundamental policy questions:

1. How and why do South African agricultural enterprises innovate?
2. What facilitates innovation in agricultural enterprises?
3. How do agricultural enterprises benefit from innovation?
4. What constrains innovation in agricultural enterprises?

These questions facilitated the design of the research study that helped to close existing data gaps and provide a critical review of innovation in the South African agricultural sector.

Phase 2: Design of measures and indicators

To construct indicators of potentially innovative firms, measurement instruments need to take into account all enterprises i.e., both innovation-active enterprises and enterprises without innovation activity. This aims to address the main issues related to innovation strategies,

Table 2: Enterprises per SIC stratum on AGRIBIS sampling frame and sample.

	Agriculture (SIC 11)	Forestry (SIC 12)	Fisheries (SIC 13)	Total
Frame size	7090	252	346	7688
Sample size	1514	95	81	1690

such as innovation capabilities, linkages and outcomes (OECD/Eurostat 2005).

Survey design

The proposed agricultural business innovation survey indicators were adapted from the standard indicators for the sub-Saharan African context. These are strongly shaped by the standard indicators in the Community Innovation Surveys (CIS) questionnaire. These include type of innovation, how firms innovate, as well as benefits of innovation. Although innovations were profiled at crop level for Colombian agricultural enterprises, the South African approach was different in that the South African Agricultural Business Innovation Survey 2016–2018 (Agri-BIS) profiled innovations at a higher level of aggregation, for the agriculture, forestry and fisheries sub-sectors. Profiling at crop level was not possible, given that it would require highly detailed information from respondents, increasing the survey burden, and is thus more suited for investigation using a case study approach at a later stage. Therefore, in terms of coverage, the South African Agri-BIS 2016–2018 included three main sub-sectors at the higher level, namely: agriculture (e.g., crop producers, wineries, livestock and poultry), forestry, and fisheries (SIC codes 11, 12 and 13, respectively).

The survey design was further informed by Eurostat Guidelines and the structure of Statistics South Africa's business register. Based on recommendations in the Oslo Manual and Eurostat Guidelines (OECD/Eurostat 2005), businesses to be included in the survey are those with 10 or more employees. In the context of South Africa, this included commercial and smallholder farmers, but not subsistence farmers.

Sampling

Statistics South Africa (Stats SA), the statistics bureau of South Africa, drew a stratified random sample from the universe of agricultural firms, based on sub-sector (SIC 11, 12 or 13) and size class. Given that the Stats SA business register has incomplete information on employment, the specification for size cut-off was based on turnover. This was not ideal, as the Oslo Manual recommends size cut-offs based on employment, but was the best that could be done under the circumstances.

The number of firms in the sample frame was 7090 for SIC 11, 252 for SIC 12 and 346 for SIC 13, respectively (Table 2). A proportionate number of firms was randomly selected for the final sample, resulting in a total sample of 1 690 firms.

The sample drawn by Stats SA contained representative sample sizes of 1514 enterprises for the agriculture sub-sector, 95 for the forestry sub-sector and 81 for the fisheries sub-sector. Agri-food enterprises (food, beverages and tobacco) fall under the manufacturing sector (SIC 3) which is covered by South Africa's main business innovation survey (BIS), with the latest survey round covering the period 2014–2016. Hence, agri-food businesses were not included in the Agri-BIS 2016–2018. More importantly, the Agri-BIS 2016–2018 indicators were adapted from the current set of standardized business innovation indicators. The standard CIS-like survey questions were adapted to be more agriculture-specific and relevant (for example, the factors that promote or constrain innovation are distinctive, and new items were designed based on demand).

Measurement instrument

The adapted agricultural business innovation questionnaire sought to gather basic information on a wide range of innovation measures. A substantial portion of the questions were meant to identify the extent to which agricultural companies were innovative, as well as identify their innovation activities. The survey questionnaire was designed to elicit information to compile these indicators. The adaptation of the instrument involved changes, additions and deletions to questions from the main BIS CIS-like questionnaire to make the questionnaire appropriate to measure innovation in the agricultural sector. Table 3 provides a summary of the adaptations made.

Changes to questions included adaptations to make indicators more specific to the agricultural sector, in particular with respect to the effects of innovation, innovation outcomes and factors hampering innovation activities. A key addition was factors that support and promote agricultural innovation. Some items, although relevant, were excluded from the baseline agricultural innovation survey, as they are currently not high priorities. This included sources of cooperation for innovation activities. Open-ended questions were included to elicit information on specific innovations within an agricultural firm.

Phase 3: Stakeholder consultation

From the outset, the South African Agricultural Business Innovation Survey 2016–2018 drew on a wealth of expertise and experience from multiple stakeholders in South Africa's agricultural sector, including partners in government, universities, public research institutes, industry associations and agricultural bodies. In its execution, the South African measurement of agricultural innovation study supplemented stakeholder knowledge and ideas by assessing previous research studies on agricultural innovation systems from other countries. By working closely with these groups at all stages of the research cycle, including research design, data analysis, and

Table 3: Example of adaptation of main business innovation survey to agricultural sector.

Indicator	Questions in BIS (Based on CIS)	Adaptations for Agricultural BIS	Comment
Product innovation (goods or services)	• Entirely new products (goods or services) • Significantly improved products • Responsibility for development of firm's product innovations • Main origin of product innovations (South Africa or abroad) • Novelty of product innovations and breakdown of turnover by product novelty level (new to the market, only new to the firm, new to the world)	We adapted the question to refer to an 'agricultural firm' as opposed to an 'enterprise'. The content of the questions did not change. The questions were rearranged from Q2 in BIS to Q3 to Agri-BIS.	The novelty levels (i.e., new to the market, new to the firm, new to the world) were used in the profiling of the technological levels of agricultural innovations. The classifications were used to profile the innovations due to the diversity of the agricultural products and frequency of innovations. The profiling also applied to other types of innovations, i.e., process, organizational and marketing innovations.
Process innovation	New or significantly improved manufacturing/production methods New or significantly improved logistics, delivery or distribution methods for goods or services New or significantly improved supporting activities for processes Responsibility for development of firm's process innovations Main origin of product innovations (South Africa or abroad)	This question was changed to ask whether the agricultural firms introduced new or improved processes to improve: (1) yields; (2) reduce production and/or distribution costs; etc. The question was followed up by allowing firms to briefly describe examples of these new or improved processes.	In the original BIS, the question on process innovation was specific to manufacturing and services. Hence, the question was adapted to the agricultural sector.
Organizational innovations	New or significantly improved business practice Major changes to the organization of work within the enterprise New or significant changes in the external relations with other firms or public institutions Effects of organizational innovations	This question was adapted to elucidate whether the agricultural firms introduced new or improved organizational and marketing innovations.	In the original BIS, the question on organizational and marketing innovations was specific to manufacturing and services. Hence, the question was changed/ adapted for the agricultural sector.
Marketing innovations	Significant changes to the design or packaging of a good or service New or significantly changed sales or distribution methods New media or techniques for good or service promotion New methods for good or service placement or sales channels New methods of pricing goods or services	This question was adapted to elucidate whether the agricultural firms introduced new or improved marketing innovations.	In the original BIS, the question on organizational and marketing innovations was specific to manufacturing and services. Hence, the question was changed/ adapted for the agricultural sector.

dissemination, the survey aimed to be inclusive of and responsive to the needs of the sector.

Phase 4: Implementation of fieldwork

Data collection process

To reduce the costs and time associated with running the survey, the survey design followed this approach:

1. An online questionnaire using REDCap, an online survey tool, was administered with at least two telephonic contacts and two written communications made (follow up was by e-mail, with postal administration on request).
2. Use of an electronic questionnaire in Adobe PDF or a paper questionnaire sent via the postal service, where required or requested by the respondent. Such requests are expected to be small in number, as it is assumed that most respondents can access the online questionnaire.
3. Conduct of a non-response survey, if the response rate is below 70%, with these results used to adjust the sample weights for potential bias due to non-response.
4. Extrapolation of the sample results to the target population based on the weighted sample.

It was necessary to take into account the unique nature of agricultural businesses, particularly within the production sector. It was recognized that most work in the production sector is not office based. Therefore, in certain situations it was difficult to directly reach a potential respondent to complete the survey questionnaire (SQ) simply because these respondents spend most of their time on the farm. To address this, it was necessary for the designation and targeting of both a contact person and a designated person. The contact person being a personnel member based in the office, such as the personal assistant to the person designated to respond to the survey, human resources or administration staff. Ultimately, however, the designated person in most cases completed the survey. The contact person was

responsible for receiving and passing on the questionnaire to the designated person.

As indicated earlier, the initial sample obtained from Stats SA contained 1690 enterprises. A process of sample cleaning identified 364 enterprises as invalid. In particular, these were enterprises that were not identifiable or traceable through several methods, duplicates or inactive enterprises. Invalid enterprises were excluded from the original sample, resulting in a final survey sample of 1326 enterprises. In a difficult business climate, a total of 303 enterprises responded to the survey over a short and intensive fieldwork period of three months.

Use of digital tools

Survey responses were achieved using online digital tools to conduct data collection. In particular, the online software Mailchimp was used to dispatch and direct potential respondents to either the online questionnaire, created using the REDCap survey tool licensed by Vanderbilt University to the South African Human Sciences Research Council, or to a downloadable Adobe PDF form (with English and Afrikaans translations available). Mailchimp and REDCap were also used to monitor the status of the questionnaires, including whether an agricultural enterprise had opened the email, or whether responses to the questionnaire had been attempted or completed. This enabled an informed, targeted, and efficient fieldwork follow-up strategy.

Non-response survey

A simple random sample non-response survey, covering 15% of all the enterprises that did not respond to the survey, was conducted, with 10% recommended by the Oslo Manual (OECD 2005; 2018) for surveys that achieve response rates of less than 70%. The purpose of the non-response survey was to correct for bias that might arise should enterprises that did not respond to the survey, be less or more innovative than the enterprises that responded. The non-response survey covered 117 enterprises, and a response rate of 74.3% was achieved.

The correction for bias due to non-response was implemented by adjusting the probability weights used to extrapolate the sample results to the target population of enterprises. This weights-adjusting methodology also adjusts for invalid enterprises (those found to have merged or liquidated). The results from the survey were then extrapolated to the target population of South African enterprises in the three sub-sectors of agriculture, forestry and fisheries, and size classes of large, medium, small and very small enterprises.

Phase 5: Evaluation and reporting

Once the study was completed, a report was drafted providing a high-level profile analysis of the state of innovation in South Africa's agricultural sector, including forestry and fisheries. The main aim of the report was to contribute to understanding how South Africa's agricultural businesses innovate to remain competitive and sustainable. It also aimed to inform evidence-based policymaking with respect to South Africa's agricultural innovation system. As such, the report presented data about key questions that face agricultural enterprises with respect to innovation.

The survey results indicated that South African agricultural enterprises were innovative, though most innovations are incremental rather than radical. Most agricultural enterprises indicated that they were more involved in technological innovations (product and process innovations) than non-technological innovations (organizational and marketing). Overall, most agricultural enterprises performed process innovations above any other type of innovation. Of the enterprises that reported technological innovations, 42.2% implemented product innovations, while 47.9% implemented process innovations. Among agricultural enterprises that implemented non-technological innovations, 32.3% implemented organizational innovations, while 31.4% implemented marketing innovations.

Conclusion

The conceptual framework presented in this paper builds fundamentally on the existing innovation measurement frameworks from the OECD/Eurostat (2005; 2018), adapting these for the agricultural sector in developing countries. The underlying logic that informs the conceptual framework is that the measurement of innovation within the agricultural sector is subject to a wide range of complexities and challenges, identifying and indicating innovation dynamics present in the sector. As a result of the shortage of studies on the measurement of agricultural innovation in developing countries, primarily due to the limitations, complexities and challenges of measurement in the sector, the need for a new measurement approach, particularly for developing countries in sub-Saharan Africa, is essential.

Therefore, this study provides a conceptual framework which can be used as a roadmap to measure agricultural innovation in developing countries. The paper also provides a practical example from South Africa, including logical and methodological guidelines for innovation studies scholars who wish to measure innovation within the agricultural sector (including forestry and fisheries). The application of the methodology in the South African example shows logical patterns and trends of innovation behaviour for agricultural enterprises in a developing country context. The paper thus contributes to understanding the complexities and dynamics of innovation in the agricultural sector.

Finally, the conceptual framework presented is designed as a guiding tool for innovation scholars and allows for systematic investigation of innovation with respect to the main categories and types of innovations that exist in the agricultural sector, i.e., product, process, organizational and marketing. Due to the limited measurement approaches for developing countries, the proposed conceptual framework is not exhaustive and can be considered as a foundation for the further development of new measurement approaches, and is open for further strengthening and adaptation to other agricultural subsectors and contexts.

Policy implications

From a policy perspective, measurement insights can help policymakers set innovation targets, and develop policy instruments to improve innovation in the agricultural sector, especially since these are largely excluded by the main business innovation measurement framework: the Oslo Manual. More specifically, evidence from the measurement of agricultural innovation can help address critical policy questions related to the state, characteristics of innovation, and the innovation behaviour of agricultural businesses in developing countries. Understanding such characteristics and patterns of innovation provides a basis for policymakers to effectively design and target specific policy interventions. Finally, insights into the state of innovation in the sector provide direct feedback about the successes and failures of policy instruments and initiatives aimed at stimulating innovation in the agricultural sector in developing sub-Saharan African countries. This can contribute to the alleviation of food insecurity and economic growth, amidst the negative impact of the COVID-19 pandemic.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID iD

Yasser Buchana http://orcid.org/0000-0002-0894-2575

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