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The Need to Customise Innovation Indicators in Developing Countries

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Abstract

Innovation is becoming more and more important as a driver of economic growth. In developed countries, a diverse set of innovation indicators has been developed to monitor innovation performance and the impact of innovation policies. Developing countries have been late to jump on this bandwagon and are now faced with a set of well-established innovation indicators that might not be that well suited to measure innovation in their economies.

Existing innovation indicators can be broadly classified into three different types: Science & Technology (S&T) indicators, Innovation survey indicators, and Composite innovation indicators combining different indicators, including S&T and Innovation survey data, into one indicator. All of these have their own particular strengths and weaknesses, and they score above or below average on a wide range of attributes considered to be favourable, if not downright necessary, for innovation indicators.

This paper argues that, for innovation indicators, and for innovation survey indicators in particular, data collection has to be customised to the different socio-economic structures of developing countries. For this, the definition of innovation has to become more inclusive by recognising the multitude of innovation actors and processes in developing countries. Developing countries also need to build competence regarding innovation indicators, not only within their statistical systems but also among their policy makers.

JEL CODE: O38, O32, O29, P47

Keywords: innovation, indicators, developing countries, policy use

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1. Introduction

Innovation indicators are increasingly being adapted to inform the Science, Technology and Innovation (STI) policy making process in developing countries. The proliferation of innovation indicators is generally perceived as good news, as indicators, through enabling benchmarking, monitoring and evaluation, improve the effectiveness of innovation policies (UNCTAD, 2010). This also has particular current importance, as STI is considered as the means to achieve the UN's Sustainable Development Goals by diminishing capability gaps with the global North as well as within Southern countries (UNESCO, 2015, UN, 2016). Innovation indicators, therefore, play a pivotal role in helping to achieve and monitor broader developmental challenges.

Several factors have facilitated the rapid uptake of innovation indicators in developing countries. To start with, various innovation indicators are made available with increased coverage for developing countries by international and supranational organisations as well as public agencies[1] (Gault, 2010, UNCTAD, 2010, UNESCO-IUS, 2012). Increasing data availability is accompanied by an improved access to data through improved ICT infrastructure in developing countries. These developments are reinforced by the recognition that STI generate economic gains through enhanced productivity and eventually help achieve sustainable development among developing countries. Moreover, the adaption of indicators is deemed feasible following the general trend of public policy towards 'evidence based' and 'participatory' approach in the decision making process (OECD, 2012).

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). Given that indicators are essentially an extracted part out of complex realities for the purpose of comparison, the simplistic adoption of an indicator can lead to precarious policy choices (Espeland and Sauder, 2012). In other words, indicators should always be used under coherent policy goals of a country and never to be blindly adopted for the sake of getting a seal of approval. Yet in reality, a sense of urgency in adopting indicators is shared among developing countries, largely due to their growing power of setting policy agendas.

[1] Includes organisations 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 organisations such as RICYT, AOSTI among others. These organisations have disseminated manuals and methodologies for measuring innovation.

Currently, a gap seems to exist between realities in developing countries and what indicators are intended to portray, possibly leading to the wrong questions for identifying the right policy directions. This can be implicitly felt from statements of policy makers referring to the use of innovation indicators as seen in the following examples (these will be discussed in detail in section 4):

> *This year, our country is ranked 58 in the World Innovation Index compared to rank 60 a year before. Has our innovation performance improved?*
>
> *How much R&D expenditure is needed to generate innovation in our country?*
>
> *Should we conduct an innovation survey as developed for OECD countries? Would it provide useful information for innovation policy in our country?*

Formulating possibly incorrect questions results from the use of indicators without a clear understanding of one or more of the following: the concept of innovation (Borras and Edquist, 2016), the methodology of data collection and construction of the indicators, the process of selection and simplification of complexity (Espeland and Sauder, 2012), and the interpretation and grounding of the indicators to local realities (Tijssen and Hollanders, 2006).

Innovation plays a critical role for developing countries on their path towards sustainable development. Indicators play a pivotal part in designing policies for navigating a country towards its goal. To ensure that indicators effectively address the policy agenda in developing countries, a close examination of their role in identifying challenges is deemed necessary. The research question for this paper hence is: How to make existing innovation indicators more relevant for the policy goals of developing countries?

Section 2 describes existing innovation indicators, their function, desired attributes for policy making and strengths and weaknesses. This is followed in section 3 with an illustration of problematic uses of indicators in developing countries, with section 4 discussing some illustrative examples. Section 5 will conclude with identifying possible steps towards making innovation indicators more relevant for developing countries.

2. Which innovation indicators are currently available[2]?

2.1 Different types of innovation indicators

Largely three types of innovation indicators are currently in use. These are: Science, and Technology (S&T) indicators, Innovation survey indicators and Composite indicators for innovation combining different indicators, including S&T and Innovation survey data, into one indicator (hereafter Composite indicators). Each indicator has distinctive characteristics, data collection methods and sources of data, and shows different aspects of the innovation process.

S&T indicators measure activities concerning 'knowledge generation, diffusion and transfer', which are considered central activities leading to innovation. Examples of such indicators include: resources allocated to R&D, publications, citations, patents, and Human Resources in Science and Technology (HRST). These are not direct measurements of 'innovation' but they provide information on different aspects of the innovation process as well as flows of the knowledge creation process, particularly those surrounding research activities.

Innovation survey data are collected from firms and are used to construct indicators capturing (Mairesse and Mohnen, 2010: 6):

- Innovation output, such as indicators measuring the introduction of new products and processes, organisational changes and marketing innovations, the percentages of sales due to new products, as collected e.g. in the Community Innovation Survey for most European countries;
- A wider range of innovation expenditures or activities than mere R&D expenditures, such as the acquisition of patents and licenses, product design, personnel training, trial production, and market analysis;
- Information about what precedes innovation, such as sources of knowledge, the reasons for firms to innovate, and perceived obstacles to innovation.

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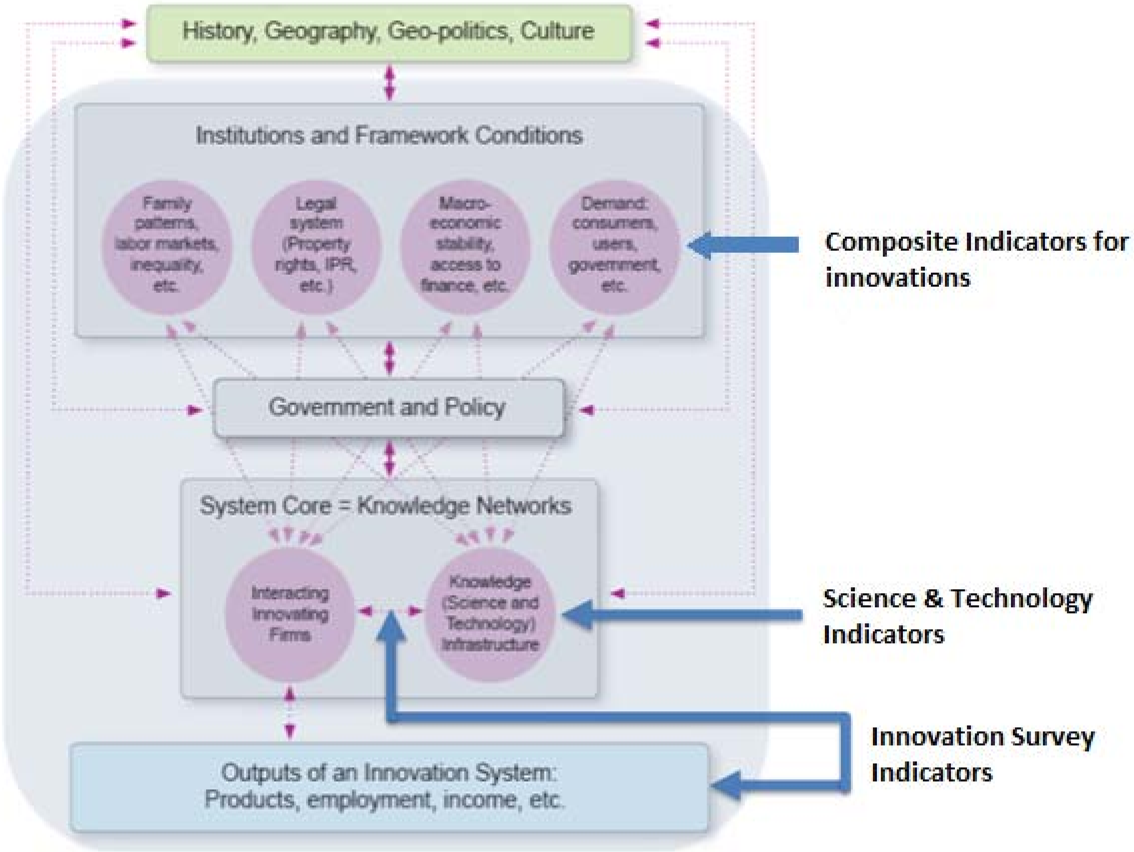
[2] This paper adopts the Oslo Manual definition of innovation (OECD/Eurostat, 2005) which defines innovation as follows: *"An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organization or external relations (paragraph 146)."* This is linked to the market through *'implementation'*: *"A common feature of an innovation is that it must have been implemented. A new or improved product is implemented when it is introduced on the market. New processes, marketing methods or organizational methods are implemented when they are brought into actual use in the firm's operations (paragraph 150)."*

Composite indicators summarise multidimensional characteristics of complex ideas such as innovation, and are constructed using available data to explain innovation processes and the performance of systems of innovation. The use of composite indicators to measure innovation is relatively recent, but is rapidly increasing, as the variety and coverage of topics and countries are increasing. Some well-known composite indicators that measure ‘innovation’ capacity include the Global Innovation Index (WIPO: introduced in 2007), Global Competitiveness Report (World Economic Forum: introduced in 1979) and the European Innovation Scoreboard (European Commission: introduced in 2001).[3]

Figure 1 shows the coverage of each indicator in the innovation system. 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, process, organisational change and marketing innovations) at the firm level, and measure innovation and interaction of firms for knowledge. Composite indicators can be used to illustrate the performance of innovation systems as a whole, by defining dimensions and normalising 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.

[3] The European Innovation Scoreboard (EIS) was introduced in 2001 and since then been published annually. In 2010 the EIS was renamed into Innovation Union Scoreboard (IUS), in 2016 the IUS was renamed into, once more, European Innovation Scoreboard.

Figure 1 Innovation systems and what each category of indicator illustrates



Source: Created by authors based on Farley et al, 2007

2.2 What are the functions and desired attributes of innovation indicators?

2.2.1 Functions of innovation indicators

In general, innovation indicators are used for improving policy design by obtaining information about the progress of the implemented policy made by comparing the current status with the past. Alternatively, the comparison can also be made with other countries with, ideally, similar socioeconomic structures. At large, indicators foreshadow trends, and pick up patterns, expectations and intentions (National Research Council, 2014). Gault (2010) presents four ways in which indicators are useful: monitoring, benchmarking, evaluating and forecasting. While indicators should be standardised to allow a general comparison, they should also refer to local conditions that are pertinent for policies in generating innovation. Good indicators are the ones that can carefully balance comparability and specific aspects to effectively inform users about innovation performance (Edler, 2016).

Indicators should ideally be disaggregated at country, sector (economic activities, public sector, households, non-profit etc.) or sub-national levels, as well as by type of actors involved in the innovation process (firms, universities, governments) to provide an appropriate scope of information for monitoring and evaluation to improve policy elaboration (UNCTAD, 2010).

2.2.2 Desired attributes of innovation indicators

Literature lists several favourable attributes for innovation indicators (Gault, 2013[4], Maleki and Yazdi, 2016, National Research Council, 2014, UNCTAD, 2010). First, the **quality** of indicators should be credible and analytically sound. This implies that indicators are carefully evaluated for their conceptual soundness, and feasible steps are taken to minimise measurement error. **Measurability** and robustness are attributes that refer to stable and obtainable information with wider coverage of countries as well as time periods. Another important attribute is the **transparency** of indicators, whereby the collection methods of indicators should be known rather intuitively to potential users.

Second, indicators should be **policy neutral**, impartial to political motivations. The use of explicit numbers and judgement by statistical inferences commonly leaves small scope for subjective interpretation, despite the fact that political compromise/manipulation may influence the selection and definition of data. **Timeliness** of data is crucial for indicators to be used in the policy making process[5] . **Comparability** is critical for benchmarking, monitoring and evaluation purposes. By reducing information into a concise form, indicators can contribute to the **communicability** of a public agenda to the general public.

Thirdly, **accessibility** of indicators to users does not only mean that information is available, but that it is available in a user friendly format. This is closely associated with **affordability** of indicators. Obtaining indicators on innovation and R&D, for example, can be costly, as these

[4] Gault (2013:446) lists the Canadian framework that has six dimensions of quality: relevance, accuracy, timeliness, accessibility, interpretability and coherence.
[5] Attempts are currently being made to provide more timely innovation survey data. The 2016 innovation survey adopted by EU Member States, also known as CIS, includes future oriented questions about planned innovation activities to partly overcome the time lag problem.

require the collection of data using surveys, and developing countries are faced with limited financial resources.

Last but not least, **relevance** to policy goals should be mentioned as the most critical attribute for indicators. This is often overlooked in developing countries when adopting existing innovation indicators. These countries, as late-comers, feel obliged to accept existing indicators without these indicators actually reflecting their realities. For instance, Eastern European countries adopted existing innovation indicators at EU level; however, not all indicators are policy relevant given different socioeconomic structures in these countries (Radosevic and Yoruk, 2016).

2.2.3 Strengths and weaknesses of innovation indicators

No indicator can satisfy all favourable attributes, as there is often a trade-off between two attributes. Decisions regarding which innovation indicator or combination of indicators to use should, therefore, always be made based on a careful consideration of policy purposes, together with a focus on the associated desirable attributes.

Table 1 summarises an assessment of the relative degrees of strengths and weaknesses of each type of innovation indicators. This assessment is useful for delineating the distinctive features of each indicator.

S&T indicators score better on the criteria of *quality, credibility and analytical soundness* and *policy neutrality, objectivity, and good statistical quality* than innovation survey and composite indicators. This is due to the fact that S&T indicators are more narrowly defined and available in a more explicit format that can be considered to be of higher quality in a statistical sense and also impartial regarding a subjective judgement. Innovation survey indicators are collected through surveys asking respondents to evaluate themselves if a change that has been introduced qualifies as an innovation, and how such innovations came to be introduced. This involves a certain degree of subjectivity in respondents' answers[6]; as a result, such indicators are sometimes considered lower in quality and less policy neutral. Composite indicators also

[6] Respondents e.g. have to decide when a product or process has been sufficiently changed to qualify as new or significantly improved. Products or processes that were unchanged or only marginally modified are not considered to be an innovation. In particular the distinction between significantly improved and marginally modified leaves ample room for personal interpretations.

suffer in terms of quality and objectivity because of a less objective selection of the multidimensional information for the construction of the composite. Composite indicators, do worse than innovation survey indicators for policy neutrality because they are more vulnerable to policy interests by their design (e.g. Foray and Hollanders, 2015; Schibany and Streicher, 2008) and, due to their complexity of summarising information from multiple indicators into one composite, cannot be linked directly to a particular policy designed to support innovation.

Table 1 Weaknesses and strength of different categories of innovation indicators

	Science and Technology indicators		Innovation survey indicators	Composite innovation indicators
	Publica-tions & Patents	R&D, S&T Human resources		
Quality, credibility and analytical soundness	+++	+++	++	++
Measurability, coverage and robustness	++	++	++	++
Clarity, simplicity, transparency	++	+++	++	+
Policy neutrality, objectivity and good statistical quality	+++	+++	++	+
Timeliness of availability	+	++	+	++
Comparability for evaluation and benchmarking	++	++	+	++
Communicability to the users	++	+++	++	+++
Accessibility to the relevant users	++	++	++	+++
Affordability to construct and sustain	++	++	+	+++
Relevance for innovation policy	+	++	+++	+

Source: perception of authors
Note: more '+' indicates more presence of perceived positive attributes

All indicators score the same on *measurability, coverage and robustness*, but the underlying reasons are very different. For example, indicators on publications and patents suffer from an uneven coverage across different disciplines, sectors, data sources and languages. Indicators on R&D and HRST have an ambiguity in the way 'research' and 'development' are combined. Innovation survey indicators suffer from limited country and sectoral coverage and application of different sampling methods which may not sufficiently represent the business sector. 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).

Timeliness of information is important, but all indicators experience some difficulties. For instance, publication and patent data are released with a 2 to 3 year delay, and in addition, it would require 3 to 5 years to accurately assess the impact of knowledge created from publications and patents. Survey based indicators, such as R&D, HRST and innovation survey data, have delays between 2 and 5 years before data are released. Composite indicators as such are made available relatively quickly using readily available data; however, the timeliness of composite indicators is as 'old' (or 'new') as that of the data used for constructing the composite[7].

For *clarity, simplicity, transparency*, R&D and HRST indicators perform best. Indicators on publications and patents score lower because these are only indirect measures of innovation. Innovation survey indicators suffer from a transparency problem because sampling and survey methods[8] differ across countries leading to improper comparisons. Composite indicators suffer from lower transparency, as they combine multiple indicators for which it is not always clear why these indicators were selected or how they are defined. The indicators perform better on *communicability to the users*, in particular, composite indicators are considered by policy makers to be an excellent communication tool as they summarise complex ideas into a simple format (Saltelli, 2007).

Indicators are made to compare and evaluate. Consequently, *comparability* of indicators is important. Comparability of S&T indicators is not perfect, as the levels of scientific activities are subject to a country's specialisation and industrial structure. For example, bibliometric databases do not fully cover all scientific journals and scientific fields. Innovation survey indicators suffer from different methods of sampling and survey methods that may lead to substantially different results.

While composite indicators, in general, are unfit to be used for policy evaluation, they are relatively *accessible* and *affordable* compared to other indicators, as they are usually produced by international or public institutions which make the information freely accessible for public

[7] E.g. the Global Innovation Index 2016 is published in 2016, but the data used for many indicators are for earlier years.

[8] For information on sampling or census, online, telephone or face to face interviews, cut off point of firm size, covered sectors etc., see UNESCO-IUS, 2012.

use. Survey based information such as R&D, HRST, and innovation survey indicators, are collected by national statistical offices requiring investment in time and resources for building up statistical competencies and for conducting surveys and analysing the results.

Lastly, each indicator has a different degree of *relevance for innovation policy*. Publication and patent data are not very relevant, due to their narrowly defined information which has less overlap with a broader innovation concept. R&D and HRST have more overlaps with innovation policy, while innovation survey indicators, by asking firms directly about their innovation activities, are most relevant. Relevance of S&T indicators to innovation is subject to the industrial structure and maturity of the business sector in respective countries. The same is also true for innovation survey indicators, where special importance is placed on matching economic sectors of significance and the sectors and actors covered by the survey. Composite indicators, on the other hand, are unfit to be used for policy design, monitoring and evaluation by itself, because they do not provide a sufficient amount of in-depth information. Composite indicators hide differences between the encapsulated indicators, where scores for two countries could be the same but the scores across the individual indicators could be completely opposite.

The smart use of indicators for elaborating innovation policy requires a good understanding of the attributes of each indicator. The selection of indicators should be made with careful reflections on what is being measured, as well as what needs to be measured to assess the situation effectively. As indicators only provide a partial view of a complex whole reality, it is recommended to use multiple indicators to gain better policy insights, and also to complement the strengths and weaknesses of each indicator (Freeman and Soete, 2007).

3. Problems of using innovation indicators in developing countries

3.1 Innovation indicators and global governance

Many developing countries have started to use innovation indicators. These countries first adopted existing indicators, following methodologies and conceptual frameworks established in developed countries. As a start, these are steps in the right direction; however, as Tijssen and Hollanders (2006) argue, whether these adopted innovation indicators are suitable for developing countries should be carefully examined, and efforts are needed to develop S&T indicators tailored to the needs of developing countries.

Indicators, in general, are created by simplifying complex phenomena, emphasising only certain aspects as a signal of a larger process (Espeland and Sauder, 2012). While indicators do not have any legal power over users, once they have gained legitimacy, they can exert a certain degree of power to create a 'locked in' situation (David, 1985). It is thus possible that an indicator designed to capture a signal at a certain time for a certain group of countries, will continuously exert governance power to shape agendas even after the signal ceases to be relevant in new or different contexts (Davis et al., 2012, Espeland and Sauder, 2012).

Innovation indicators have been created based on research in developed countries. As new adopters, developing countries have had difficulties in challenging existing indicators, and most countries ended up accepting them, without proper reflection on whether these indicators were adequate in explaining innovation processes in these countries, potentially resulting in formulating less effective policy recommendations. Although improvements have been made (see e.g. Gault, 2010), there is still a risk that lesser developed countries adopt too easily indicators developed for more developed countries, resulting in statistics providing a suboptimal evidence base for policy making. The following section will discuss some observed problems of using innovation indicators in developing countries. This will be followed by a discussion on the underlying reasons for the problematic use of innovation indicators in developing countries.

3.2. Use of innovation indicators in developing countries

3.2.1 Composite indicators

Composite indicators are usually published by international organisations or public entities and they are open to public access (e.g. Global Innovation Index (Cornell University et al., 2016), and

Global Competitiveness Index (World Economic Forum, 2016b)). Composite indicators have an advantage of being available at a low cost, but also being readily available in comparable formats that can be used to benchmark a country with other countries. In addition, composite indicators come with ready-made lists of indicators, so that policy makers in developing countries 'just' have to decide which indicators to use. Developing countries thus do not necessarily have to conduct their own innovation and R&D surveys, and go through the complexity of harmonising results to make indicators comparable, if the indicators used in these reports provide sufficient information. The use of composite indicators, as a result, has gained huge popularity.

However, much caution is needed in relying too much on composite indicators, as many of these are using information from opinion surveys, e.g. data from the World Economic Forum's Executive Opinion Survey are used in the Global Innovation Index and the Global Competitiveness Report, where cross-country comparability is questionable, as answers are more likely to reflect perception and satisfaction relative to expectation (Hollanders and Janz, 2013). Most composite indicators are relevant for measuring innovation, as they usually measure a variety of aspects considered to be relevant for countries' innovation systems. However, the design of composite indicators is usually based on existing understandings of innovation processes in developed countries. Therefore, existing composite indicators may not effectively demonstrate the particular features of the innovation systems in developing countries. Moreover, even though composite indicators rely on internationally most available data with broad coverage, data for developing countries are often missing and substituted with other data, or the original data may exist, but due to the differences in contexts, the very same data can have different meanings[9]. Composite indicators, therefore, are not sufficient as a basis for policy design and evaluation because they can promote a simplistic policy design based on incorrect assumptions. If such recommendations were to be used, they would need to be complemented with other sources of data on innovation (OECD/JRC, 2008). Much of the problem of incorrectly using composite indicators, stems from an insufficient comprehension of their design and limitations in addressing innovation policy. This problem, apart from the issue of availability of data in developing countries, applies to all countries, also the developed ones. Despite this problem, the easy access to (seemingly) comparable data on innovation, free of

[9] E.g., the 'Number of YouTube uploads' in the Global Innovation Index can be a sign of ICT literacy for developing countries and infrastructure provision for developed countries rather than a sign of creativity etc.

charge, combined with a shortage of resources to carry out ground work for innovation indicators, make developing countries more vulnerable for stretching the use of indicators beyond their intentions and requirements.

3.2.2 Science and Technology (S&T) indicators

S&T indicators have been around for a long time as indirect metrics of innovation. These do not measure innovation directly, but measure the factors that are closely associated to the innovation process based on common understandings.

Developing countries have been collecting S&T indicators using surveys. These data are considered to signal the presence of factors and conditions that have a significant influence on innovation processes based on the experience from developed countries. There is a potential gap from the realities of developing countries where economies and innovation systems are different (Sutz, 2012, UNCTAD 2010). For instance, in less developed countries, it is more common that higher shares of firms innovate without R&D (Gault, 2010, Huang, et al., 2010), and knowledge is diffused as embodied knowledge by purchased machinery and equipment, existing outside formal channels measured by indicators on R&D, HRST, patents and publications.

For example, in developed economies firms are stimulated to innovate through tax incentives, subsidies and grants. However, these policies are not applicable to many developing countries where a large proportion of R&D is done by the public sector (government and universities). For these countries, instead of focusing on R&D, policies should focus on creating enabling conditions for business innovation, e.g. through the provision of infrastructure and human resources. Existing S&T indicators should be examined from a different perspective, while new indicators need to be explored to match policy goals.

Patents are generally seen as an indicator for the development of frontier technology. But this is only true for countries with significant activities in so-called high tech sectors (pharmaceutical and chemical industries in particular) because research in these sectors is highly patentable. In developing countries, however, the most important sectors often include agriculture, mining, food, textile, and services, i.e. sectors where research is not very patentable (UNCTAD, 2010, World Economic Forum, 2016a). In these sectors, different indicators are needed to signal innovation and knowledge creation.

Indicators measuring publications and citations are often biased against research in developing countries 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 to developed countries (e.g. genetic traits of red tomatoes sold in major supermarket chains). Moreover, many scientific journals publish in English and creating a bias against publications in other languages.

As S&T indicators are more narrowly defined and transparent, the problem of their use in developing countries is different from that of composite indicators. A deeper understanding of innovation processes in developing countries is needed to find the right S&T indicators for monitoring innovation processes[10].

3.2.3 Use of innovation survey indicators

Innovation survey indicators are considered the best 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, or training personnel involved in, the development of new products or processes), whether they introduce specific innovations (product, process, marketing or organisational), and what their perceived barriers to innovation, their information sources and possible collaboration partners are. An increasing number of developing countries 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). Currently, about 95 countries have introduced an innovation survey (Gault, 2016) and numbers of developing countries are growing[11].

[10] Iizuka et al (2015) provide more details on attempts made in creating innovation surveys in African countries, but available innovation survey data are still insufficient to allow a detailed analysis of innovation processes of use for policy.

[11] For instance, in Africa, ASTII and NEPAD are trying to conduct both R&D surveys and innovation surveys following the Frascati and Oslo Manuals with support from SIDA. Regional international organisations such as RICYT, IDB and ECLAC are supporting, both technically and financially, several Latin American countries to conduct innovation surveys. UNESCO also provides technical support via the Go-Spin programme for all developing countries.

Initially, applying Oslo Manual based innovation surveys in developing countries suffered from a misfit to the needs of developing countries. The earlier versions of the Oslo Manual did not quite capture the particularities of innovation in developing countries. 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 incorporated into the third revision of the Oslo Manual (OECD/Eurostat, 2005).

Despite support from international organisations, implementing an innovation survey is still a complex operation in developing countries due to a lack of fully equipped and capable statistical offices with sufficient resources. Resource constraints are much more serious in developing countries due to competing issues of importance, insufficient provision of business registries to grasp firm population, and too low numbers of sufficiently trained and experienced surveyors and statisticians.

There are also 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 for innovation surveys not providing the information needed included lack of: timeliness of the data, better access to the results of the survey, and the legitimacy or acceptance by policy makers[12]. Obtaining survey results requires time, including the time that the survey is out in the field and the time to process the responses. Therefore, results usually became available with an average time lag of two years, and were by that time considered to be obsolete in the eyes of policy makers. Also, 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 could be a possible solution for making these results more policy relevant.

[12] Policy makers interviewed prioritised their experiences over the information obtained from innovation surveys for making policy decisions.

Most critical is to match the contents of innovation surveys to important policy questions in developing countries. For instance, the economic structures of developing countries are different from those of developed countries. Developed countries 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 services has increased significantly in developed countries, and innovation surveys were adapted to also cover the services sector, but mainly those service sectors perceived to be more innovative. Many less developed countries still do not or only partially cover the services sector (UNESCO-UIS, 2012).. Nevertheless, there is no guarantee that developing countries follow the same development path (i.e. Lee and Lim, 2001, Rodrik and Macmillan, 2011). 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 in fine tuning surveys to the realities of respective countries are already being made, e.g. in agriculture in Uruguay and Argentina (Aboal et al., 2015), and in informal sectors in Africa (de Beer et al., 2013, Charmes et al., 2016, Konte and Ndong, 2012).

Copy-pasting survey questions from existing surveys would not lead to the most policy relevant results for developing countries. These countries should customise their surveys to best portray their innovation processes (Tijssen and Hollanders, 2006). The following are possible areas to identify mismatches:

- Selection of industrial coverage so that it reflects countries' economic structures;
- Identification of all key performers of innovation, including firms, farms, households, the informal sector, universities, public research organisations, government, and NGOs;
- The size distribution of the sample population, e.g. acknowledging that in developing countries, micro firms (those with 1 to 9 employees) are more prevalent than in developed countries;
- Types of innovation: product, process, organisational innovations, business models and new markets, investment, firm efforts, provisions of infrastructure or any other forms of knowledge creation;
- 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, so that proper questions can be developed which will provide useful information for a better understanding why and how firms innovate.

Moreover, for developing countries, it is also relevant to monitor efforts made in learning and problem solving towards innovation, e.g. provision of various basic infrastructures (physical, legal, institutional), regardless of concrete innovation outputs as defined by the Oslo Manual (Sutz, 2012). 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, 2016), which implies needs for extensive coverage[13] involving different innovation agents.

The problem of innovation survey data is mainly in matching survey contents, coverage, and sampling survey methods to local needs and context so that results can provide policy relevant information. The timely delivery of, and providing access to the results to pertinent users, are also important for innovation surveys 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 developing countries, and a better understanding would help in identifying better indicators that correspond more closely to the policy needs of these countries.

3.3 Underlying reasons for the problematic use of innovation indicators in developing countries

The previous section illustrated different problems for each type of innovation indicator. For composite indicators, much of the problems stem from a lack of comprehension of their design and limitations for addressing innovation policy. For S&T indicators, as indirect measures of innovation, problems arise from differences between assumptions and realities in terms of what the S&T indicators signal about the innovation process. Innovation survey indicators collect information directly from the performers of innovation, but problems with aligning survey methods, among others, to the economic structure of a country (e.g. differences in firm size,

[13] For instance, there are on-going discussions in expanding the target of innovation surveys to all sectors included in the System of National Accounts, also including public and household sectors. The definition of innovation could be made more inclusive by shifting, in the current Oslo Manual definition, from the implementation of significant change to be 'introduced to the market' to making it 'available to potential users' (Gault, 2016). Such proposed changes reflect the shifting nuances of innovation from productivity to a more inclusive approach with attention to social welfare as well as sustainability.

presence of an informal sector) can significantly reduce the relevance of the results for policy needs. In addition, the timely delivery of data, accessibility to pertinent users and legitimacy are necessary pre-conditions for making innovation surveys relevant for policy use.

The problems of using innovation indicators in developing countries can be categorised as follows:

1) Problems caused by a lack of comprehension on the nature and design of indicators.

   The mismatch between attributes (strengths) of indicators and their purpose can generate misleading policy judgements. A possible solution is to enhance the understanding of indicators and use of multiple indicators to complement weaknesses of other indicators.

2) Problems associated with a lack of understanding of the innovation process in developing countries.

   In many developing countries, indicators are being used to signal the presence of innovation processes similar to those in developed countries. However, for developing countries with different socio-economic structures and dealing with different policy challenges, indicators designed in developed countries may not provide relevant information and could be misleading innovation policy, e.g. by promoting R&D thereby ignoring the fact that many innovation activities do not involve any R&D at all, both in developing and in developed countries (Huang et al, 2007).

3) Problems associated with timely delivery, accessibility, availability, communicability, and legitimacy of innovation indicators.

   For innovation indicators to be useful for benchmarking, monitoring, and evaluating innovation policies, they should be provided to appropriate users in a timely and usable format. Moreover, the legitimacy of such indicators should be supported by policy makers.

The first and third problem apply to all countries, although challenges are perhaps more severe for developing countries due to their scarce resources and being late adopters of innovation indicators. The second problem is of particular importance to developing countries.

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 developing countries by discussing how to interpret three examples of typical statements.

4.1 This year, our country is ranked 58 in the World Innovation Index compared to rank 60 a year before. Has our innovation performance improved?

Policy makers sometimes seem obsessed with the performance of their country in global innovation rankings. Interpreting relative performance towards other countries and changes over time can be difficult. Assume that in a hypothetical global ranking, called the World Innovation Index, the rank of a country was 60 in last year's edition. This year the country is ranked 58th, an improvement of two rank positions. Does this mean that the innovation performance has improved?

There is no simple answer to this question, as global rankings are about relative performance towards other countries included in the same ranking. 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, some are more and others are less skewed. In order to make indicators directly comparable, values are usually recalculated (normalised) 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. Say, 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, than 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, 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. Innovation will also take place without R&D because much of new technologies and knowledge technology would be adapted from abroad (Gault, 2010, Huang et al, 2010). R&D intensities also differ across industrial activities; countries with different industrial structures will have different 'optimal' R&D intensities.

Further, R&D statistics are better able to capture innovation activities in the manufacturing sector, as manufacturing firms historically have spent more on R&D than firms in services. This can create a problem when different sectors, such as services, agriculture and natural resource based activities, are to be assessed applying aggregate statistics. This point is already being identified by the OECD. The technical notes of OECD directorate for STI states that 'Direct R&D intensities are not much help for service activities. Instead other indicators such as skill intensity and indirect R&D measures such as technology embodied in investment or investment in ICT goods by industry must be explored' (OECD, 2011). The same document also admits the limitation in disaggregating low tech industries due to the limited detailed R&D expenditure data across countries. Regarding low tech industries, several studies also question the underlying assumption associated with 'low tech' and 'low' knowledge/technology intensity

(Hirsch Kreinsen and Schwinge, 2014, Mendonca and von Tunzelmann, 2004, Smith, 2005, von Tunzelmann and Acha, 2005). Therefore, applying the preconceived notion from a particular context may not be applicable to measure the conditions in different countries with different endowment conditions. Increasing the proportion of R&D in GDP may not be the best way to increase productivity via increasing innovation for countries where innovation for most firms does not rely on R&D.

The OECD provides a classification of industries by their average R&D intensities (Hatzichronoglou, 1997). This categorisation 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 2).

Table 2 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, 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[14]. But also within the manufacturing sector there are 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(cf. Table 2), 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

[14] 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).

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?

Table 3 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 3). Chile's business sector spends almost as much as the higher education sector. In developing countries, the sources and main performers of R&D are often public rather than business, resulting in different policy implications, as compared to developed 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).

4.3 Should we conduct an innovation survey as developed for OECD countries? Would it provide useful information for innovation policy in our country?

Many developing countries recognise that innovation plays a critical role in productive development to enable long term economic growth, leading to a growing interest towards conducting innovation surveys. Despite the results of an innovation survey potentially being able to bring better informed policy decisions in the long run, an innovation survey is still a costly endeavour, especially for developing countries where resources are scarce. Careful reflections are needed regarding the relevance of such a survey for policy needs.

There are several initiatives in developing countries with support from international organisations 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 standardised 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% resp. 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 standardised 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-NEAPD, 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 of firm employee size at 10 or more. 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.

Over and above these technicalities, it is important for these countries to equip themselves with experts and policy makers who can make the most use of the information generated by an innovation survey. Countries should make continuous efforts to build capacity to use the available data, as well as to explore ways to make policy relevant and comparative data sets. The objective of having an innovation survey should not only be to identify how many firms introduced an innovation; the prime objective should be to better understand how and why some firms innovate and why other firms do not innovate. The design of the questionnaire, should also take into account country-specific needs and challenges. For example, access to raw materials might not be an issue for resource-rich countries, but could be the prime reason to innovate for firms in countries without natural resources. Firms in countries sharing similar cultures or the same language as developed countries, will experience challenges in either inward or outward mobility of skilled workers, as compared to firms in countries which are more isolated from the rest of the world. For every country, and in particular developing countries, innovation surveys should include two sets of questions, one set of harmonised questions allowing a comparison with other countries, and a second set of country-specific questions specifically aimed at the countries' specificities.

5. Conclusion

Innovation is becoming more and more important as a driver of economic growth. In developed countries, the importance of innovation has already been recognised by policy makers for a long time and a diverse set of innovation indicators has been developed to monitor innovation performance and the impact of innovation policies. Developing countries have been late to jump on this bandwagon, and at first glance, they seem to benefit from already existing indicators. However, innovation indicators have been developed to better understand the particularities of developed economies, and due to their design, these indicators might not generate the information needed for designing policies that meet the different socioeconomic structures of developing countries.

Developing countries 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 policy in developing countries. 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 developing countries 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. 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 developing countries?', reveals the need for catching up in building capabilities for innovation indicators in developing countries. 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 innovation processes, sectors, actors, sources of knowledge and developmental goals to accommodate diverse arrays of developmental needs[15]. Second is to build expert capacity on innovation and innovation indicators among policy makers and academia in developing countries, to adequately convert existing innovation indicators into local and specific contexts that address distinctive policy needs while keeping some comparability with developed countries. 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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Appendix: Description of innovation indicators

1. What are the Composite indicators for innovation?
Composite indicators summarise multidimensional characteristics of complex ideas such as innovation. Composite indicators are constructed with available data with the design based on existing theory to explain innovation processes, performance and/or systems. The use of composite indicators on innovation is relatively recent but is rapidly increasing. For instance, well-known composite indicators that measure innovation capacity at country level are Global Innovation Index (Cornell University, INSEAD and WIPO; introduced in 2007), Global Competitiveness Report (World Economic Forum: introduced in 1979) and the European Innovation Scoreboard (European Commission: introduced in 2001). There are several other related composite indicators on entrepreneurship, and capacity of ICT.

Composite indicators generally consist of groups of sub-indexes each representing distinctive dimension of the concept. Each dimension is comprised of several indicators that contribute to the characteristics of that dimension. The index for this indicator is derived by calculating the average of these dimensions, where indicator scores are normalised to ensure that identical measurement scales are used for all indicators. Different weights can be used to emphasise differences in importance for dimensions or individual indicators.

The strength of a composite indicator is its ability to summarise complex concepts, such as innovation performance, innovation systems and competitiveness, in a concise single index that is easily compared across countries and communicated to the public. Composite indicators have a significant impact on policy (Grupp and Mogee, 2004). In fact, the ranking table of indices is easily being politicised and becomes a powerful tool (for policy makers to dialogue with public/budget officers) to mobilise the policy agenda by creating a narrative (Saltelli, 2007, Davis et al., 2012). While policy makers can use composite indicators to communicate with citizens, under evidence based and participatory policy making, there are limitations in capturing local realities. In fact, experts caution their use in policy making without referring to other sources of data (e.g. S&T and innovation survey indicators) in a careful and thorough manner (OECD/JRC, 2008, Adams, 2014). This is due to their simplicity and non-transparent nature of construct (OECD JRC handbook, 2008; Freudenberg, 2003; OECD/ JRC, 2008; Foray and Hollanders, 2015; Edquist and Zabala-Iturriagagoitia, 2015; Schibany and Streicher, 2008; Adam, 2014, amongst others) that may lead to misuses.

2. What are the Science & Technology (S&T) indicators?
S&T indicators measure activities concerning knowledge generation, diffusion and transfer. These include R&D indicators (expenditures and personnel), publications, citations (bibliometrics), patents, and Human Resources in Science and Technology (HRST). These indicators are not direct measurements of innovation. From a perspective of knowledge generation and diffusion, these indicators represent input, output and/or throughput and trace knowledge flows. Usually, R&D and HRST are considered inputs for knowledge production while publication and patents are seen as outputs. The knowledge diffusion process can be traced by the mobility of HRST as well as citations of publication and patents.

R&D data
R&D, as defined by the Frascati Manual (OECD, 2015), is the amount invested in basic research, applied research and experimental development (but not the actual experiment)[16]. R&D data are available for a long period of time and cover a large number of countries. R&D data is considered as a precursor for innovation and capacity to innovate (Cohen and Levinthal, 1990) and an indication of the knowledge stock that is critical for increasing productivity (Romer, 1990). While R&D predicts innovation potential, it does not include commercialisation or implementation of knowledge. In order to understand the knowledge creation and diffusion process in a country specific manner, R&D indicators should be examined in a disaggregated form by the sources of finance (public, private, non-private organisation), the users (firm, university or public research institute, government) and by sector of economic activities, in proportion to GDP[17].

HRST
Human Resources in Science and Technology (HRST) consist of two kinds of personnel data: those who have an education (tertiary level) in Science and Technology (ST) and those who are employed in an ST occupation (OECD, 1995). The data can be disaggregated by fields of science, gender and age. The data are collected from education, labour, and R&D statistics which are collected via national census and or household survey.

Patents and publications
Patents and publication both portray the visible part of knowledge output and flows via observing both issuance records and their citation[18]. However, this does not paint the whole picture of the innovation process because patent data are considered to provide information on the invention part of knowledge creation. Moreover, 'not all inventions are patentable, not all inventions are patented and inventions that are patented differ greatly in quality' (Griliches, 1990: 1669). Similar logic can be applied to publications; not all knowledge is publishable or published and can differ greatly in individual quality and impact for the further development of knowledge (Moed, 2005). Furthermore, the differences in ease of converting knowledge into output (patent/publish) differ across disciplines[19] (Nagaoka et al, 2010; Moed, 2005). Also, not all patents[20] and publications are used in the intended manner in contributing to innovation. Lastly, data sources for both indicators can be biased due to legal structures in collecting data[21] and coverage of sectors (Rafols et al., 2016 for example)[22].

[16] Despite the fact that the definition of R&D seems clear, the data collection process suffers from subtle differences between research and non-research activities, due to differences in the intentions behind the actions taken. For example, 'action of taking temperature measurement' can be categorised as research and experimentation if the intention was to perform research and experimentation, while if the action was part of routine activities, it is not counted as R&D.
[17] There are some overlaps with HRST data as R&D statistics also cover data on personnel working on R&D.
[18] Patent information contains citation of prior/related patents as well as academic papers.
[19] For instance, patents are more likely to be observed in the Pharmaceutical and Chemical industries while not so much in Electronics equipment, General equipment and ICT. Technologically more simple products are likely to be patented than complex ones (Merges and Nelson, 1990). Furthermore, if knowledge is applied to processes, it is less likely to be patented than if embodied in products. (Nagaoka, et al,, 2010). In case of publications, humanities and social sciences have fewer publications than natural sciences and engineering.
[20] In case of patents, many patents are filed just to block competitors for strategic reasons.
[21] For instance, Japan and Europe do not require examination of patents upon application like the USA, causing various differences in firms' patenting behaviour due to time, cost and disclosure of information.
[22] In case of patent data, the patent office has different laws and obligations, and lead times from filing to granting. These make a simple comparison across countries difficult.

3. What are the Innovation survey indicators?

Innovation indicators differ from S&T indicators, as they focus on firm specific innovation activities that are introduced in the market. For the collection of information, innovation surveys are conducted to measure innovation activities as defined in the Oslo Manual (3rd revision)[23] The definition of innovation, collection methods, survey questions, and method of data compilations have evolved over the years to reflect the changes that took place regarding innovation processes[24]. These evolving changes in the definition of innovation have positive implications to developing countries through creating a more inclusive approach towards broad types of innovation.

Despite the shared definitions and contents, implementation of an innovation survey follows different methods across countries. For instance, surveys in some countries are conducted as a census, while others take samples applying distinctive sampling methods. The sector coverage for identifying firms and cut off level of firm size (e.g. more than 10 employees[25]) also differs across countries (UNESCO-IUS, 2012). Moreover, responses to the innovation survey very much depend on survey methods (e.g. online, postal or by telephone) and on the subjective judgement of respondents (Arundel, 2014). Therefore, survey results can reveal basic trends across countries but comparison requires careful examinations of the survey methods (Mairesse and Mohnen, 2010, UNESCO-IUS, 2012).

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[23] The Oslo Manual follows the subject approach of surveys, which collects information from the firms, instead of the object approach, which collects the number of innovation outputs (SPRU study conducted in the 1960s). The subject approach collects comprehensive data at the decision making level of the firm, allowing to conduct much richer analysis that can be linked to the sectoral statistics and national accounts, while the drawback of the subject approach is that it does not distinguish between successful and unsuccessful innovations. Oslo Manual (OECD/EU STATS: paragraph 146) defines innovation as 'the implementation of a new or significantly improved product (good or service) or process, a new marketing methods or a new organizational method in business practices, workplace organisation or external relations' and further, paragraph 150 states that 'a common feature of an innovation is that it must have been implemented. A new or improved product is implemented when it is introduced on the market. New processes, marketing methods or organisational methods are implemented when they are brought into actual use in the firm's operations."

[24] For detailed history of evolutionary development, please see the following: for Oslo Manual Gault (2013) and for Community Innovation survey Arundel and Smith (2013).

[25] Some countries also survey enterprises with 1 to 9 employees.

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