Science and technology indicators: new issues and challenges

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Over the years the methodologies for collecting data on science and technology (S&T) and developing indicators based on the analysis of the data collected have been useful to policy makers and the scientific community as the indicators help in developing evidence-based policies, assessing the impacts of investments in S&T and identifying the strengths and weaknesses in the innovation systems. However recently, there have been initiatives to develop better indicators, improve the methodologies and identify what is more relevant in terms of policy making. This article provides an overview of these debates and related developments in the Indian context, with a focus on access, equity and inclusion aspects of S&T policy and how to integrate them in S&T indicators.

Keywords: Access, equity, inclusive growth, indicators, science and technology.

COLLECTION of statistical information on science and technology (S&T) and developing various indicators based on the data and analysis has a long history dating back to the first and second decades of the last century. While at first the statistics collected was on industry, later the scope was expanded to cover S&T data in both the government and the private sector. In this article we provide an overview of the S&T indicators and recent issues on them. While the methodologies on S&T indicators have been refined further and the quantum and quality of data have increased manifold, the limitations of current S&T indicators are being acknowledged widely. At the same time, policy makers and society need new sets of indicators to assess the impact of S&T and to evaluate its contribution to sustainable development and transition to low-carbon economy. However, it is better for developing countries like India to engage with the development of new indicators as well as to improve their systems for collection of data and analysis than to wait for the developed nations to do so as this would help our policy makers to meet the objectives of the 12th Five-Year Plan which has, *inter alia*, inclusive growth and promoting ‘frugal innovation’ as an objective[1]. Under the Global Ethics in Science and Technology (GEST) Project, research on access, inclusion and equity issues in S&T policy making is being pursued[2]. We propose to use them to assess S&T policies, new technologies and the outcomes. For this purpose, access is defined as access to S&T, the fruits of S&T and access to information; inclusion is defined as inclusion of all sections of society as beneficiaries and meeting their needs so that they enjoy the fruits of S&T and also benefit as citizens/consumers, while equity is defined as equitable distribution and sharing of the fruits of S&T and directing S&T to facilitate this. Thus instead of using ‘universal’ values or ethical principles, we are using these three normative values to assess S&T policy.

Indicators and measurement

The USA was a pioneer in measurement of S&T and in the 1950s, the National Science Foundation (NSF) of USA developed the concepts and definitions in measuring S&T. The Organization for Economic Co-operation and Development (OECD) started its work on S&T measurement in the 1960s using to a great extent the methodologies and concepts developed by NSF. In 1973, NSF published for the first time a report titled ‘science indicators’. The objective was to develop a set of indicators that would reveal the strengths and weaknesses of S&T in USA and the capacity to perform and meet the national objectives was the tool used to assess this[3].

Since then, development of S&T indicators and developing methodologies to collect S&T statistics and analyse them has been a major issue in studying impacts of S&T and in assessing the innovation capacity of the nations. Over the years the deficiencies in concepts and methodologies have been debated and as a result well-developed methodologies and manuals on these are widely used now. But there are limitations in the methodologies and in terms of coverage, despite availability of manuals and methodologies, there are significant gaps[4].

Another issue is the relevance of these for developing countries. While UNESCO and OECD have been the major sources of S&T statistics, many countries have their

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national systems to collect and review statistics and develop indicators based on the data available. These indicators can be used for various purposes, including strengths and weaknesses of the S&T system, measuring the progress made, tracking developments, evaluation and review of programmes[5].

The OECD model for science, technology and innovation (STI) indicators studies the relationship between actors and activities. The activities that are studied include research and development (R&D), diffusion, invention and innovation. The STI indicators in the OECD model rely on R&D indicators. As R&D plays an important role in developing inventions and innovations, the importance given to it is understandable, but too much emphasis on R&D and excessive reliance on R&D data to develop indicators results in missing out on other important aspects. One of the reasons for this emphasis on R&D data is that the linear model of innovation gives much importance to R&D. According to Arundel[6], the predominance of supply-side R&D programmes in innovation policy is another reason for the excessive focus on R&D indicators.

The indicators can be categorized into different types depending upon the need for policy. If the policy focus is to capture the inter-linkages, then the indicators that capture them should be used. For example, to study the effectiveness of commercialization of innovation that arises out of R&D programmes sponsored by the government, the indicators necessary would include the number of patents obtained, licensing fee, co-patenting, spin-offs and collaborations, patents licensed and acquired, number of publications, number of publications cited in patents and the value of intangible assets, including knowledge assets. But typical indicators like R&D expenditure alone cannot capture the dynamics. From a policy perspective, the indicators can be broadly classified into three categories – structural, innovation and research indicators[7]. In this regard, the Oslo Manual, a code book of innovation indicators, is being continuously updated both in terms of number of indicators, coverage of data and linkages.

In the OECD Blue Sky Forum I held in 2006, it was observed that while the current indicators had some advantages, they did not fully capture the dynamics in economic and social change. In Blue Sky Forum II held in 2007, the importance of micro data analysis, greater emphasis on output measures of STI activities and the importance of using indicators were stressed, particularly measuring of social goals and social impacts of innovation[8].

In the subsequent publications and initiatives of OECD, the shift towards this perspective is obvious. For example, in, Measuring Innovation, A New Perspective, the recommendation is 'that survey and administrative data need to be aligned with aggregate economic measures and become a visible part of the System of National Accounts (SNA). The goal is to help recognize the important role of STI policies in promoting economic growth' (as cited in Gault)[9]. The OECD Innovation Agenda of 2010 had a measurement agenda which is being implemented. Some of the objectives of this Agenda are oriented towards designing new statistical methods and interdisciplinary approaches to data collection and improving the measurement of broader innovation and its linkage with macro-economic performance.

Thus the move towards developing new indicators is gathering momentum. It is important to understand that this activity is not confined to OECD or its member countries. In fact, the China Society for S&T Indicators organized a meeting in 2004 to review the process of indicator development. In fact, Gault[9] points out that initiatives have been taken up in South East Asia, Africa and Latin America to revise manuals and enhance coverage of data.

On the other hand, over the years these indicators have been standardized and many developing countries in Asia, Africa and Latin America have been using them. But a perusal of these indicators shows that while they provide important information and data, the classification into the three categories is not helpful because structure, innovation and research are linked and this differentiation is not suitable to capture the dynamics. According to the United Nations Conference on Trade and Development (UNCTAD), 'In India and China, although they count with an important amount of information about human resources in S&T (in all cases according the Frascatti and Canberra Manual recommendations), official innovation indicators are scarce, probably due to the lack of innovation surveys[10].'

Although the UNCTAD study points out the problems and issues about the lack of important data/information in S&T data in many countries, the key message is that the official innovation indicators in most countries do not capture the relevant data, particularly those on firms and innovation. A major shortcoming is that most of the data tell little about private-sector R&D. As a result, the data on S&T capacities do not reveal the actual picture or tell us about the potential.

One approach to solve this problem is to evolve an analytical framework that is relevant to policy makers in a region and collect policy-relevant statistics as advocated by the Asian Biotechnology Innovation and Development Initiative in the context of biotechnology statistics for Asian countries[11].

While the World Bank is not a major collector or source for innovation indicators, the knowledge assessment methodology developed by the World Bank provides the knowledge economy index (KEI) and the knowledge index (KI). KI is based on the premise that education, innovation and information and communication technologies (ICT) enable a country to generate, adopt and diffuse knowledge. While the idea behind both indicators is to help the countries to make a transition to knowledge-based economy, both KEI and KI can be used in conjunction with other traditional S&T indicators.

The National Science and Technology Management Information System of the Department of Science and Technology, New Delhi conducts National S&T surveys and studies the resources developed for S&T activities in India, besides conducting national innovation surveys and sectoral innovation studies. The major indicators captured in these include national R&D expenditure, sector-wise growth in R&D expenditure, R&D expenditure incurred by scientific agencies, agency-wise R&D projects, industry-wise R&D expenditure, human resources in terms of educational qualification (doctorate degrees), sector-wise distribution of R&D personnel, R&D personnel in terms of fields of specialization and qualifications, patents filed and granted and patents granted to Indians and foreigners[12].

While data on private sector R&D and foreign direct investment (FDI) can be extracted from databases like Prowess, National Institute for Science, Technology and Development Studies (NISTADS), some other institutions under CSIR also provide information on publications, citations, impact analysis and patents. Thus based on these, statistical data indicators can be developed. However, as pointed out earlier, these indicators have many limitations even in capturing the dynamics of innovation or diffusion of technologies. While data on patents and commercialization indicate the utility of the invention/innovation, they are not suitable to measure the equity, inclusion and ethical dimensions. Typical indicators of scientific outputs, impacts and other measures for innovation do not measure equity, inclusion and access dimension, although some indicators take into account the gender dimension.

According to a recent report from the National Academy of Sciences, USA[13]: 'Not everything that counts can be counted, and not everything that can be counted counts (an idea attributed to Albert Einstein). It seems clear that some outcome measures that reflect the importance of research and development (R&D) and innovation to society are illusive. For example, social well-being is difficult to measure, yet one of the key interests of policy makers is the return on investment of public funding for science and technology, for the good of the society[13].'

While acknowledging the import role played by S&T indicators, Freeman and Soete[14] caution: 'It is here, we would claim that the broadening of the STI concept to include "innovation" with its much stronger local links towards growth and development dynamics is particularly insightful, and contains significant new policy insights. From a global growth and development perspective, it is indeed no longer the impact of the transfer of industrial technologies on economic development which should be at the centre of the debate but rather the broader organisational, economic and social embedding of such technologies in a development environment and the way they unleash or block particular specific development and growth opportunities. That process is in all likelihood much more complex in a developing country context than in a developed country one[14].'

Instead this indeed is the time to think on these lines and arrive at the data needs and methodologies that can address these dimensions.

Devising new indicators

There are initiatives like access metrics index that include the access dimension and assess the effectiveness of technology transfer by universities[15]. At University of California, Berkeley, USA, social impact of the innovation and impact of the work on global disease burden are some of the indicators/measures that are being included in a study on performance measures[16].

However, devising new indicators is not an easy task. This issue is not unique to S&T indicators. For example, the idea of inclusive growth has been discussed by economists and methodologies are now being developed by the Asian Development Bank to develop relevant indicators to capture this[17]. But the understanding of what constitutes inclusive development is deepened only when different categories of inequalities are examined. The identification of horizontal and vertical inequalities as two categories helps in devising appropriate indicators to measure how inclusive the growth has been[18]. Thus while traditional socio-economic data and analysis are used with a focus on measuring inequality, new indicators have been developed and these can help the policy makers understand the dimensions of exclusion and devise corrective measures. The focus on inclusive growth arises out of the concern that raising inequalities can threaten the sustainability of growth in Asia.

In the debates on social impacts of S&T, the inclusion dimension has been more or less missing. While the gender dimension has received attention since the 1970s, both in terms of access to S&T education and opportunities, and involving women in all branches of S&T, inclusion and equity per se have not been given much importance[19]. Although policy documents and various statements have mentioned this, in terms of S&T indicators or assessing impacts in terms of inclusion, not much has been done. With respect to access to ICTs, there has been growing literature that unravels the different dimensions of the digital divide and access to the internet and ICTs[20]. Similarly, in the case of access to medicines, there has been an intense debate for more than a decade, and too much attention has been paid to the role of intellectual property rights and policies than to the access indicators per se.

But as the debates on the digital divide and inclusive growth demonstrate, there are no simple indicators to measure the lack of access and exclusion and the multi-dimension and cross-cutting aspects cannot be ignored. For example, poverty and gender are two important dimensions in any framework to describe exclusion, as these seem to be the major factors that restrict access to technologies, services and opportunities. Taking into account socio-economic considerations in decision making with regard to import of and using living modified organisms (LMOs) is a contentious issue, as identifying the relevant considerations and criteria for incorporating them in decision making is beset with methodological questions, assessing the impacts of LMOs in both the short term and long term, and *ex ante* evaluation of the impacts of the LMOs[21].

The current S&T indicators are not suited to capture these exclusions, although in some issues like access to fuel and water, the gender dimension has been well researched, but this has not looked at S&T aspects per se. Hence the challenge in developing S&T indicators can be met only if the different factors that cause exclusion or restrict access are understood and the linkages explored. This would involve developing new concepts that would help us understand the nexus between S&T and its impacts in terms of exclusion.

Policy perspectives on S&T: values and objectives

Science and Technology Policy Statements (STPS) are the policy tools for the Government of India for stating technology policy objectives and approaches. Since independence, three Technology Policy Statements (TPSs) have been issued in 1958, 1983 and 2003. Incidentally, the 1958 statement was called as the Science Policy Statement (SPS), while that of 1983 as TPS, and of 2003 as STPS. These three documents have provided overarching framework for S&T policy and have guided its societal linkages. The 2003 document has also acknowledged the importance of linking up modern technology with indigenous knowledge base. S&T was part of a framework for an independent industrial base to be achieved through planned economic growth[22]. This led to the creation of a huge institutional base of R&D funding organizations and research institutions.

One important driver for science in India was its equalization with progress and development. The first few Prime Ministers, particularly Jawaharlal Nehru and Indira Gandhi vigorously pushed science as a solution for most of India's challenges and through their direct participation at the Annual Sessions of the Indian Science Congress Association (ISCA), they made it a point to invariably push the idea that science cannot remain obvious to the miseries and drudgery of rural India. The TPS 1983 stated that the fundamental objective of pursuing science was to meet the basic needs of the people in terms of food, water, housing, health and education. There was equally high government support for S&T initiatives related to national security. As a part of this, nuclear and atomic energy received high priority, but India refused to divert any portion of her atomic resources for the preparation of atomic bombs[23]. One of the key features of India's drive was to explore policy options with S&T so as to achieve self-reliance in diverse areas of economic significance[24]. This was largely influenced by the role of S&T in national development as well as the social and economic achievements of the Socialist block. Given India's initial political commitment for non-alignment, a policy of self-reliance in S&T was a strong driver with emphasis on self-sufficiency in food and energy.

Although self-reliance is not a theme that one would encounter in S&T policy discourse today, the idea that India cannot afford not to develop capacity in critical areas and it should seize new opportunities in S&T still underscores the policy perspective. This is evident in the documents prepared for the 12th Five Year Plans on various topics, including the one on the Working Group to review the existing institutional mechanisms and structures as well as the management and governance of the S&T sector. According to the Working Group on cross flow of technology, 'This enabling role of technology towards society has been the chief propellant for its emergence as a vehicle for facilitating inclusive economic development envisaged in the Five Year Plans[25].'

The report of the Working Group to review the existing institutional mechanisms and structures as well as the management and governance of S&T sector states, 'XII plan envisages expanding the scope of Science and Technology to areas that would help realize full potential of national S&T efforts. A paradigm shift in the approach for the Science and Technology sector is therefore being contemplated which seeks to shift to an output directed development path strategy rather than the input driven model hitherto followed[26].'

The current indicators and data collected are based on the input model and hence they may not be able to fulfil the needs of 'an output directed development path strategy' and using S&T for inclusive economic development. These would need relevant indicators to measure the impact of S&T in terms of new criteria that have not been specified in the report. But in view of the initiatives in many countries and changes in the outlook of OECD on indicators and the shift in the approach for S&T, the time has come to develop new indicators as well as to change the existing system for data collection, analysis and developing indictors. In fact, it is the right time to embark on such a step so that India can make its unique contribution to the global efforts by developing indicators that meet the demands of S&T for the 12th Five Year Plan.

Conclusion

Developing S&T indicators has come a long way since the first two decades of the last century. Since the 1970s, the various attempts to take it forward have resulted in better understanding of impacts of S&T and have been helpful in devising relevant policies. Whereas their shortcomings and weaknesses are acknowledged by organizations like OECD, the initiatives to develop new indicators and improve existing methodologies are in progress in many continents. Bringing in inclusion and exclusion, equity and access dimensions in S&T indicators should be seen as another challenge that will enhance their relevance. The shift in the approach for S&T in 12th Five Year Plan provides an opportunity to develop indicators for an output-directed development path. Hence despite challenges, developing such appropriate indicators is a task that deserves to be given priority.

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