The science race continues in Asia

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The geography of science, technology and innovation is changing. It is no longer that the United States, western Europe and Japan are the only key players. Asia is emerging in a significant way. Not only China and India, but also South Korea and Singapore are moving forward rapidly. The growth of science in these countries and investments in research made in Brazil and South Africa are leading to a new equilibrium in global science and technology.

Indeed, China was a mere spec in the atlas of science a little less than two decades ago, but today China has overtaken Japan, UK, Germany and France to become second only to the US in the number of scientific research papers produced annually, as seen from both the *Web of Science* and SCOPUS (Table 1). As the Global R&D Report[1] of Battelle and *R&D Magazine* points out, former Third World countries are assuming major roles in the sourcing and performance of R&D, and offshore outsourcing forces a more even distribution of effort throughout the world. In 2006, in terms of PPP (purchasing power parity), China was the second largest investor in R&D (gross domestic expenditure on R&D or GERD = 141.7 billion US dollars), and India the sixth (GERD = 38.85 billion US dollars). The United States continues to occupy the first position with a 2006 GERD of 343 billion US dollars.

However, as the dollar is sinking and the Indian rupee is gaining in strength and cost of living in India is growing at a frenetic pace, India needs to invest a lot more in R&D, in terms of both funds and research personnel, to retain and hopefully improve its position. That is precisely the course India is opting for. At the annual meeting of the Indian Science Congress Association held in early January 2008, Prime Minister Manmohan Singh made several announcements that were manna for the science establishment. Apart from the threefold increase in R&D investment recommended by the Planning Commission in its Eleventh Plan document, Singh announced his Government's intention to set up five new Indian Institutes of Science Education and Research, eight new Indian Institutes of Technology, 20 new Indian Institutes of Information Technology, and 1600 polytechnics. These initiatives, welcome as they are, have come two or three decades too late, according to S. S. Krishnamurthy, one of India's leading inorganic chemists. As pointed out by T. Ramasami, Secretary, Department of Science and Technology, Government of India, our country is growing slowly compared to global trends. India has a paltry 157 researchers for every million people compared to 633 researchers per million people in China, 3222 in Germany, 4526 in USA, 5085 in Japan, 5171 in Sweden and 7431 in Finland. The new institutions that India is planning to set up will take at least a decade to make a difference and one is keen to see how they are going to meet the challenge of attracting good faculty. In the mean time it is likely that foreign companies may set up many more R&D centres in India and attract the cream of young Indian researchers.

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In 2002, *Current Science*[2] carried a short article showing that the People's Republic of China was racing ahead in science as seen from the number of papers published annually and indexed in *Science Citation Index*, *Chemical Abstracts*, *PubMed* and *MathSciNet*, and that science in India was stagnating. The article also showed that science was growing at a fast pace in South Korea and Brazil, even if not at the same pace as in China. The article was largely ignored by the nation's science administrators. Indeed, some feeble attempts were made to argue that what was said in the *Current Science* article was not true and that all was reasonably well with science in India.

To be fair, a few years later both the immediate past President and the current President of INSA, New Delhi, have mentioned in private conversation that the 2002 *Current Science* article rang the alarm bell, although corrective action did not follow immediately. It took some time for the fact to become widely acknowledged and its implications articulated. 'The fact, however bitter, is that India's contribution to science has come down enormously. We are not comparing ourselves to the US or Japan anymore, but to

Table 1. Output of research papers from selected countries

	China			India			South Korea			Brazil		
Year	Doc	Rank	C/d	Doc	Rank	C/d	Doc	Rank	C/d	Doc	Rank	C/d
1996	26,853	9	4.37	20,106	13	6.13	9,669	20	8.55	8,497	21	9.42
1997	29,871	9	4.55	20,694	13	5.67	11,876	16	8.17	10,167	20	8.45
1998	31,887	8	4.24	19,755	13	5.78	11,579	16	8.88	10,357	20	8.49
1999	36,180	8	4.58	22,578	12	5.30	14,645	16	8.54	12,196	18	7.95
2000	42,250	6	4.29	22,788	12	5.17	16,321	15	8.07	12,857	17	7.36
2001	55,850	5	3.22	23,362	12	4.34	17,930	14	6.63	12,708	19	5.84
2002	55,400	5	3.32	24,838	12	3.82	18,740	14	5.74	14,590	16	4.93
2003	66,748	5	3.26	28,741	12	3.31	23,406	14	5.00	16,978	17	4.31
2004	98,577	2	1.92	30,258	12	2.26	27,200	14	3.14	18,695	18	2.93
2005	148,221	2	1.92	34,849	11	1.00	32,488	13	2.88	21,239	17	1.29
2006	166,205	2	0.12	38,140	10	0.19	34,025	12	0.22	25,266	15	0.22
1996–2006	758,042			286,109			217,879			163,550		

Source: SCImago Journal and Country Rank (based on data from SCOPUS), courtesy Prof. Félix de Moya, Grupo SCIMAGO, Spain. Doc, Number of documents; C/d, Citations per document, computed for the 11-yr period. Note the decrease in value for later years.

Table 2. Research output of different countries in 2006 (data from SCImago, courtesy Prof. Félix de Moya)

Rank	Country	Doc	Cit/doc
1	USA	340,268	0.56
2	China	166,205	0.12
3	UK	107,528	0.50
4	Japan	97,073	0.33
5	Germany	95,310	0.50
6	France	67,652	0.44
7	Canada	56,571	0.49
8	Italy	54,298	0.43
9	Spain	41,914	0.37
10	India	38,140	0.19
11	Australia	37,836	0.45
12	South Korea	34,025	0.22
13	The Netherlands	31,332	0.59
14	Russian Federation	26,687	0.17
15	Brazil	25,266	0.22

Cit/doc, Citations to 2006 papers in 2006.

China and South Korea', said C. N. R. Rao, JNCASR, Bangalore, in June 2004. In August 2006, the Science Advisory Council to the Prime Minister acknowledged in public that China was racing ahead in science and that India has been left far behind. The Chairman of the Council, Rao is reported to have written to the Prime Minister that, 'Indian science will be finished in the next five years. Our universities have dried up'. Fortunately, this time around the Government, science administrators and the media paid immediate and abundant attention. The Government committed to increase funding for S&T research and it seems to have helped: Data on annual output of journal articles for recent years indicate a perceptible increase in the number of research papers from India. But as science in China has continued to grow at a much faster pace, India is still going through a phase of relative decline.

Table 1 presents data on the number of documents from India, China, South Korea and Brazil, and their citation rates from SCImago[3] based on SCOPUS, a multidisciplinary database which indexes a larger number of Indian and world journals than the *Science Citation Index Expanded* part of the *Web of Science* (not necessarily good for international comparisons of quality research output). India's research output stood at 20,106 papers in 1996 for the country to be ranked 13th in the world. With 22,578 papers, India advanced to the 12th rank in 1999. India held the 12th rank until 2004, and in 2005 jumped to the 11th rank and in 2006 to the 10th rank. In these two years, the number of papers from India increased by 4591 and 3291 respectively. China started off with rank 9 in 1996, moved onto rank 8 in 1998, jumped to rank 6 in 2000, rank 5 in 2001 and rank 2 in 2004. Today China is second only to USA in the total number of papers published annually.

Table 2 provides data on the numbers of papers published in 2006 by the top 15 countries and their citations per document. Between 2003 and 2004, China's research output surged from 66,748 to 98,577 papers, a phenomenal 47% increase. The number rose by more than 50% to 148,221 in 2005 and then to 166,205 in 2006. Compared to China, India's growth is rather modest. But when it comes to citations per paper, India has scored uniformly higher than China, although way behind the G7 countries.

During the 11 years when India moved up three ranks, from 13 to 10, South Korea moved eight ranks (from 20th in 1996 to 12th in 2006) and Brazil moved six ranks (from 21st with 8477 documents to 15th with 25,266 documents). Both South Korea and Brazil have a much higher rate of citations per document than India.

Let us now look at how India fares in selected areas of great current relevance relative to China and South Korea. In the field of fuel cells, as seen from the *Web of Science*, during 2001–07 researchers from India had published 374 papers compared to 2017 from China, 1834 from Japan, and 979 papers from South Korea. The US was the obvious world leader with 3865 papers. In the field of nanoscience and nanotechnology, in the two years 2006 and 2007, India had accounted for 3446 papers compared to 18,112 from China, 8476 from Japan and 5121 from South Korea. The US had accounted for 22,959 papers. Japan accounts for a large number of patents.

China is determined to do even better in the future. In its 'Medium-to-Long Term Plan for Development of Science and Technology' released in January 2006, China has articulated its resolve to become an innovation-oriented society by 2020 and a global leader in science and technology by 2050. Over the next 15 years, China plans to increase its investment in R&D from 1.23% of GDP in 2004 to 2.5% (of a much larger GDP) in 2020. The two goals set by China are to become one of the top five countries in the number of patents granted for inventions and for Chinese authors to be among the world's most cited.

Since 2002, the gap between China and India has increased considerably, despite a modest increase in India's output of research papers. What is more, even a small country like South Korea is catching up with India and doing better in some niche areas. It is important at times like these to be alert to signals, whichever quarters they may come from and act quickly and decisively.

An American science policy analyst observed a year ago, that 'The real question is: Will India revise its research policy to compete head-on with China? From the numbers, India has the demographics. It is a much younger society than either China or USA, and has a much larger birth rate than either. It has the potential to be a major player in global S&T. It has a well-trained cadre of professionals. When I went to graduate school in the early-mid 60s, invariably the best students were those from India. Unfortunately, for India, most probably stayed in the USA. The raw materials are there; if India can only exploit them as China appears to be doing, they will become a force with which to be reckoned!'.

As Rao has been pointing out, a lot depends on our ability to attract bright young students to research, literally weaning them away from more lucrative avenues such as information technology and the stock market.

1. Global R&D Report 2008, sponsored by Battelle and *R&D Magazine*, September 2007.
2. Arunachalam, S., *Curr. Sci.*, 2002, **83**, 107–108.
3. http://www.scimagojr.com/countryrank.php?area=0&category=0&region=all&year=2006&order=it&min=0&min_type=it

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