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EDITORIAL

Science in India: projections and prospects

India turns 75 on 15 August 2022. It is a good time to mark the progress we have made since independence. I shall restrict attention mainly to science (i.e. that which produces understanding) and only slightly refer to technology and innovation (that which produces utility). I shall use some of the simplest metrics, based on techniques. It was around 1975 that I began to read *Current Contents*, and particularly Eugene Garfield's *Essays of an Information Scientist*. A window into the history and philosophy of science opened up to me, apart from the main thrust on science evaluation and measurement.

As early as 1939, J. D. Bernal attempted to measure the amount of scientific activity in a country and relate it to the economic investments made. In *The Social Function of Science* (George Routledge & Sons, London, United Kingdom, 1939), Bernal estimated the money devoted to science in the United Kingdom using existing sources of data: government budgets, industrial data (from the Association of Scientific Workers) and University Grants Committee reports. He was also the first to propose an approach that became the main indicator of science and technology (S&T): gross expenditures on research and development (GERD) as a percentage of GDP. He compared investment of the UK at that time (0.1%) with that of the United States (0.6%) and USSR (0.8%), and suggested that Britain should devote (0.5–1.0%) of its national income to research. Since then, research evaluation at the country and regional levels has progressed rapidly, and there are now exercises carried out at regular intervals in the USA, European Union, OECD, UNESCO, Japan, China, etc.

Science is a socio-cultural activity that is highly disciplined and easily quantifiable. The output of science can be measured in terms of articles published and citations, etc. Inputs are mainly those of the financial and human resources invested in S&T activity. The financial resources invested in research are used to calculate GERD, and the human resources devoted to these activities (FTER – full time equivalent researcher) are usually computed as a fraction of the workforce or the population.

The first attempt known to me to correlate and rank the relationship between national scientific size and national economic size was made by Derek J. de Solla Price in 1965. For scientific size, Price used as a proxy the number of first authors from each country for papers listed in the first digital database for scientific publications in 1967. This was operationalized using search engines and digital computers as the Science Citation Index (SCI), the idea for which was mooted by Garfield in 1955. Articles were linked to journals, authors and their addresses. Since the electronic computers of the early 1960s had modest computing power and memories, early versions kept track of first authors and only a fraction of all scientific serials were covered in a selective and therefore elitist manner. These were called the SCI journals and were judged good enough to be tracked and archived in printed volumes. Thus, Price had privileged access to what was a list of top authors of articles in leading journals and their country-wise affiliations. For economic size, he used the gross national product (GNP) as was fashionable in those days. The correlation was positive – higher GNP implied a greater number of first authors. In terms of scientific size then, USA was ahead of the rest, followed by a cluster comprising the UK, the then USSR and Germany. This was followed by France, Japan and Canada. India and Italy came close together in another cluster. Thus, arguably, India had the eighth rank among these nations in terms of this proxy, 20 years after independence. Note that Price did not count the number of articles or the number of citations accruing to each nation at this time, but instead relied on a count of top authors, as it were.

Let us now fast forward to 2022. An interesting curiosity that had just emerged is a portal that uses a deceptively simple domain name: Research.com (Research.com – Leading Academic Research Portal). It allows us to list the top authors in 17 disciplines (at the time of writing, it is still a work in progress and some disciplines are yet to be covered). The ranking is based on data regarding scientific contributions since 2014 based on an examination of 166,880 scientists on Google Scholar and Microsoft Academic Graph. This is approximately 2% of the 8.85 million scientists on the planet (Schneegans, S., Straza, T. and Lewis, J. (eds), *UNESCO Science Report: The Race Against Time for Smarter Development*, UNESCO Publishing, Paris, 2021). The displays contain *h*-index, publications and citation values collected on 6 December 2021. The number of ranks varied: for biology and biochemistry, over 23,129 profiles were examined, while for mechanical and aerospace engineering, over 3637 profiles were examined. Ranking was then based on shortlisting using thresholds. The thresholds also varied, for example, it was 40 for biology and biochemistry, and 30 for mechanical and aerospace engineering.

It is possible to extract from these lists the percentage of top scientists from India discipline-wise. It ranged from 0.1% for ecology and evolution to 2.6% for aerospace and mechanical engineering. One can compute an overall average for all 17 disciplines at about 0.9%. Note that this must be compared with our population share (about 16–17%) or GDP share (about 3.5%). Our share of 0.9% of the global list of top scientists put us at the 16th rank. If we take the appropriate measures to be the number of top scientists on a GDP basis, we go down to 57th rank, and on a population basis, we slide further down to the 78th rank.

This is how it is conventionally, and admittedly facilely and simplistically done, and in this manner, we rank fourth globally (SJR – International Science Ranking (scimagojr.com)), after China, the US and the UK. Papers vary greatly in impact and quality. If these aspects are factored in, then India's ranks drop to 9th by citations, 21st by *h*-index and 168th (out of 234 countries) by impact (metrics computed by the present author using the SJR data for 2020).

We have followed the same trajectory that most countries have adopted, a legacy of poor investment in higher education and research, that led to both GERD and FTERs/million that are considerably sub-optimal. While the best practice targets a GERD that is 3% of GDP and FTERs that number about 0.5% of the population, for India it is 0.7% and 0.025% respectively. This is reflected in the numbers that come out when we look at figures such as highly-cited papers (not reported here), or counts of highly-cited authors (as shown here). Since most of India's GERD originates from the public sector and Government spending is only about 20% of GDP, it is the private sector that should chip in with another 2.8% (i.e. $4 \times 0.7\%$), or at least another 2.3% (to top up the total GERD to 3% of GDP). I would expect that this will target the technology and innovation sectors.

Technology and innovation, and higher education, are two of the 41 areas identified by NITI Aayog, Government of India, in its 'Strategy for New India @ 75' that requires a sharper focus to achieve our true potential. At the titular level, science is given a go-by here. It is subsumed in the two categories of technology and innovation, and higher education. A 2% GERD/GDP ratio is targeted, with equal shares from the public and private sector. A more realistic ratio will be 1 : 4, reflecting the 20% share of public spending to GDP. For a US$ 4 trillion economy, this will mean a dedicated share of 1.2 lakh crores of rupees for Government spending on the science component of science, technology and innovation (STI) alone. This will support roughly 400,000 scientists (my projection based on recent NIRF data) at Rs 30 lakhs per scientist to cover salaries, and all infrastructure and equipment costs. It is doable, considering that in the premier IITs almost as much as Rs 100 lakhs is spent on a professor (again, my calculations based on the recent NIRF data).

In the same tenor, one should expect New India Inc. to spend Rs 4.8 lakhs crores per year on another 400,000 FTERs (at Rs 120 lakhs per FTER per year) to pursue the technology and innovation component of STI that would lead to better patents, products, processes and technology transfers.

I have kept the total number of FTERs in New India at a modest 800,000 (the latest UNESCO Science Report puts the number for India in 2018 at about 340,000). China has about 1.9 million or more, while the EU and USA with much lower populations are around the 2.1 and 1.4 million mark respectively.

In summary, the task cut out for New India is perfectly achievable.

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