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Innovation Indicators: for a critical reflection on their use in Low- and Middle-Income Countries (LMICs)

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Innovation Indicators: for a critical reflection on their use in Low- and Middle-Income Countries (LMICs)[1]

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Abstract

It has been widely recognized that innovation is an important driver of economic growth. Many Low- and Middle-Income Countries (LMICs) have adopted innovation indicators to monitor innovation performance and to evaluate the impact of innovation policies. This paper argues that innovation indicators should be customized to the different socio-economic structures of LMICs. For this, the definition of innovation needs to be relevant to the multitude of innovation actors and processes in LMICs. LMICs also need to build competences not only in the construction of innovation indicators within their statistical systems, but also in the use of these indicators by among others policy makers. Especially as the fourth edition of the Oslo Manual (OM 2018) has broadened the scope of "innovation", opening up policy space for LMICs to accommodate the diversity in their national systems of innovation and to develop accompanying innovation indicators.

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1. Introduction

Innovation indicators are increasingly being used to inform the Science, Technology and Innovation (STI) policy making process in LMICs[2]. The proliferation of innovation indicators is generally perceived as good news, as these indicators can theoretically be used to guide the design of effective innovation policies (UNCTAD, 2010). This also has particular importance, as

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[2] The UNESCO Institute for Statistics (UIS) has carried out two global data collections on innovation indicators. The 2013 data collection covered 28 LMICs (UNESO-UIS, 2015), with the number of LMICs increasing to 32 in the 2015 data collection (UNESO-UIS, 2017).

activities of implementing STI (e.g. inventing medicines, improved seeds etc) can help to achieve the UN's Sustainable Development Goals. Enhancing STI capability for all population is critical, in this context, so that no one is ‘left behind’ from enjoying the fruits of progress (UNESCO, 2015, UN, 2015). Innovation indicators, therefore, play a pivotal role in identifying and monitoring developmental challenges.

Several factors have facilitated the rapid uptake of innovation indicators in LMICs. To start with, international and supranational organizations, as well as public agencies[3], have increased the number of innovation indicators available for LMICs (Gault, 2010, UNCTAD, 2010, UNESCO-IUS, 2012). Increasing data availability is accompanied by improved data access and ICT infrastructure in LMICs. These developments are reinforced by the recognition that STI activities can generate economic gains through enhanced productivity and support sustainable development among LMICs. The pervasiveness of new technologies (e.g. artificial intelligence, internet of things etc) in Industry 4.0 also creates an urgency for policies to encourage STI activities in LMICs. Moreover, STI indicators can assist the general trend of public policy towards ‘evidence based’ approaches to the decision-making process (OECD, 2012).

Despite its growing popularity, there seems to be a gap in understanding between realities of LMICs and an understanding of how existing STI indicators can support policy. Due to rapid and increased access to innovation indicators, some indicators are used or interpreted in the wrong context due to a lack of profound background knowledge. Typical examples of such are discussed in section 4 for different types of innovation indicators. The capacity to use innovation indicators correctly would benefit greatly the understanding of a country’s status on innovation benchmarked with comparative variables.

Innovation, through providing solutions to societal challenges, plays a critical role in sustainable development in LMICs. To ensure that indicators can effectively support the policy agenda in LMICs, a close examination on what indicators do is very much needed. The research question for this paper hence is: How to use (and not use) existing innovation indicators to support the policy goals of LMICs?

[3] Includes organizations such as OECD, European Union (EU), Inter-American Development Bank (IDB), African Union (AU), UNESCO Institute for Statistics (UIS), WIPO and World Bank, as well as regional organizations such as RICYT, AOSTI among others. These organizations have disseminated manuals and methodologies for measuring innovation.

Section 2 describes existing innovation indicators, their desirable properties, their relevance to measuring innovation, and their generic shortcomings. Section 3 describes possible challenges in the use of specific types of innovation indicators in LMICs. Section 4 provides illustrative examples for the issues discussed in section 3. Section 5 discusses the future prospects in using innovation indicators for policy making in LMICs.

2. Which innovation indicators are currently available?

2.1 Different types of innovation

This paper adopts the Oslo Manual definition of innovation, which defines innovation as follows: "An innovation is a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)"(OECD/EURSOTAT, 2018, p32 1.25). This new definition has introduced minor but significant changes in the meaning of innovation that has deeper implications to innovation in LMICs. The new definition does not limit innovation to be introduced to the market. It opens up to innovations that are being used by anyone regardless of sector, informality and high R&D contents, which can be created, traded, sold, and even shared among users. Such broad notion of the new definition creates new space for LMICs to explore on their policy relevant STI indicators.

There are three types of commonly used indicators of relevance to innovation in policy discussions. These are: 1) Science and Technology (S&T) indicators that measure different inputs, throughputs and outputs in relation to innovation processes, 2) indicators derived from surveys that cover innovation activities, outputs and outcomes of innovation by firms and other economically relevant units such as households, universities and government entities, and 3) indicators for framework conditions that support the ability of economic units to invest in and benefit from innovation. Among others, these include indicators for political and regulatory environments, infrastructure, and market conditions. Each indicator has distinctive characteristics, data collection methods and sources of data, and covers different aspects of the innovation process.

Innovation indicators should meet a number of desirable properties. In 2010 the European Commission, as part of a project to develop a new headline indicator for innovation, identified the following desirable properties (European Commission, 2010) of an indicator: 1) simple and understandable, 2) sizable and direct (i.e. they should measure a significant part of what is intended to be measured), 3) objective (with a preference for statistical data and survey data collected from well-informed respondents), 4) presently computable, i.e. data should be available to calculate these indicators, 5) stable, such that the indicator is useful and its interpretation does not change over time, 6) internationally comparable, 7) decomposable (indicators should be translatable into policy targets), 8) low susceptibility to manipulation, 9) easy to handle technically, and 10) sensitive to stakeholders' views.

Although it is almost impossible for a single indicator to meet all desirable properties, it is essential to critically evaluate existing indicators for LMICs on each of these properties, as the properties of an indicator could differ between HICs and LMICs.

(1) Science and Technology (S&T) indicators

S&T indicators measure activities concerning 'knowledge generation, diffusion and transfer', which are considered as central activities or inputs to innovation. Examples of such indicators include resources (both in terms of money and human capital) allocated to R&D, publications, citations, patents, and Human Resources in Science and Technology (HRST). These are not direct measures of innovation activities, but a strong association between these indicators and knowledge generation is well recognized. Strong performance on these indicators is considered as an important pre-condition for innovation, particularly in endogenous growth theory where innovations are derived from R&D (Aghion and Howitt, 1992, Grossman and Helpman, 1994, Romer, 1990). Although the endogenous growth approach mainly uses R&D and human capital, of the latter measuring knowledge, to explain economic growth, in relation to innovation, knowledge has much broader connotations and implications such as "social capacity" (Abramovitz, 1986),"absorptive capability" (Cohen and Levinthal, 1990) and "technological capability" (Bell and Pavitt, 1993) among others.

(2) Innovation surveys to understand firm behaviour

The endogenous theory of innovation (Aghion and Howitt, 1992, Grossman and Helpman, 1994, Romer, 1990) focused on the importance of science-based technology in economic development, but also recognized the importance of firm activities and behaviour –via opening up the Blackbox– to better explain economic performance. This contribution has stimulated the importance of understanding firm level innovation and needs for firm level surveys. Innovation surveys have been used on a consistent basis since 1992 with the publication of the first Oslo Manual. However, there were a series of firm level innovation surveys being conducted to understand innovative activities that predate the Oslo Manual[4] and even endogenous theory of innovation (Arundel and Smith, 2013).

OECD countries have been conducting multiple rounds of innovation surveys. In Europe, the survey is known as the Community Innovation Survey, which is co-ordinated by Eurostat, the statistical office of the European Union. Member states of the European Union are legally required to implement the harmonized Community Innovation Survey (CIS), using a range of identical questions of relevance to innovation policies to incentivize firms' innovation activities. Innovation surveys, following the guidelines in the third edition of the Oslo Manual, have been conducted to collect the following information (Mairesse and Mohnen, 2010: 6):

- Innovation outputs such as the introduction of new products and new business processes (including organizational changes and marketing innovations) and innovation outcomes such as the share of sales from new products;

- Innovation expenditures on activities other than R&D, such as the acquisition of patents and licenses, product design, personnel training, trial production, and market analysis;

- Information about innovation inputs and activities, such as different sources of knowledge, innovation drivers, the use of collaboration, and perceived obstacles to innovation.

This information sharpens the understanding of how firms use knowledge and the factors that influence how knowledge is used. With the introduction of the fourth edition of the Oslo Manual (Cf. Box 1 for a discussion on the changes introduced compared to the third edition of the Oslo Manual), only two types of innovations remain: product innovations and business process innovations. Future innovation surveys will thus no longer collect separate data on organisational and marketing innovations as these are now integrated in business process innovations. For the EU Member States this change will take effect from the 2018 edition of the CIS onwards.

[4] These started in the 1950s in form of Object based innovation survey, by Arthur D. Little (1963), Carter and Williams (1957), De Bresson and Murray (1984), IIT Research Institute (1968), Myers and Marquis (1969), Pavitt et al. (1987), Townsend (1981). These are based on the object approach of measuring innovation focusing on the phenomenon of interest instead of on the actors that are responsible for the phenomenon (the subject approach). The focus changed to the subject approach after 1984 (see the discussion in Arundel and Smith, 2013).

Box 1 Oslo Manual 2018 edition

Several changes have been made in the 2018 edition of the Oslo Manual (OM 2018) that may have implications understanding the innovation process in general and in particular in LMICs:

1) The definition of innovation was changed to *"new or improved product or process that differs significantly from the unit's previous product or process and that* ***has been made available to potential users or brought into use by the unit (process)"*** (OECD/EURSTAT, 2018:32). Loosening the definition of innovation from "introduction to the market" to "made available to potential users or brought into use by the unit" opens the avenue for measuring non-market mediating innovations, such as innovation in or by the informal sector, public sector, or household sector, but also for measuring innovations provided for free to consumers by enterprises (e.g. apps or Facebook).
2) The types of innovation have been reduced to two:
    - "A **product innovation** is a new or improved good or service that differs significantly from the firm's previous goods or services and that has been introduced on the market." (OECD/EUROSTAT, 2018:70)
    - "A **business process innovation** is a new or improved business process for one or more business functions that differs significantly from the firm's previous business process and that has been brought into use by the firm. "(OECD/EUROSTAT, 2018:72).

The OM 2018, as the previous OM 2005, also includes a granular firm distinction distinguishing "innovative firms" from "non-innovative firms":

- *"An* ***innovative firm*** *reports one or more innovations within the observation period."*
- *"An* ***innovation-active firm*** *is engaged at some time during the observation period in one or more activities to develop or implement new or improved products or business processes for an intended use.".*
- *A "****non-innovative firm*** *is innovation active if it had one or more ongoing suspended, abandoned or completed innovation activities that did not result in an innovation during the observation period. "*

Differentiating between different types of innovating firms is relevant as it helps policy makers to design policies targeting firms with different innovation strategies. Building on the work by Arundel and Hollanders (2005), who used innovation firm-level data to differentiate innovative firms into four mutually exclusive groups with different innovation activities across European countries and sectors, a recent initiative by Eurostat developed 6 'innovation profiles' differentiating between different types of innovating firms by taking use of the more advanced survey questions in the revised 2018 CIS survey, which already adopted the recommendations from OM 2018, emphasizing the importance of different strategies for firms to innovate (Eurostat, 2019a).

Furthermore, OM 2018 included a suggestive inclusion of System of National Account (SNA) to expand the coverage to all sectors of the economy.[5] The process is initiated by aligning the definitions of different sectors of innovation while reflecting the emerging innovation literature in respective sectors (public sector, users, social among others); not all entities active in SNA are currently covered in the innovation survey and the methodology is underdeveloped, and expanding the scope in the Oslo Manual may accelerate research. The broader scope of innovation included in OM 2018 allows adjusting indicators and their usage to diverse contexts in which economies operate, including those of LMICs.

(3) Framework indicators for innovation

S&T indicators signal the presence of knowledge and the resources spent on knowledge creation processes, while survey data on innovation capture innovation behaviours at the level of the firm or other economic units. These alone are insufficient in explaining the differences in innovation performance among different countries. Underlying systemic elements such as institutional, historical, and infrastructural conditions also contribute to overall innovation performance (Freeman, 1987, Lundvall, 1992, Nelson, 1991). Several attempts have been made to capture the evolutionary and dynamic aspects of countries' capacities to generate innovations; however, it has been difficult to collect data that are reliable and comparable on a periodic basis, in particular

[5] Specifically, SNA classifies economic activities by the following 4 institutions: 1) Corporate sector (business sector: those involved in the production of market goods and services; incline with the definition of firms in Frascati Manual): 2) General government including political and regulatory responsibilities, redistribute income and wealth and product services and goods for individual or collective consumption on non-market basis. Includes non-profit institutions controlled by government; 3) NPISHs: Legal entities engaged in the production of non-market services for households or the community at large and whose main resource is from voluntary contributions (if controlled by government, part of general government, if controlled by firms, part of business enterprise sector); and 4) Households, these are institutions consisting of more than one individual. Households supply labour and undertake final consumption and, as entrepreneur, produce market goods and services (p.51, 2.43, Oslo Manual 2018) (OECD/EUROSTAT, 2018).

in LMICs (Castellacci and Natera, 2015, Fagerberg and Srholec, 2008). Existing measurement frameworks for monitoring and benchmarking the innovation performance of countries usually also capture indicators measuring framework conditions. The European Innovation Scoreboard (European Commission, 2019), which provides an annual comparative analysis of innovation performance in EU countries, other European countries, and regional neighbours, distinguishes between three framework conditions. The 'Human resources' dimension measures the availability of a high-skilled and educated workforce. 'Attractive research systems' measures the international competitiveness of the science base by focusing on the number and quality of scientific publications. 'Innovation-friendly environment' captures the environment in which enterprises operate and includes broadband penetration among enterprises and the degree to which individuals pursue entrepreneurial activities as they see new opportunities. Other reports, like the Global Innovation Index (Cornell University, INSEAD, and WIPO 2019) include a larger number of indicators measuring framework conditions, using 29 indicators to measure countries' performance on 'Institutions', 'Human capital & research', and 'Infrastructure'. The indicators are usually compiled using data from official data sources, including among other UN organisations and the World Bank.

2.2 Composite indicators

Composite indicators summarize a wide range of factors that contribute to innovation performance. The use of composite indicators to measure innovation capacity is relatively recent but is rapidly increasing. These indicators are usually publicly available at a low cost and in comparable formats that can be used to benchmark a country with other countries. Composite indicators summarize complex ideas into a simple format and are consequently considered by policy makers to be an excellent communication tool (Saltelli, 2007). Ranking tables produced by composite indicators have the power to mobilize the policy agenda. E.g. both the European Innovation Scoreboard (European Commission 2019) and the Global Innovation Index (Cornell University, INSEAD, and WIPO 2019) construct a composite innovation index used for comparing countries' current performance and in the European Innovation Scoreboard these are also used to compare performance over time. The advantage of using composite indicators is that countries can also be monitored if data for several indicators are not available by using the average of the indicators for which data are available. As long as the number of missing data is not too big, composite indicators can overcome the problem of unavailable data, in particular for LMICs.

2.3 The coverage of different types of innovation indicators

Here we focus on S&T, innovation survey and composite indicators only, as indicators measuring framework conditions are broader and will also facilitate other activities. S&T indicators cover mainly the areas of knowledge activities that take place in knowledge creation, diffusion and transfer. Innovation survey indicators cover the interaction of firms and knowledge (acquisition of patents and licences, product design, personnel training etc.), as well as outputs of the innovation system (product, business process) at the firm level, and measure innovation and interaction of firms. Composite indicators illustrate the performance of innovation systems as a whole, by defining dimensions and normalizing each dimension in accordance to its design principle, based on a common understanding of innovation. The three types of indicators describe different aspects of the innovation system. These aspects are not mutually exclusive, but rather complementary.

2.4 Generic shortcomings of innovation indicators for policy use

(1) Science and Technology (S&T) indicators

The interpretation of S&T indicators often assumes that "more is always better". However, as the sectoral composition of the economy differs across countries, the appropriate level of S&T activities also varies. Differences in knowledge intensity across sectors demand different levels of R&D expenditures, number of researchers as well as patents and publications. For instance, the pharmaceutical sector tends to require high R&D and patent intensities compared to most other sectors, and therefore countries with a large pharmaceutical sector will almost automatically have higher performance scores on many S&T indicators (Foray and Hollanders, 2015). There are, therefore, no prescribed targets for a country as capability levels, sectoral composition and framework conditions all differ. This means that a country should identify the appropriate level of S&T for reaching its developmental goals. S&T indicators, by relying on traditional indicators as R&D and patents, many miss out on "innovation" activities which are the outcome of non-R&D based innovation (Huang et al, 2010).

(2) Innovation surveys

Difficulties in country level comparison

Innovation surveys ask respondents in a firm about the firm's innovation activities. There is a risk that the answers to the survey are biased by the respondent's perceptions (Gault, 2010), which can vary by country due to cultural differences in how questions are interpreted. These biases do not create large differences within a country; however, it may result in less accurate international comparisons. Some of the difficulties in using the data from innovation surveys for policy purposes stem from possible bias and methodological differences across countries in how data are collected. For example, technical factors can influence the quality and comparability of survey data, such as differences in sampling frames (census versus sample), sampling methods (how the sample is selected and the type of respondent), minimum size cut-off levels, data collection methods (online, postal or face to face), and sector coverage (many LMICs only survey their manufacturing sector) (UNESCO-UIS, 2012). Diversity in the way data is collected makes comparing results difficult across countries, though it is possible to benchmark across periods if the methodology used for collecting the data is the same. Also, the sample coverage may limit generalizability to the whole economy, for instance if important economic sectors are not included in the survey (e.g. agriculture, mining and informal sectors in LMICs).

Time lag and communication

There is usually a substantial time lag in processing survey data, such that the results may not be recent enough for conducting policy relevant analyses. A Latin American study found that a lack of timeliness reduces the interest of policy makers in using innovation survey data (details in section 3.2 (2)).

Within European countries, the time needed to collect and process innovation survey data ranges from less than one year to almost 1.5 years for different countries. In addition, it can take up to another 6 months before the tabulated data are released for all countries by Eurostat. Time lags can be improved by using provisional innovation survey data, as done for the CIS indicators used in the European Innovation Scoreboard (EIS). As part of a forward-looking exercise, European statistical offices shared provisional CIS data on the share of different types of innovators about ten months before the final data were released by Eurostat. An evaluation in the EIS 2017 report on the use of provisional CIS data found that there was hardly any difference between the provisional and final data for most countries (EUROSTAT, 2019b).

(3) Composite indicators for innovation

The selection of indicators to construct a composite indicator is based on a combination of innovation theory (what matters) and data availability. There are several limitations in using composite indicators for policy design and evaluation. First, the selection of the indicators depends on a specific theoretical framework for innovation and data availability. Different theoretical frameworks can produce different results, or they could be inappropriate for a specific country, due to differences in framework conditions (OECD/JRC, 2008). Second, it is not always clear why the indicators included in the composite indicator were selected or how they are defined (e.g. Schibany and Streicher, 2008). For example, opinion survey data are often subjective, as when a small number of experts are asked their opinions on a number of national characteristics, such as an 'entrepreneurial attitude'. Opinion survey data, for instance from the World Economic Forum's Executive Opinion Survey, are used in the Global Innovation Index and the Global Competitiveness Report. The cross-country comparability of opinion survey data is questionable, as answers are more likely to reflect perception and satisfaction relative to expectations (Hollanders and Janz, 2013). By themselves, composite indicators are not considered sufficient as a basis for policy design and evaluation, which requires using the original data behind the composite indicators or other sources of data on innovation (OECD/JRC, 2008).

3. Particular problems of using innovation indicators for LMICs

3.1 Diversity of LMICs

LMICs comprise a diverse set of countries ranging from OECD new member countries (e.g. Chile, Estonia, Israel, and Lithuania), new EU member countries (Bulgaria, Croatia and Romania) and EU candidate countries (Albania, Northern Macedonia, Montenegro, Serbia and Turkey), BRICS countries, countries trapped in the middle income range (such as Thailand, Indonesia, Malaysia among others), to low income countries as well as fragile states. The differences between these countries are not limited to economic performance but also geographical conditions (small island, landlocked), size of territory, population, purchasing power, resource endowment, and governance system. All of the above conditions shape the context in which innovation takes place. LMICs may fall in using a "one size fits all" strategy when adopting or using existing innovation indicators to shape their policies. The examples below are from different parts of the world to highlight the features of problems but there are not intended to give complete answers. Besides, the pathways for LMICs are currently considered as diverse precisely for the distinctive nature of context in which economic activities take place (Hidalgo et al, 2007, Lee and Lim, 2001, Lee and Malerba, 2017, Rodrik, 2015, Rodrik et al, 2014). The uncertainties in the direction of future pathways make the correct use of innovation indicators even more important for shaping policies. Certainly, the new definition of innovation in OM 2018 provides sufficient space for flexibility to adjust for countries in different contexts.

3.2 Areas to take into consideration in using indicators for policy making by LMICs

(1) S&T indicators

How to interpret the indicator and how to complement the missing information?

S&T indicators can be used to benchmark performance across countries. However, a comparison in aggregate form hides important details to be examined about the complex process of knowledge creation (Cowan et.al, 2000, Kline and Rosenberg, 1986, Nonaka and Takeuchi, 1995) that are important in unveiling policy issues. In the context of LMICs, S&T indicators may not be sufficient to understand the sources of innovation as most innovations are generated without doing R&D (Huang et al, 2010) and less quantifiable information is available for important economic sectors in LMICs (i.e. agriculture, mining, fishery, forestry, informal sector).

Due to slightly better data availability, many S&T indicators (i.e. R&D, patent, HR in science, publications) have been in use for a longer period of time in LMICs than innovation survey data.

Although these data are considered as inputs for innovation the interpretation of these indicators may differ from that in high-income countries (Sutz, 2012, UNCTAD 2010). For instance, a higher share of firms in LMICs innovate without R&D (Gault, 2010, Huang et al, 2010). Moreover, indicators that signal accumulation of technological capabilities should not be restricted to the traditional S&T indicators. The import of capital goods in the form of machinery and equipment, embodied technology, can equally be an important indicator to understand efforts to invest in enhancing capability upgrading (for example, Crespi and Zuniga, 2012). For some countries, provision of framework indicators that demonstrate the provision of basic infrastructure (such as electricity or road) are more valuable in understanding productivity upgrading and provide better explanations for innovative efforts not taking place in increasing production.

S&T indicators can provide guidance in selecting appropriate innovation policy instruments in LMICs. At the same time, there are also limitations to what the S&T indicators can do, especially due to the stages of technological development as well as sectoral composition in which countries wish to specialize in. At broad level, identifying who are the creators and users of S&T indicators such as publications, patents and number of graduates, can reveal to whom policy needs targeting. For example, innovation incentives targeting firms -such as tax incentives, subsidies and grants- are often used in high income economies to stimulate innovation in firms. The policy measures targeted to firms to conduct R&D may not be applicable in some LMICs where many firms do not perform R&D. For LMICs, a focus on creating enabling conditions for business, e.g. through the provision of infrastructure and human resources for entrepreneurship development, are better policies for stimulating innovation. Alternatively, as higher education and public research institutes generate knowledge, policies to encourage university-industry collaboration and promoting university spin-offs can also be possible measures. Existing S&T indicators can be used to examine policy issues from different perspectives, while new indicators need to be explored to match policy goals. For more specific policies to enhance innovation, more qualitative information may be needed.

Patents are generally seen as an indicator for the development of frontier technology. But this is only true for countries with significant activities in science-based sectors such as pharmaceutical and aerospace industries (Hatzichronoglou, 1997) because research in these sectors is highly patentable. In LMICs, however, the economically important sectors often include agriculture, mining, food, textiles, and services, i.e. sectors where research is not very patentable nor considered important (UNCTAD, 2010, World Economic Forum, 2016). In these sectors, different indicators are needed to signal the development and availability of knowledge, for instance, plant breeders' right, trademarks, design or use of standards. For example, WIPO recently classified patents according to their sector of application, identifying an increase in patents and R&D expenditures by the mining sector and the presence of relatively high shares of resident patents in mineral rich LMICs such as South Africa, Brazil and Chile (Daly et al, 2019). These are important steps in understanding the innovation process in under-researched sectors; however, it is crucial to integrate these ad-hoc studies into the standard collection of STI indicators.

Indicators measuring publications and citations can be biased against research in LMICs which tend to conduct location specific and problem solving research (e.g. local insect control of green tomatoes in one region of Mexico), whereas major scientific journals prefer publications that are more generic and universally applicable (e.g. genetic traits of red tomatoes sold in major supermarket chains). Moreover, many scientific journals publish in English and create a bias against publications in other languages (Rafols et al 2016). In LMICs, publications are occasionally distorted by the presence of globally renowned research institutions or organizations (e.g. funding by the Bill & Melinda Gates Foundation) as we observe in Panama's Smithsonian Tropical Research institute, which produced 63% of all national scientific publications between 1970-2014 (UNESCO, 2015).

(2) Innovation Survey indicators

How to identify who are the right target and how to collect appropriate information?

Innovation survey indicators are considered the most appropriate for measuring innovation processes, as they directly ask firms, the 'performers' of innovation, whether they engage in innovation activities (e.g. by performing R&D, buying advanced machinery used for innovation, or training personnel involved in, the development of new products or processes), whether they introduce specific innovations (different types of products and business processes), their perceived barriers to innovation, and their use of different information sources and collaboration partners. An increasing number of LMICs are taking up innovation surveys, especially since the 1990s. In Latin American countries, the first survey was conducted as early as in the 1980s (Crespi and Peirano, 2007, Gault, 2013, UNESCO-IUS, 2012), while African and Asian countries started to introduce innovation surveys in the 1990s and increasingly in the 2000s (UNU-INTECH, 2004).

Initially, applying Oslo Manual based innovation surveys in LMICs suffered from a misfit to the needs of LMICs. The earlier versions of the Oslo Manual (before Rev.3) did not quite capture the particularities of innovation in LMICs. In the early 2000s, the Bogota Manual (RICYT/OEA/CYTED, 2001) was produced in response to meet the idiosyncrasy of the Latin American innovation processes. The recommendations in the Bogota Manual were later included as an annex of the third revision of the Oslo Manual providing guidelines for the implementation of innovation surveys in developing countries (OECD/Eurostat, 2005).

Implementing an innovation survey is still a complex operation. It can be technically difficult to cover all economically important sectors of its economy of relevance to critical policy questions in LMICs. The economic structures of LMICs are different from those of HICs. High income countries (HICs) initially increased their productivity through innovation in the manufacturing sector and innovation surveys were focused on measuring innovation in manufacturing. Over time, the importance of innovation in some services sectors became recognized and innovation surveys were adapted to also cover the services sector. Some LMICs have important growth in service sectors preceding the manufacturing sector such as India in software (Arora and Athreye, 2002) as well as in Africa (Rodrik, 2015, Rodrik et al, 2014); however, the innovation surveys of LMICs still do not or only partially cover service sectors (UNESCO-UIS, 2012).

Indeed, there is no guarantee that LMICs follow the same development path (i.e. Lee and Lim, 2001, Rodrik et al, 2014, Rodrik, 2015). In fact, many African and Latin American countries have industrial structures with high reliance on natural resources and service sectors, while innovation in these sectors is not sufficiently captured in existing surveys. Some attempts to adapt surveys to the realities of respective countries are done, for instance to cover agriculture in Uruguay and Argentina (Aboal et al., 2015), and the informal sectors in Africa (Charmes, 2016, Charmes et al., 2016, De Beer et al., 2013, Konte and Ndong, 2012), which constitute a considerable part of the economy.

In many African countries, a high proportion of employment is generated by the informal sector (cf. Iizuka et al., 2018). For instance, the informal sector accounts for more than 80% of employment in Burkina Faso (90.5%), Benin (89.6%), Guinea (86.7%), Nigeria (83.4%) and Ghana (80.0%). Though data is limited, the informal sector is generating a substantial share of

GDP in countries such as Niger (72.6%), Togo (72.5%) and Burkina Faso (55.8%). Many of these informal sector activities are to be found in the agricultural sector.

Considering the diversity of LMICs and their developmental pathways, copying questions from existing surveys would not lead to the most policy relevant results. These countries should customize their indicators and surveys to best portray their innovation processes (Tijssen and Hollanders, 2006). The following are possible areas to improve the relevance of an innovation survey to the needs of LMICs:

- Ensure that the industrial coverage reflects the country's economic structure;
- Identify and survey all key performers of innovation, which in addition to firms can include farms, households, the informal sector, universities, public research organizations, government, and NGOs;
- Ensure that the size distribution of the sample population is representative of innovation activity. This could require coverage of LMICs' micro firms with 1 to 9 employees, or firms with 5 to 9 employees;
- Collect data on a range of outputs and innovation activities, including data on different types of innovation (including sub-categories of product and business process innovations), business models, new markets, investment, firm efforts, provisions of infrastructure and firm capabilities to innovate;
- Sources of knowledge: in addition to official sources, expanded to acquisition of capital goods, labour mobility or informal linkages;
- The goals and objectives of innovation to provide useful information for why and how firms innovate.

Innovation in a development context has much broader implications that go beyond productivity increases by firms, but also address the improvement of livelihoods (Chataway et al, 2014; Gault, 2018), which implies needs for extensive coverage involving different innovation agents. This is well in line with the SNA approach suggested by OM 2018.

Apart from possible conceptual mismatches on targets of the survey, there are also technical issues in conducting surveys as this would require fully equipped and capable statistical offices with sufficient resources. Resource constraints are much more serious in LMICs due to competing issues of importance, insufficient provision of business registries to identify firm populations, and low numbers of sufficiently trained and experienced survey experts and statisticians.

There have also been general concerns as to how results from innovation surveys may serve in improving innovation policies. For instance, a report by the Uruguayan National Agency for Research and Innovation (ANII) indicated that among several Latin American countries (Argentina, Chile, Colombia and Uruguay), innovation survey results were neither used in policy instrument design, re-design, monitoring nor evaluation, except for Colombia which used them for designing and re-designing (Baptista et al., 2009). Possible reasons included low timeliness of the data, limited access to the results of the survey, and the legitimacy or acceptance by policy makers. Timeliness is still an important issue in LMICs, but in these countries, there was no clear public access to the survey results, adding to the lack of legitimacy of the survey results. The report suggested that better prior consultation with policy makers is needed to increase the use of results from the survey.

For making innovation survey indicators relevant for LMICs, it is critical to match survey contents, coverage, and survey sampling methods to local needs and context. The timely delivery, providing access to anonymised data to pertinent users, and gaining legitimacy of innovation survey results are critical to be used in policy processes. As stated in the section on S&T indicators, there is still much to be learned about the pattern of innovation processes in LMICs, and a better understanding would help in identifying better indicators that correspond more closely to the policy needs of these countries.

(3) Composite indicators

Increasing availability of composite indicators has expanded the coverage of comparable data on innovation performance among LMICs. These come with ready-made lists of indicators, and policy makers 'just' have to decide which indicators to use. LMICs thus do not necessarily have to conduct their own innovation and R&D surveys and go through the complexity of harmonizing results to make indicators comparable, if the proxy indicators used in these reports provide sufficient information. The use of composite indicators, as a result, has gained huge popularity.

However, composite indicators are less robust because results are influenced easily by the selection of indicators included in the model and the weighting scheme used for calculating the average across all indicators (e.g. Schibany and Streicher, 2008). The problem of incorrectly using composite indicators, stems from an insufficient comprehension of their design and limitations in addressing innovation policy.

(4) Problems of using innovation indicators in LMICs

Many LMICs have started to use innovation indicators. These countries first adopted existing indicators, following methodologies and conceptual frameworks in HICs. As a start, these are steps in the right direction as part of a learning process. However, countries should keep in mind that indicators are made by simplifying complex phenomena, emphasizing only certain aspects as a signal of a larger process (Espeland and Sauder, 2012) and hence have limited power explaining complex realities. Also, indicators do not have any legal power over users though once they have gained legitimacy, they can exert a certain degree of power to create a 'locked in' situation (David, 1985) to shape policy agendas even though these may not be relevant in the new context (Davis et al., 2012, Espeland and Sauder, 2012).

4. Specific examples illustrating the use of innovation indicators

Building on the discussions in previous sections, we illustrate the issues of using innovation indicators in LMICs by discussing how to interpret three examples of typical statements.

4.1 Our innovation performance improved because our ranking in the World Innovation Index raised to 58 from 60

International rankings using composite indicators have advantages in communicating information effectively to mobilize resources to policy purposes. Interpreting relative performance towards other countries and changes over time can be difficult. The global rankings are about relative performance compared across countries included in the ranking table. The average performance is usually constructed by taking the average of a number of indicators, where indicators can measure both relative shares between fixed upper and lower limits (e.g. the share of population with completed tertiary education) and shares which can take on infinite values (e.g. patent applications per population). Indicators also face different distributions, with some indicators being highly skewed. In order to make indicators directly comparable, values are usually recalculated (normalized) so that they are all measured on the same scale and the recalculated data follow a normal distribution. As a result, the composite indicator has no direct real meaning, but rather reflects an index. E.g., a 10% higher index score, as compared to last year, thus does not mean that performance has improved by 10%, as due to the recalculation procedure average performance of the underlying indicators could have increased by less or more than 10%. Even with an unchanged indicator performance, if performance of other countries changes, in particular, that of the best and worst performing country, the recalculated score of the indicator could still change, despite the fact the indicator value itself did not change. A change in a composite indicator has thus to be interpreted with care, as increasing index values do not necessarily imply that the underlying indicators have improved; the increase in the composite indicator could also be the result of a worsened performance of better performing countries.

Similarly, rank changes are difficult to interpret as they hide real performance changes. Improved indicator performance could increase a country's composite indicator value where the increase in the composite thus righteously signals a real improvement in innovation performance. But if, at the same time, performance of close-by ranked countries improves even more, then the country's rank could worsen, even if its innovation performance improves. Rank changes should not thus be interpreted at face value; instead, one should have a closer look at the change in the value of the country's composite indicator and the changes in the scores of the underlying innovation indicators.

4.2 How much R&D expenditure is needed to generate innovation in our country?

The share of R&D in GDP (GERD), the R&D intensity, is often used to set a policy target on R&D spending. For the European Union the target is to spend 3% of GDP on R&D, while many African and Latin American countries have 1% as their intensity target. The R&D intensity tells us how much is spent on investments in research and experimental development, but it is not a measure of innovation. Consequently, R&D will only be translated into more innovation, if other framework conditions are of sufficient quality, e.g. there is a sufficient supply of skilled workers. R&D intensities also differ across industrial activities; countries with different industrial structures will have different ‘optimal’ R&D intensities (OECD, 2011). The OECD provides a classification of industries by their average R&D intensities (Hatzichronoglou, 1997). This categorization has slightly changed recently (OECD, 2011), but overall the principle of associating industrial activities to the level of R&D intensity remains much the same, distinguishing between four types of industries (Table 1).

Table 1 Taxonomy of sectors according to average R&D intensity (%)

	Direct + indirect R&D as a share of production	R&D as a share of production	R&D as a share of value added
High tech industries	> 7.5%	> 7.5%	> 15%
Medium high-tech industries	2.5% −7.5%	1.5% −7.5%	4% −15%
Medium low-tech industries	1% −2.5%	0.5% −1.5%	1.5% −4%
Low tech industries	< 1%	< 0.5%	< 1.5%

Source: Hatzichronoglou, 1997

Countries with higher (lower) shares of high-tech industries are more likely to have a higher (lower) R&D intensity. The optimal R&D intensity can differ due to the industrial structure of a country. Consequently, a 3% or 1% R&D intensity should be taken only as a guideline and not be applied blindly in policy.

For example[6], in 2013, Chile and Uruguay had similar R&D intensities, 0.38% in Chile and 0.32% in Uruguay. The economic structures of Chile and Uruguay are, however, different, with Uruguay having a larger agricultural sector and Chile a much larger mining sector[7]. Within the manufacturing sector there are also differences. High and medium high-tech industries are more prevalent in Chile (17.4% vs. 14.9% in Uruguay), whereas the low and medium low-tech industries are more prevalent in Uruguay (85.2% vs. 82.7% in Chile). Based on the average R&D intensities for different industries (cf. Table 1), one can calculate that Chile is expected to spend 1.4% of GDP on R&D and Uruguay is expected to spend 1.2% of GDP, as compared to actual levels of 0.38% and 0.32%, respectively. The actual figures are substantially lower than what each country is expected to spend given its industrial structure. If these two countries are to increase their R&D expenditures, can policy incentives be the same given that the structures of the economies are different?

[6] The following example uses two HICs as detailed R&D data are unfortunately not available for most LMICs.

[7] The percentage shares in GDP for Uruguay and Chile are respectively: Agriculture, hunting, forestry and fishing (7.6, 3.0), Mining and quarrying (0.5, 11.1), Manufacturing (11.3, 10.8), Public utilities (8.2, 8.4), Construction (9.7, 7.7), Retail and financial services (34.2, 34.3), Public administration (18.9, 16.1), other (9.6, 8.5) in 2013.

Table 2 Differences in funding and performing sectors in total R&D expenditures (%)

	% funded by					% performed by			
	Business	Govern-ment	Higher education	Private Non-Profit	Abroad	Business	Higher education	Govern-ment	Private Non-Profit
Uruguay	10.2	39.8	44.1	0.5	5.4	10.1	44.0	44.0	1.8
Chile	34.5	38.2	11.0	1.2	15.1	35.5	38.8	4.7	21.0

Source: RICYT database

In Uruguay, R&D expenditures are financed mainly by the public sector, including both government and higher education, while in Chile the business sector is almost equally important in funding R&D as the government sector (Table 2). Chile's business sector spends almost as much as the higher education sector. In LMICs, the sources and main performers of R&D are often public rather than business, resulting in different policy implications, as compared to high-income countries. In countries where the private sector is more active in R&D, policies should target the private sector with instruments such as tax incentives, subsidies etc., to boost business R&D expenditures. If the share of R&D is larger in the public sector, the strategy to increase R&D expenditures would need to be preceded with policies to enhance human resources to carry out R&D and investments in public research infrastructures (i.e. laboratories, university and research institutions, administrative capacities to carry out R&D) or to encourage university-industry linkages and promotion of university start-ups.

4.3 Conducting innovation survey would better inform policy makers

There are several initiatives in LMICs with support from international organizations to conduct innovation surveys. For instance, in Africa, under the African Science, Technology and Innovation Indicators (ASTII) initiative, innovation surveys are carried out in 12 countries including Egypt, Gabon, Ghana, Kenya, Lesotho, Mali, Nigeria, Senegal, South Africa, Tanzania, Uganda and Zambia. As the conventional focus of attention for an innovation survey is on manufacturing and those service sectors considered to be highly innovative, even with the perfect implementation of a standardized survey, the results may not help policy makers to fully understand the innovation process of those economic activities not covered in the innovation survey. For instance, some countries, such as Burundi and Ethiopia have a relatively large agricultural sector (41% and 49% of GDP). Furthermore, several countries have a large informal sector (e.g. 90% of GDP in Tanzania, 84% in Zimbabwe, and 77% in Kenya (Iizuka et al., 2015)) which would be missed out completely from the survey results. Implementing a standardized innovation survey would, despite huge efforts, only illustrate the innovation process taking place in a relatively small segment of the economy.

The African innovation Outlook II (AU-NEPAD, 2014) warns about comparing survey results. This is due to different sampling methods applied to each country. For example, the Oslo Manual recommends the cut-off point for collecting data to firms with 10 or more employees more for international comparisons. Many countries interpret this recommendation by only collecting data for firms with 10 or more employees. This size cut off seems to be too large to capture the already relatively small industry sector in most African countries. In fact, some countries lowered the cut-off level to 2 employees while others, just targeted large firms raising it to 20 employees. Moreover, South Africa uses revenue as the cut-off size, rather than numbers of employees. Sector coverage also differs among countries within the ASTII initiative. All 12 African countries covered the manufacturing sector, some also included mining and services, while others covered sectors such as higher education and research establishments. The inclusion of higher education and research institutions in addition to the manufacturing sector is understandable given that a high share of R&D, an important component of innovation, is spent by the public sector. The inclusion of economically important sectors would make the innovation survey results more policy relevant, but at the expense of international comparability. However, there are ways that the inclusion of new elements can be done without harming this comparability. Furthermore, the comparability could be strengthened among African countries, similar to what Latin American countries did with the Bogota Manual by elucidating the regional structural characteristics as well as common challenges in the innovation process.

The case of correctly interpreting innovation survey data can be clarified by the example of the 2008 South African innovation survey. In the accompanying report (CeSTII, 2011, p.2), it is said that the "South African rate of technological innovation [of 65.4%] compares favourably with the EU average of 39%", ranging "from 16% in Latvia to 63% in Germany. However, results for South Africa not only include firms that introduced innovations, but also firms that did not have any product or process innovations but only abandoned or ongoing innovation activities. In particular for South Africa the share of firms with abandoned or ongoing innovation activities was, at 38%, much higher than in any other country, and a ranking based on the share of firms that introduced an innovation would put South Africa near the bottom of the ranking, leading to quite different policy implications.

5. Conclusion

Across the globe the use of innovation indicators is increasing by both policy makers and scientific researchers. Different types of innovation indicators exist, each having its own merits. However, despite being a useful policy tool for achieving developmental goals via monitoring the progress in STI, indicators potentially exert excessive governance power over those being measured, forcing them to conform to a set of criteria without sufficient reflection on its relevance to policy objectives (Davis, et al, 2012, Espeland and Sauder, 2012, Fukuda-Parr, 2016). In other words, indicators should always be used under coherent policy goals of a country and never be blindly adopted for the sake of getting a seal of approval or to be a part of exclusive communities. Yet in reality, a sense of urgency in adopting indicators is shared among LMICs, largely due to the growing power of an ongoing global policy agenda that stresses innovation.

In HICs, the importance of innovation has been recognized by policy makers for a long time and a diverse set of innovation indicators has been developed to monitor innovation performance and the inform about the innovation processes to better formulation of policy. LMICs have been late to jump on this bandwagon, and at first glance, they seem to benefit from adopting existing indicators. However, innovation indicators have been developed to better understand the particularities of high-income economies, and due to their design, these indicators might not generate the specific information needed for designing policies that meet the different socioeconomic structures of LMICs.

LMICs have a broad choice of indicators to use for policy purposes, but all indicators have their strengths and weaknesses. Composite indicators are available at low cost and provide readily comparable indicators that can be used to benchmark with other countries; however, these alone are not sufficient for understanding innovation processes and for elaborating policies in LMICs. S&T indicators, as tightly defined indirect metrics on factors that are closely associated with innovation, propose credible and analytically sound options; however, without a contextual understanding of the innovation processes in LMICs it is difficult to fully exploit the results of the analysis. Innovation survey indicators, via directly collecting information on innovation from firms as key performers, offer the best source of information on innovation; however, innovation survey data are costly to obtain and for deriving policy relevant results population samples need to be carefully selected so they match with policy needs and the methodology for collecting these data should both take into account country specificities and ensure international comparability of the data. The decision which indicators or combinations of indicators to use require a careful reflection on policy goals to identify what is to be measured and how.

This paper, by trying to answer the question, 'How to make innovation indicators more relevant for policy goals of LMICs?', reveals the need for catching up in building capabilities for innovation indicators in LMICs. The argument is very similar to that of catching up in technological capability (Bell and Pavitt, 1995, Hobday, 1995, and Lall, 1992), which illustrated how countries started off from imitation, moving to adaptation, and eventually leading to creating a unique set of capabilities to improve their performance. Upgrading technological capabilities required conscious efforts, so does the catching up in innovation indicators. The directional indications can be considered as follows. First, the definition of innovation should be made more inclusive, paying attention to diverse types of activities, processes, sectors, actors, sources of knowledge and policy goals to accommodate diverse arrays of developmental needs[8]. Here particular attention needs to be paid in the latest recommendations for measuring innovation in the OM 2018. Second is to build expert capacity on innovation and innovation indicators among policy makers and academia in LMICs, to adequately convert existing innovation indicators into local and specific contexts that address distinctive policy needs while keeping some comparability with HICs. Third is to build indicator literacy among journalists and the general public to correctly understand innovation processes that are critical in achieving developmental goals. The emergence of a critical audience and public forum would further strengthen the legitimacy of survey results and shape effective policy instruments to reach overarching goals in a not so distant future.

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[8] This goes along with the argument by Gault (2018). This also reflects the statement made by Dr N. Mustapha, a Chief Research Specialist at the HSRC of South Africa on trying to discover innovation in informal sector (HSRC, 2019).

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