Table 4 and Figure 1 display the totalized input and output after the multidimensional input and output have been projected to an institution space.

Jawaharlal Nehru Centre for Advanced Scientific Research and the Institute of Chemical Technology are seen to be the best institutions from the productivity or efficiency point of view. They are followed very predictably by IISc and various Indian Institute of Technologies. Note that faculty size and expenditure are totalized into a single input term, and earnings and bibliometric output are totalized into a single output term for each institution. No private university finds a place in the list of top 20 here.

All the matrix operations are performed here with a cohort of 25 institutions; this restriction is due to the use of Excel spreadsheets alone. The matrix algorithms are general and if a computer algorithm is used, there need not be any restriction on the number of institutions assessed by this totalization procedure.

Research evaluation is a multidimensional problem as there are multiple input and output dimensions, and in the present case an institution space of many dimensions as well. Both research excellence (high-quality research output) and economic performance (earnings from sponsored research and consultancy) are taken into account, and this becomes a multidimensional problem with two input dimensions, two output dimensions and an institution space of 25 dimensions. The data making the connections are taken from NIRF 2017 and rearranged in matrix form. Here, we have used a protocol based on matrix normalization and multiplication so that totalized input and output measures can be obtained and comparative research evaluation can be made using NIRF 2017 data for 25 leading institutions in the country. The totalization process reveals that no private university finds a place in the top 20. The wisdom of letting 10 private universities join the Rs 10,000 crore club appears to be suspect.

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A modification to Hirsch index allowing comparisons across different scientific fields

The Hirsch index (h-index) was introduced by physicist Jorge E. Hirsch in 2005, originally to determine the 'quality' of theoretical physicists by citation counts of their publications. Since then, the h-index has been used as a measure of the scientific proficiency of scholars in various scientific disciplines, university departments, scientific journals, etc.

However, the h-index also has several drawbacks. First, it does not enable comparisons across different scientific fields due to different citation habits and the number of researchers active in different fields. Secondly, the h-index does not account for the age of scholars, thus discriminating younger researchers. Also, the h-index cannot distinguish different positions in the authors' list of collaborative publications and can be biased by self-citations. Therefore, many modifications of the h-index were proposed in the last decade[1–6].

Here we propose a novel and simple modification of the original h-index, the relative Hirsch index (h_r-index), which assigns each researcher a value between 0 (bottom) and 1 (top), expressing his/her distance to the top in a given field of science. By this 'normalization', scientists from different disciplines can be compared.

The Hirsch index assigns each scientist a positive integer value such that a scientist with an index of h published h papers, and each of them has been cited at least h times[7]. The number of scholars' citations is usually acquired from main bibliographic databases such as the ISI Web of Knowledge (WoK), Scopus, Google Scholar or REPEC (for economists). However, data from these sources differ due to different coverage[8]. Moreover, according to Meho and Young[9], SCOPUS and Google Scholar have limited coverage of publications prior to 1990.

A more precise definition of the h-index is as follows: Let f be the function assigning each publication i its number of citations, and let f be in decreasing order. Then the h-index is given as follows

$$h = \max_i \min(f(i), i). \tag{1}$$

Table 1 provides several indices derived from the h-index that avoid some drawbacks mentioned above.

The h_r-index of a given scientist active in a scientific field S is defined as his/her h-index divided by the current maximal Hirsch index in the field S

$$h_r = \frac{h}{\max_S h}. \tag{2}$$

Clearly, $h_r \in [0, 1]$.

The relative Hirsch index expresses a scholar's 'distance to the top' in his/her field, as $h_r = 1$ represents the top (the case of a scientist with the highest h-index in his/her field) and $h_r = 0$ the bottom (the case of a scientist with no citations).

Table 1. Selected citation indices

Index	Explanation
c-index	A scientist has a *c*-index *n* if *n* of his/her *N* citations are from authors who are at collaboration distance at least *n*.
e-index	This is a complement to the *h*-index; it takes into account citations beyond h^2 core citations[6].
g-index	The largest number such that the top /*g*/ articles received together at least $/g/^2$ citations.
m-index	The *m*-index (*m*-quotient) is defined as *h*/*n*, where *n* is the number of years since the first published paper.
o-index	This is determined as the geometric mean of the *h*-index and the most cited paper.
s-index	This accounts for the non-entropic distribution of citations[11].
*i*10-index	This provides the number of publications with at least 10 citations.

Source: author.

Now consider the following example: Andrei Shleifer is an economist with the highest *h*-index in his field ($h = 81$, according to WoK). The best physicist is Edward Witten ($h = 132$, WoK). Hence, when comparing a physicist with $h = 50$ ($h_r = 0.38$), and an economist with $h = 40$ ($h_r = 0.49$), the latter performs relatively better than the former, because he/she is closer to the top of his/her discipline.

It should be noted that several other papers attempted to overcome a problem with comparisons in different fields[10]. These measures were based on dividing scholars' citations by all citations or by the average number of citations in a given discipline, but these measures were found unsuitable. Further, they lack illustrative interpretation, such as distance to the top, as is the case of the measure proposed here.

Thus the measure proposed here is a simple one, not accounting for age of the scholar or position in authors' list; but it can certainly be modified. As many other alternatives to original *h*-index have been introduced in the last decade, further research may focus on their (dis)similarity and complementarity.

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