Is India playing in the minor leagues in science?

International team sports, especially where several competing teams take part, are best organized hierarchically in a pyramid of several leagues, with one premier league and many layers of divisions at lower levels, known as the minor leagues. Minor league teams tend to 'play in smaller, less elaborate venues, often competing in smaller cities, [have] lesser fan bases and smaller budgets'[1].

Because of its size and consequently its total output of publications, we tend to put India in the top ten of scientifically active countries. However, a careful study of key underlying parameters which are size-independent makes it clear that we are in the company of very small or backward countries. An immediate provocation for this is a comprehensive recent study[2] of the scientific outputs of six countries (republics of the former Yugoslavia – the Socialist Federal Republic of Yugoslavia): Serbia, Croatia, Slovenia, Bosnia and Herzegovina, Macedonia, FYR ('the former Yugoslav Republic of Macedonia'), and Montenegro. For the sake of comparison, the data from the Group of Eight (G8) countries, several developed European countries, India, China and three neighbouring Balkan countries (Albania, Bulgaria and Romania) were also tabulated. Data for the United States, Canada, the United Kingdom, France, Italy, Germany, Japan and the Russian Federation, and some European countries similar in population to ex-Yugoslav republics were included. Altogether, the analysis included 33 countries, with data sourced from internationally recognized bibliometric aggregators for a period of five years (2008–2012).

In this note, we rearrange the data from ref. 2 in the form of underlying size-independent parameters which indicate the size of input[3] (scientifically trained manpower and R&D budgets) and efficiency of scientific output of the R&D work force of a country[4,5].

Table 1 collates data from ref. 2 and reorganizes it so that the total R&D expenditure (GERD for gross expenditure on R&D) as a fraction of gross domestic product (GDP) can be related to the number of researchers in R&D per million of population. We focus attention only on the nine countries of the Balkan peninsula which seem to be in the same league as India. From this, a dimensionless leverage term[6], the indicator (GERD/GDP)/(researchers/population), which can also be expressed as (GERD/researchers)/(GDP/population), appears as a measure of the multiple of the per capita income of a nation that each nation is willing to invest in each of its R&D workers (total of salary and infrastructure costs). The fact that the same leverage term can be stated in two different ways indicates that the data in Table 1 can be reorganized as shown in Figures 1 and 2 as two alternative descriptions of the same scenario.

Figure 1 shows how the fraction of GDP spent on R&D (GERD) varies with the number of researchers as a proportion of total population for the selected countries. Prathap[3] proposed a notional ideal for developed countries – about 3% of GDP should be spent on R&D and about 0.5% of the population should be engaged in R&D activities, for a leverage of about 6.0. The Balkan countries are in this range but India is a gross outlier with a leverage that is more than ten times the ideal. Figure 2 shows the R&D investment per researcher in millions of US dollar varying with per capita income

Table 1. Data is collated from ref. 2 and reorganized so that the total R&D expenditure (GERD for Gross Expenditure on R&D) as a fraction of gross domestic product (GDP) can be related to the number of researchers in R&D per million of population

Country	No. of researchers/population	GERD/GDP	Leverage
Serbia	0.0010	0.004	3.38
Croatia	0.0016	0.008	5.23
Bosnia & Herzegovina	0.0002	0.003	15.21
Slovenia	0.0037	0.019	5.12
Macedonia, FYR	0.0006	0.004	7.18
Montenegro	0.0008	0.004	5.39
Albania	0.0001	0.002	10.20
Bulgaria	0.0015	0.005	3.50
Romania	0.0009	0.005	5.64
India	0.0001	0.008	61.31

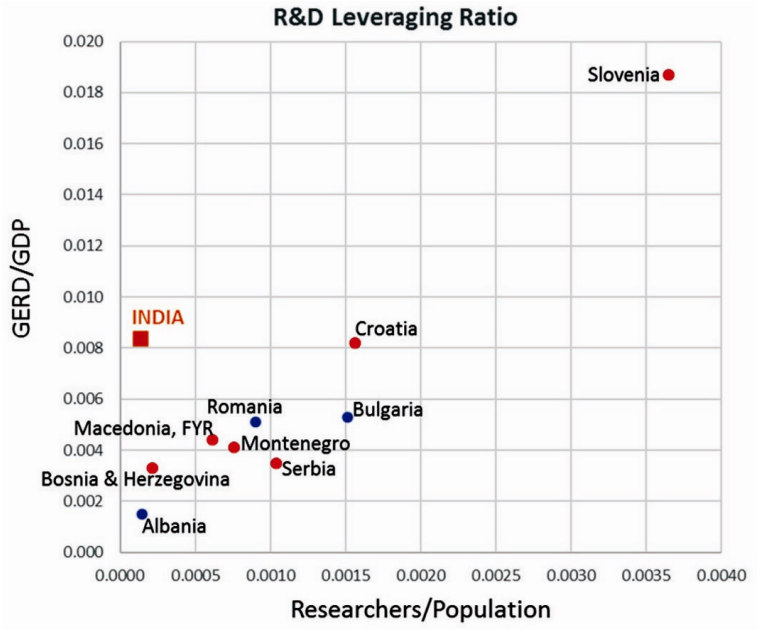

Figure 1. Fraction of GDP spent on R&D (GERD) varying with the number of researchers as a proportion of total population for selected countries.

Table 2. The number of researchers deployed by the country per million inhabitants and also the number of the number of scientific papers published per million inhabitants per year gives the average number of years a scientist takes to publish a paper

Country	Researchers/million inhabitants (2008–12)	Papers/million inhabitants per year (2018–12)	Time to publish
Serbia	1037	746.64	1.39
Croatia	1567	1303.74	1.20
Bosnia & Herzegovina	217	173.60	1.25
Slovenia	3653	2403.67	1.52
Macedonia, FYR	613	281.98	2.17
Montenegro	760	316.16	2.40
Albania	147	67.62	2.17
Bulgaria	1515	490.86	3.09
Romania	904	538.78	1.68
India	137	66.58	2.06

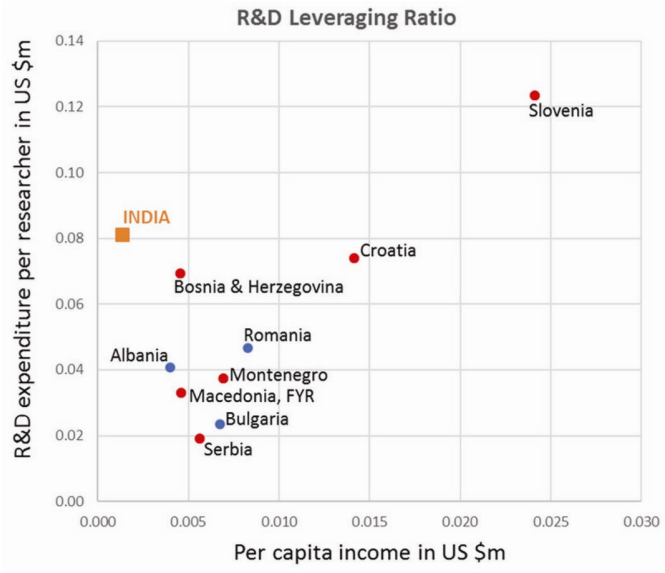

Figure 2. R&D investment per researcher in millions of US dollar varying with per capita income also estimated in millions of US dollar.

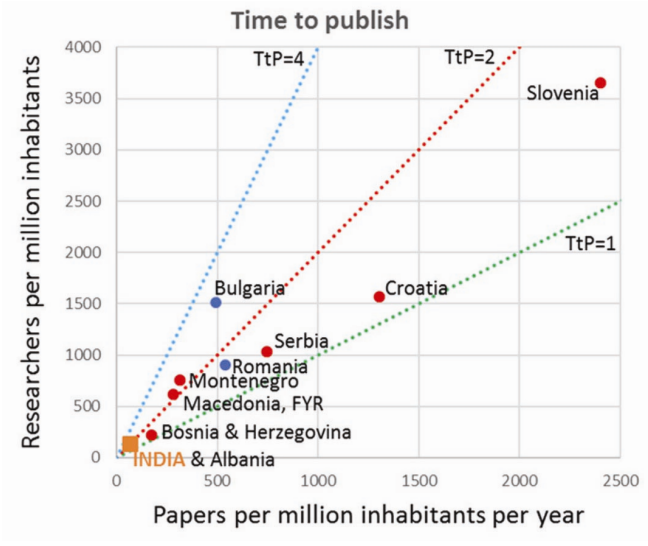

Figure 3. Time to publish (TtP) gives the number of years it takes for the average scientist to publish a paper.

also estimated in millions of US dollar. This ideal of a leverage of 6.0 is nearly met by all the Balkan countries and again, India now stands out prominently as having the highest leverage; in terms of its per capita income, its costs of academic research are very high and demands serious introspection.

So far, we have looked at the input side. The output side can also be measured by a simple but non-intuitive representation. A simple arithmetical Rule of Three, can be used to compute the time it takes for an average scientist to publish a paper[4,5]. This is a very simple proxy for measuring scientific efficiency. Table 2 gives the number of researchers deployed by the country per million inhabitants (say S scientists/million) and the number of the number of scientific papers published per million inhabitants per year (say P papers/million/year). The ratio $TtP = S/P$ has the units: years/paper/scientist. Time to publish (TtP) therefore measures the average number of years a scientist takes to publish a paper. Figure 3 displays this graphically. It is seen that even in this league, India is at the bottom of the league, sharing the spot with Albania, arguably the poorest of the Balkan countries in this analysis.

The conclusion is inevitable that India is in a minor league – it has a very low base of participants as measured by the proportion of scientifically active people in the population and very meagre budgets when taken as a percentage of GDP.

1. https://en.wikipedia.org/wiki/Minor_league
2. Roglić–Korica, V. and Milonjić, S. K., *J. Serb. Chem. Soc.*, 2017, doi:10.2298/JSC170417061R
3. Prathap, G., *Curr. Sci.*, 2014, **106**, 374–377.
4. Prathap, G., *Curr. Sci.*, 2006, **91**, 1438.
5. Prathap, G., *Curr. Sci.*, 2016, **110**, 2047.
6. Prathap, G., *Curr. Sci.*, 2010, **98**, 1182–1184.

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