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Overview

Statistical information is essential for understanding and appreciating the key contribution of science and technology (S&T) within knowledge-based economies. Quantitative indicators based on these statistics help measure, monitor and benchmark the performance of well-developed S&T systems in advanced industrialized countries. Many question whether the existing indicators have equal relevance for less developed countries. This Policy Brief reviews recent trends and highlights key advantages of the applications associated with these indicators for strategic management and policymaking within developing countries.

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Using Science and Technology Indicators to support knowledge-based economies

We live in an information-rich world where very few people question the practical value of numbers. For R&D managers and Science and Technology (S&T) policymakers, access to large amounts of objective information coupled with 'insider knowledge' of the current state of S&T systems promotes better awareness of their organization's strengths, weaknesses and potential opportunities. Such knowledge provides a base of empirical evidence that can be used for monitoring, performance assessment, informed debate, policy formulation and decision making.

Development of essential organizational infrastructures, databases and measurement methods has progressed fairly rapidly in advanced industrialized countries over the past two decades. This rapid course of development was driven by several converging forces including: public demand for evidence-based R&D management; accountability in S&T policies; broader participation of stakeholders; the recognition that statistical data and performance indicators have become a key element in modern *management by objectives* governance systems; and the ICT revolution which has enabled the storage and transfer of large volumes of relevant data and simplified access to comprehensive high-quality databases.

In this new environment of public management, S&T managers and policymakers increasingly resort to using the most accessible quantitative data for cost-effective strategic planning, priority setting, monitoring and evaluation. Evidence-guided policies require a sound basis of factual evidence to promote the implementation and assessment of measures aimed at strengthening performances, the results of which might provide compelling evidence, relevant arguments and robust justification for decision making. Oftentimes, measurements and indicators describe trends (i.e., are we progressing or digressing?) and comparative information (i.e., are we superior compared to the achievements of our competitors?) which can be used to build confidence and pride in national S&T performance.

These 'science and technology indicators' are usually supplied with official government-issued statistics and quantitative data collected by (supra) national agencies. When combined with other analytical tools, S&T indicators can provide a broad-based collection of objective information about the internal processes of 'knowledge creation' and 'knowledge utilization' systems. The importance of S&T indicators for policy formulation and for addressing socio-economic development needs extends well beyond the borders of advanced industrialized economies. Emerging 'catching-up' economies and lesser developed countries require statistical information and systemic analyses of the state of and potential for their own S&T capacity(ies) so that they are better able to promote and guide socio-economic development.

This Policy Brief discusses the benefits and shortcomings of S&T indicators with a focus on their application for compiling an evidence base to support decision making, strategic planning and policy debate at national or sectoral levels, and for assessment of S&T performance at the institutional level.

Historical background and trends

The relationship between scientific discovery, technological innovation and economic development is of central policy concern to industrialized and industrializing countries alike. Since S&T activities and capabilities are increasingly being recognized as engines of economic growth and drivers for improved welfare, many developing countries are prioritizing development programs in higher education, science and S&T-based entrepreneurship, in order to become more 'knowledge-based'.

The OECD (Organisation for Economic Co-operation and Development) and UNESCO (United Nations Educational, Scientific and Cultural Organization) have been the driving forces behind the development of good S&T statistics within the industrialized world. In Africa, S&T indicators are still in their infancy and have yet to firmly take root at regional or national level, with the exception of South Africa where two S&T indicator reports were issued during the 1990s and one booklet was released a few years ago. The African Union's *New Partnership for Africa's Development* programme has recently initiated the *African Science, Technology and Innovation Indicators Initiative* programme to help kick-start further development and application of African S&T indicators by engaging in a capacity-building effort under the auspices of the *African Observatory for Science, Technology and Innovation*.

Current sophisticated applications of S&T indicators involve a mixing and matching of indicators. The constituent statistics and sub-indicators are restructured and aggregated into indexes and composite indicators, such as the United Nation's *Technology Achievement Index*. In some cases, users and consumers may assemble their own indicators for tailor-made overviews. For example, the World Bank's web-based *Knowledge Assessment Methodology* offers an interactive benchmarking tool consisting of a wide range of indicators to help countries benchmark their S&T performance.

Essential tools

Government issued or sanctioned S&T statistics are usually the key source of information used to gauge the general health of national and regional S&T systems. Performance indicators are useful tools used for various objectives at different stages of management processes and cycles for example:

- Recording baseline measurements and analysis of strengths and weaknesses;
- Selection of benchmarks and comparators;
- Setting levels of expectation and attainment (performance milestones and targets);
- Monitoring and tracking progress towards achieving them;

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- Tracking early warning systems to identify problems and opportunities;
- Identifying the need for additional statistical data or information sources (surveys);
- Demonstrating tangible results and impacts;
- Conducting assessments, evaluations and reviews of outputs and outcomes.

The current generation of S&T indicators is especially useful for taking stock of the current economic situation by monitoring human resources and associated R&D capacities, monitoring R&D cooperation, evaluating scientific and technological performance in terms of research publications and patents, and by surveying public attitudes and knowledge.

Indicators and their applications reinforce each other in a cyclical process: decision-making is often based on partial knowledge of S&T systems, the statistics of which can only explain a specific part of the overall phenomena. Nevertheless, these statistics are used to shape policy agendas and managerial actions simply because no other reliable data and/or information exist. S&T statistics ensure accountability and transparency, and provide the necessary background information for governments and agencies to use for decision making and sound policy design. Faced with the challenge of ensuring that scarce investments are optimally spent, the focus of S&T policies in developing countries centre around issues related to the (re)distribution of existing or new resources, and to the determination of aid program efficiency and efficacy.

Ideally, users of S&T statistics seek the best evidence from the most credible sources for the most appropriate point in time. In practice, they are inclined, or forced, to work with the information at hand. The current availability of S&T statistics and indicators and the choice of the most appropriate indicators depends largely on the economic development phase of the country and the availability of facilities to collect reliable comparative statistics. We identify the following six major classes of S&T indicators that are of particular relevance to developing countries:

- R&D expenditure;
- Stocks and flows of human resources and skills;
- Absorption and generation of new knowledge and know-how;
- Transfer and application of new knowledge and know-how;
- Economic and social impacts; and,
- Governance systems and managerial structures.

A few useful indicators exist for the first three classes and a concerted effort to retrieve them would prove successful in the 'medium term'. Information for the last three classes is extremely limited and development of high-quality indicators is still beyond the horizon.

High quality indicators are essential for good science and technology policymaking

You can't manage what you can't measure

Official S&T statistics are used to describe or portray reality as close to the truth as is possible and indicators are specifically designed to explain these findings. Good indicators clarify without oversimplifying. Each indicator has its own strengths and weaknesses, as it inevitably reflects only some aspect of a very complex social or economic phenomenon. One of the OECD's 'icon'

Science and Technology Indicators Defined

Science and Technology (S&T) indicators are analytical tools traditionally defined as 'a series of data designed to answer questions about the science and technology system (STS), its internal structure, its relation with the economy and society, and the degree to which it is meeting the goals of those who manage it, work within it, or are otherwise affected by its impacts' (OECD, 1992—"*Technology and the Economy: the Key Relationships*"). In the United States, S&T indicators are referred to as 'science and engineering indicators', or similar variants such as 'science and technology competitiveness indicators'.

indicators is best known by its acronym 'GERD/GDP' (i.e., the percentage of Gross Domestic Product spent on R&D). GERD/GDP is an excellent example of an indicator which appears on the surface to be a 'simple' indicator. While it is often criticized for being a rather blunt instrument for capturing a nation's R&D-intensity based on a single measure, it is considered by many to have undisputed relevance for S&T policy in many OECD countries. That said, it has limited value for diagnosing the health of S&T systems within developing countries due to the developmental stage or idiosyncrasies of local S&T systems, and due to its wide scope of methodological and technical shortcomings in data collection and processing. Examples of such shortcomings include inappropriate, or a lack of, key concept definitions, a lack of staff and resources at statistical offices, missing data, and measurement problems. In practice, even the best indicators fall short of the mark when based on incomplete, biased or outdated information sources, or when methodologies fail to meet international quality standards and definitions as outlined in statistical manuals.

The dominant conceptual framework for collecting and analyzing data is still the traditional 'linear' model which depicts how, when and why S&T systems evolve by following the straightforward temporal sequence where: input → throughput → output → outcome → impact. Obviously this view oversimplifies the complexity of the real world. This traditional approach is gradually being phased-out in S&T management and policy analysis and is being replaced by more comprehensive interactive 'feedback' models, which introduce a new risk for information overload and 'paralysis by analysis'. However, the linear model's simplicity proves to be a beneficial methodology for exploratory analysis and for straightforward comparative overviews of S&T systems in developing countries, where the breadth and depth of data sources and technical expertise is too limited to conduct a more sophisticated 'systems analysis' approach.

There is a need for indicators that clarify without simplifying

Pitfalls and caveats

While the production of digits, indexes, tables and graphs from S&T statistics is constantly growing, it does not always provide immediate knowledge or definitive judgments. Managers or decision makers are not expected to become experts at interpreting this growing amount of data. In fact, they should be able to rely on statisticians, analysts and other technical experts to 'read' the statistical data to prevent information overload. Carefully selected and well-designed indicators act as a bridge between interesting statistics and useful knowledge. However, even when the data is of a high quality, technical experts and other intellectuals can overlook technical parameters and definitions of measurements and end up jumping to the wrong conclusions.

Statisticians and analysts can do a great deal to ensure the appropriate use of their data and to minimize the risk of 'accidents', especially those resulting from deceiving applications or blatant abuse. One of the more effective methods used to promote the appropriate use of data is through the development and application of user guides which provide the proper interpretation of statistics, expected values, and the accompanying set of criteria, yardsticks, and standards. Without an expected value it is impossible to characterize a measure as being low or high, to understand what it means to be near the bottom of a ranking, or what it means to have an average score. The ability to provide convincing answers not only requires technical expertise of the 'ins and outs' of the information sources and an in-depth understanding of the underlying metrics and statistical properties of the data, it requires, above all, a thorough grasp of the relevant contexts and goals of the indicators.

Once statistics and indicators are published, the producers lose control over external applications, which can pose a real risk in the case of high-profile 'league tables'. While rankings of research performance certainly appeal to the general public, they tend to hide the significance of survey response rates and the subjective choices associated with the relevance of the various measurements that were taken into account to compile the aggregate data. The high-profile list of the world's top 500 research universities, produced by the Shanghai Jiaotong University, is a case in point as it illustrates why many universities in the developing countries feel misrepresented by both the choice of indicators and the crudeness of some of the measurements. Nevertheless, this ranking is an extremely useful tool for raising people's interest, sparking discussion of the relative strengths and weaknesses, and for mobilizing dedicated and concerted efforts aimed at examining and explaining differences in performance levels.

Many experts advocate the use of 'scoreboards' to provide comprehensive overviews specifically designed to highlight, explain and communicate key results of statistical analyses in an understandable and balanced format, emphasizing the different viewpoints and aspects captured by these measurements. In practice, one usually has to compromise a trade-off between the desired set of indicators and the limited number of 'core' indicators. Important pitfalls and associated drawbacks of constituent indicators may be obscured by the interpretation of composite indices and scoreboards which draw their input from a variety of measurements and multiple sources, and should therefore always be carefully scrutinized.

Think globally, act locally

Currently, there is a critical need to extend the production and availability of high-quality S&T statistics to as many countries as possible. There is unanimous agreement that the less developed countries are significantly under-represented in international S&T statistics and there is an urgent need to fill this information gap. Many of the less developed countries have identified the procurement and organization of reliable human and financial resources

The history of S&T statistics in industrialized countries

Good S&T statistics are an essential tool used to monitor economic development, a fact recognized many decades ago by international agencies such as the OECD and UNESCO. UNESCO's *International Standardization of Statistics on Science and Technology* (1978) and the OECD's *Frascati Manual* (most recent edition issued in 2002) provided the foundation for many of the contemporary cross-country harmonized international S&T indicator systems. More and more, S&T indicator reports include cross-country comparative statistics on developing countries, part of which are produced by the Montreal-based *UNESCO Institute for Statistics*.

In 1984 the OECD initiated a series entitled *Science and Technology Indicators*. Various OECD member countries followed suit in the 1970s and 1980s and successfully engaged in dedicated and concerted efforts to publish national S&T indicator reports based on the OECD's internationally comparative framework. Many countries have established units within statistical offices or have launched other national or regional institutions or networks, to support the production of these reports on a regular basis. As regional integration and cooperation increased, the regional S&T surveys and the development of regionally-oriented S&T indicators gained momentum in the 1990s, especially within Latin America (e.g., *Network on Science and Technology Indicators—Ibero-American and Inter-American*) and South East Asia (e.g., ASEAN network).

S&T data into a harmonized system of S&T input indicators, as a national priority. Currently, many of the developing countries systematically collecting S&T data are complying with the international standards and protocols that were designed for, and adopted by, advanced industrialized nations. Oftentimes, the practices and methodologies outlined under these protocols are limited and incompatible with the research, management and information systems found in many developing countries. Consequently, there have been only limited national efforts in generating S&T statistics in many of the less developed countries due to weak capacities in human resources and ICT infrastructure. Historically, international organizations, such as UNESCO, have tried to collect and collate data from various countries, but have been hampered by various organizational, technical and methodological problems. The poor response among African countries to the S&T survey carried out by *UNESCO Institute for Statistics* in 2006, is a case in point illustrating some of these issues. S&T survey methods and topics must be adapted to reflect the local realities of S&T systems and socio-economic constraints, such as the significance of the informal economy, its reliance on foreign resources, and intellectual property protection of indigenous knowledge.

A dramatic increase in resources is essential to enable the timely collection of high-quality S&T statistics. It is vital that the existing international methodologies for data collection and the definition of relevant S&T indicators are adapted to meet specific needs and local circumstances. The focus of measurements should be widened to include elements in S&T processes that are more appropriate for developing countries, for example, local applications of indigenous science (i.e., the role of professional associations, and local scholarly journals), stocks and flows of human resources (i.e., monitoring the exodus of talented local researchers to richer countries), and demographical trends of PhD students and R&D staff (i.e., details on educational background, age and gender).

Activating indicators

High-level S&T measurements and statistics will not be used to their full potential by local management and decision-making bodies unless they receive high-level support from government agencies, are backed up by an appropriate organizational infrastructure dealing with technical issues and S&T policy analysis, and are embedded within a generally accepted 'measurement and assessment' culture. The development of long-term institutional capacities and sustainable S&T statistics production systems are required so that relevant data producers, users and intermediaries, can effectively cooperate through coordination systems and through a process of dialogue with all relevant stakeholders. In many countries S&T data collection is still a decentralized process. In these cases, national statistics institutes should play a central role in gathering and certifying micro-data. Positive developments in South East Asia and Latin America prove that adopting a "think globally, act locally" attitude creates the required economies of scale and scope to effectively tackle the time-consuming and costly business of creating high-quality S&T statistics.

Setting up such a framework requires sustainable investments in capacity-building, which in turn needs to be employed efficiently and cost-effectively, targeted towards pre-set objectives and milestones. Efforts to adopt or even to develop S&T statistics and indicators require each country or region to make

Useful resources online

OECD (Organisation for Economic Co-operation and Development): http://www.oecd.org

UNESCO (United Nations Educational, Scientific and Cultural Organization): http://www.unesco.org

UIS (UNESCO Institute for Statistics): http://www.uis.unesco.org

RICYT (Network on Science and Technology Indicators—Ibero-American and Inter-American): http://www.ricyt.edu.ar/

ASEAN (Association of Southeast Asian Nations): http://www.aseansec.org/

NEPAD (New Partnership for Africa's Development): http://www.nepad.org/

Shanghai Jiaotong University: http://ed.sjtu.edu.cn/ranking.htm

WorldBank: http://www.worldbank.org/

WorldBank Knowledge Assessment Methodology (KAM): http://info.worldbank.org/etools/kam2005/

a distinction between its short-term, medium-term, and long-term priorities. The key question here is: 'Which statistics are essential for future decision-making?' Although many S&T data collecting agencies and statistical offices have reached a certain degree of sophistication during the last 15-20 years, addressing these issues requires a level of technical expertise that may need to be imported from abroad, and mechanisms for interaction with stakeholders that may need to be furtherdeveloped.

Developing countries need to build their own science and technology indicators

Stakeholder dialogue

Policymakers and stakeholders must work together to formulate feasible objectives, such as the development of better diagnostic tests for food safety and the establishment of targets to increase domestic food production. Statisticians and analysts will then be better able to design appropriate and effective surveys and questionnaires to provide information about the domestic S&T infrastructure for the agricultural sector (e.g., funding, number of researchers, etc.) and its related outcomes (e.g., new plant breeds) and socio-economic impacts (e.g., quality and quantity of local food delivered to the market).

Tailor-made indicators require a firm theoretical and empirical footing. Research into the relevant features of S&T resources, activities and results is likely to draw on a range of disciplines (e.g., economics, information science, sociology) and methods (e.g., surveys, modelling). Most of the higher education and science systems of the less developed countries lack critical mass in terms of facilities and support systems to develop and modify S&T indicators to local circumstances and for local applications. Therefore, dedicated research on S&T indicators for developing countries is often completed by experts based in more advanced countries, and is usually funded by international donors and agencies. Developing countries should invest in creating local or regional centres of excellence, where they can conduct independent research and offer expert advice, teaching and training on quantitative methods and statistical studies. Those conducting the surveys and the organizations being surveyed should develop 'best practices' throughout the process of data collection, data analysis and indicator development.

Shifting the focus from the immediate need to procure local S&T indicators to a 'strategic intelligence' focus that supports long-term capacity-building and knowledge production, will promote change from the 'passive' absorptive mode to the 'active' explanatory mode which is directly connected to decision-making processes. It is critical that we remain open-minded about the possibility to design indicators as interactive diagnostic tools that help pave the way for focused and structured dialogue between analysts, users and stakeholders, as this can ultimately lead to participatory settings for consensual evidence-based decision-making. In other words, S&T indicators should become facilitators as well as descriptors, bringing information, insight and long-term institutional commitment to the forefront.

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UNU-MERIT is the United Nations University Maastricht Economic and social Research and training centre on Innovation and Technology. It integrates the former UNU Institute for New Technologies (UNU-INTECH) and the Maastricht Economic Research Institute on Innovation and Technology (MERIT). UNU-MERIT provides insights into the social, political and economic contexts within which innovation and technological change is created, adapted, selected, diffused, and improved upon. The Institute's research and training programmes address a broad range of relevant policy questions dealing with the national and international governance of innovation, intellectual property protection, and knowledge creation and diffusion. UNU-MERIT is located at, and works in close collaboration with Maastricht University in The Netherlands.

INSIDE:

Policy Brief

Science and Technology Indicators for knowledge-based economies

Advantages and limitations of using statistics and measurements for S&T management and decision-making in developing countries

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