

Editorial

India, China, and the world

Two just published reports *viz.*, The Science and Engineering Indicators 2010 (S & E-10)¹ brought out by the National Science Foundation, USA and the reports on India and China^{2,3} by the Thomson Reuters (earlier Thomson Scientific) could well trigger another *us vs them* debate in India⁴. New data on global trends in science and technology reconfirm that China is surging ahead at a scorching pace and is miles ahead of India. Having left behind EU-27, Japan *etc.*, sometime back, China is all set to occupy the top slot from the USA. Other data and trends from the Asian countries suggest formation of a new Asia-Pacific S & T order.

Here are some highlights. The global R & D (2007) has crossed the US \$1 trillion mark with the USA accounting for over a third (US\$ 368 billion). The U.S. investment broadly matched the combined R & D expenditures of the next four largest economies: Japan, China, Germany, and France. The R & D expenditures of the Asia-8 (China, India, Japan, Malaysia, Singapore, South Korea, Taiwan, Thailand) surpassed the EU-27, ranking next to the USA. India's investment on R & D in 2007-08 is a modest US\$ 24 billion, about a fourth of China's US\$ 104 and a mere 6.52 per cent of the US. These comparative allocations have not changed much since. The rate of increase of R & D investment of most developed north was small - US and the EU averaged about 5-6 per cent annual increase (1996-2007). The Asia-8, on the contrary, maintained an annual average increase of about 10 per cent with China recording a staggering 22 per cent, a trend that was evident as early as 1980s. With the EU, Japan, USA *etc.*, in the grip of economic recession, it is unlikely the trend is going to change in the near future. What is more, according to reports, during the 11 Plan "independent innovative capabilities (of China) shall be enhanced, with spending on research and experiments rising to

2 per cent of GDP"⁵. In contrast to other members of Asia-8, only India, despite high GDP and over 8 per cent annual growth rate, could not adequately invest in S & E which is reflected in the rather average overall S & E performance.

The total global Science and Engineering (S & E) article output (2007) in the 10500 journals indexed by the Web of Science database was 758,142, a modest rise from 740,270 papers during 2006¹. The USA expectedly contributed to about a third (209,694) of these papers followed by the EU (245,851) and Asia (167,388). China with 56806 papers beat all traditional rivals - Japan (52895), the UK (47121) and Germany (44407). Significantly, the proportion of publications of the major scientific super-powers like the US, EU and Japan has been declining relative to the growth of the emerging nations like China, India and Brazil. Over the last five year period, the US barely managed to retain its 1995 share (34.16%) in 2007 (34.21%); the share of the EU dropped from 34.27 per cent in 1995 to 27.70 per cent in 2007 and Japan's share plummeted from 14.72 per cent (1995) to 6.99 per cent (2007). The S & E article output of Asia (China, India, Japan, Malaysia, Singapore, South Korea, Thailand, Taiwan and Vietnam) as a whole doubled from 11.7 per cent in 1995 to 22.03 per cent in 2007 and of the Asia-8 from 3.5 per cent (1995) to 7.38 per cent (2007). India's share of global S & E papers doubled from 1.6 per cent in 1995 to 2.37 per cent in 2007. But China is a real winner with a staggering rise in both absolute and relative terms: a six fold rise from 9601 (1.59 %) in 1995 to 56806 (7.51%) in 2007. In fact, India's publication output was almost stagnant during 1995-98 and took off only after 2001. India was in the 12th place in 1995 and it took about 13 years to reach the 11th place in 2008. China, on the other hand jumped from the 14th place in 1995 to the 2nd place by 2007. If the current

'relative growth' trajectory is maintained (setting 1981 output as 100), India is expected to catch up with the G-8 countries within 7-8 years and perhaps overtake them around 2015-2020². But it is very unlikely, if not impossible, for India to catch up with China.

Growth in S & E article output across these five countries/regions has also been uneven. Twelve-year growth rates in the mature economies of the U.S. (0.7%), Japan (1.0%), and the European Union (1.9%) have been lower than the rapidly growing economies of the Asia-8 (9.0%) and China (16.5%). Only Israel and Canada managed to hold on their own over these years.

The total number of researchers grew from about 4 million in 1995 to over 5.8 million in 2007 with India's share of just 154,000¹. Similar to the trend in funding and publications, the growth was more rapid in emerging than in the industrialized countries. The combined U.S./EU-27 share of researchers declined from 51 to 49 per cent while Japan's share dropped from 17 to 12 per cent. South Korea, Taiwan, China, and Singapore, on the other hand, together doubled their share from 16 to 31 per cent between 1995 and 2007. The US and the EU each accounted for about 1.4 million researchers contributing to about 49 per cent of the total but less than the 51 per cent share they held a decade earlier. The number of researchers from China more than doubled over the same period, from just over half a million to more than 1.4 million also boosting its global share from 13 to 25 per cent. The US and the EU showed moderate annual growth of about 3 per cent in S & E personnel between 1995 and 2006 and below 1 per cent for Japan. Growth in the Asian region (except Japan) ranged from 7-11 per cent with China averaging nearly 9 per cent growth. Currently, every fourth researcher in the World is from China.

The top ten areas from India for the period 2004-08 were Chemistry, Agricultural Sciences, Material Science, Pharmacology and Toxicology, Plant and Animal Science, Physics, Engineering, Geosciences, Space Science and Microbiology². Over 10 per cent annual growth was seen in Plant and Animal Science, Space Science, Agricultural Science, Physics, Geosciences and Chemistry. Two areas in life-sciences Microbiology and Pharmacology & Toxicology, showed significant rise perhaps reflecting India's strength in the area of drugs and pharma. The pharmaceuticals industry accounts for about 45 per cent of India's private sector

R & D. Computer Science, actually accounted for the highest increase between the two intervals, showing more than 100 per cent rise. Significantly, both the pharma and IT sectors are largely private sector driven.

Where is China heading? There seems to be a clear focus on research in the physical sciences and technology, with Materials Science, Chemistry and Physics being dominant areas³. Perhaps understandable considering China's traditional core strength rooted in heavy industry and primary manufacturing. But there is a clear shift towards newer areas of technology over the last decade. Engineering and Material science had twice the publication output while Agriculture, Microbiology, Molecular Biology & Genetics and Immunology showed a 3-4 fold rise. There were continued investments in Materials and related physical sciences to ensure China's domination in the manufacturing sector. Papers in agriculture, immunology, microbiology, molecular biology and genetics should provide China with the necessary innovation-impetus to modernize the industry with cutting-edge technology to catch-up with neighbours Taiwan, South Korea and Japan. There was also emphasis on medical research especially clinical trials where India, incidentally, is strong. The number of PubMed articles by Chinese authors have shot up by nearly tenfold from 4,891 in 1999 to 46,842 in 2008. The number of paper focusing on clinical trials also showed a six-fold rise from 190 in 1999 to 1264 in 2008⁶. In the area of clinical medicine, China is all set to overtake the USA⁶. Regenerative medicine is another emerging area in China (see below).

India's major international collaborators over the past 10 years were the US, Germany, the UK, Japan and France. India is forging academic alliances with Japan, South Korea, Singapore and Taiwan. The India-China S & T linkages are distinctly on the wane. China's major international research partners during 2004-08 were the USA, Japan, Germany, the UK and Canada. While linkages with Asia-Pacific partners - Singapore, Australia, South Korea and Taiwan are getting stronger, India does not even figure in the top 15 collaborating countries. China's linkages with South Korea and Singapore have trebled over the last 5 years with the University of Singapore being the top international collaborator, ahead of the US and Japanese institutions.

Thus, a new clear 'look east' shift for both China and India is evident with strong linkages being forged

with neighbours in the Asia and the Pacific in preference to the traditional trans-Atlantic research axis⁷. Strong linkages are emerging between China and Japan, South Korea, Singapore and Taiwan. It is perhaps the turn of G-8 to invest in their relationship with countries like India and China before the opportunity to engage in such links with a reinvigorated sub-continent is pre-empted by equally innovative regional neighbors⁷. In the newly shaping scientific geography of research, there is going to a distinct shift in regional balances, with Europe and the USA would want to be partners in the coming years⁷. It is already happening with MNCs setting up their R & D centres in India and China⁴.

The citation-landscape is also changing with global citations to U.S. articles declining from 36 per cent (1992) to 27 per cent (2007) with the Asia's share increasing from 37 to 41 per cent¹. While, Japan's citation share fell from 31 to 17 per cent, China's rose from 2 to 12 per cent and Asia-8's from 5 to 12 per cent. Significantly, citations in US articles to their own papers has dropped from 69 per cent (1992) to 60 per cent (2007), an acknowledgement of work done outside the shores of the US.

But the real driver of a nation's economy remains value-added knowledge and technology, especially of the cutting-edge kind. This is where the USA, Japan and the EU continue to be way ahead of the rest as reflected by the total number of patents¹. The US Patent Trade Mark Office (USPTO) granted a total of 64888 patents in 2008 up from 21,621 in 1995. The share of US was 31404 (48.4%) up from 10334 (47.79%) patents granted in 1995. The entire Asia-9 countries (India, Indonesia, Malaysia, The Philippines, Singapore, South Korea, Thailand, Taiwan and Vietnam) accounted for just 8674 patents in 2008. India's share in 1995 of 6 (0.27%) shot up over 50 times to 347 in 2008 which is a mere 0.5 per cent of global output. US patents awarded to China also rose over 40 times between 1995 (13) and 2008 (607) but still less being only 0.91 per cent of total. Japan's share of US patents granted, on the other hand, saw a steep fall from 35.74 per cent (7729) in 1995 to 24.36 per cent (15200) in 2008. The US, EU and Japan account for over 85 per cent of US patents granted in 2008. The share of Asia-9 rose from 3 to 10 per cent between 1995 and 2008, mostly on the strength of South Korea and Taiwan.

Most middle income countries over the last decade have been aiming to become knowledge-intensive economies through increased investments in world-

class S & T infrastructure, sustained efforts on high quality S & E education, exposure to institutions in the West, promote 'reverse brain drain' *etc.* Data show the emergence of Asia-9 as the new global world S & T leader. Unsurprisingly, the growth of articles in engineering research generally outpaced the science disciplines over the past 20 years¹. Like the growth of engineering papers in Asia was almost 10 per cent (China 16%) as compared to science disciplines while the US and Japan averaged less than 2 per cent increase. Another significant feature of the growth of Asia-8 is the huge investments by the industry and lesser Government controls. In common with the US, EU and Japan, industry now supports close to 60 per cent of total R & D in the Asia-8, especially in China, Singapore, and Taiwan. But the global share of knowledge-driven economy continues to be dominated by the US, EU and Japan with Asia-9 (and China) fast catching up.

Clearly, China has not looked back from the economic reform initiatives set into motion from 1980, emerging from a poor developing country to become the second-largest economy in the world outpacing everyone else. Currently over half of the nation's technologies like atomic energy, space science, high-energy physics, biology, computer science, and information technology, have reached or are set to touch the best international benchmark^{3,7}. Other areas are also growing at a scorching pace with new initiatives being announced regularly. As many as 20 venture capital funds worth US\$1.3 billion are just being created by the National Development and Reforms Commission, China to speed up establishment of spin-off companies to commercialize technologies⁸. This support is to be shared between the Central and local governments and private sources. China is also all set to launch a massive US\$ 3.5 billion research initiative on genetically modified (GM) crops to help address the growing food demands⁹. Chinese scientists have also developed several strains of GM rice, soybean and corn. With Premier Wen Jiabo firmly backing the GM technology, this new initiative is expected to spur commercialization of GM rice and other GM crops⁹.

But for China new problems are emerging with the unforeseen growth, and inconvenient questions being raised on quality and credibility of science being reported in learned journals. A just published report claims that about a third of Chinese researchers admitted to unethical practices like plagiarism, fabrication and falsification of data¹⁰. The UK-based

Acta Crystallographica Section E has in December 2009 retracted 70 published crystal structures reported from Jingtangshan University, the Jiangxi province, that were detected through a software that tracks errors. The widely reported incentive scheme of the Chinese Government of cash prizes, housing benefit and other perks to papers published in high impact journals⁴ is reportedly responsible for the increasing dubious practices. Ghost writing papers based on non-existing research also has shot up 5 times since 2007 and has become a huge US\$160 million market¹⁰. The anxious editors of the *Acta* are checking the authenticity of all the 200,000 structures, half of which have come from Chinese laboratories over the last five years¹⁰. Another cutting edge-science that got embroiled in controversy is stem cell research and therapy. According to Halla Thorsteinsdottir, editor of *Regenerative Medicine*, of the 1116 papers on stem cells in 2008, about a fifth have come from China¹¹. Thorsteinsdottir's team visited various hospitals, stem cell labs, *in vitro* fertilization clinics *etc.*, in China and spoke to 47 experts from all sectors including the Government. She claims that hundreds of hospitals in China are offering unauthorized stem cell therapies with the Government turning a blind eye. Despite stem cell regulations announced last May, the enforcement in China is slack¹¹. What is more, many Chinese researchers believe that regenerative medicine, an area where China fast emerging as a global leader, could well fetch them a Nobel prize¹¹.

India and China started the process of modernization of S & T almost at the same time with strong State support. While China may have stormed ahead with associated growth pangs, the slow and measured increase may well have helped India build up and put a stronger regulatory and other systems in place for facing newer challenges. Like in the areas of GM crops and stem cell research and therapy, appropriate guidelines and rules are framed alongside the growth of their R & D in India. More importantly, the Indian Government has evolved a system of transparency for wider public participation in areas as the GM crops

and stem cell therapy which at once have significant economic and public health implications. The poor averages on nearly all counts reflect not the ability of Indian mind to perform and excel but the prevailing environment that stifles innovation, encourages mediocrity and rewards cronyism. It would be nice if the anxieties expressed by the Prime Minister at the 2010 Indian Science Congress about improving the environment for scientific research, promoting systems for rewarding excellence, revamping the current S & T administration system mired in red tape, among other ills, are addressed fast.

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References

1. National Science Board 2010. Science and Engineering Indicators. Arlington, VA: National Science Foundation (NSB 10-01); 2010.
2. Adams J, King C, Singh V. *Global Research Report India: Research and Collaboration in the New Geography of Science*. Leeds: Evidence Ltd; 2009.
3. Adams J, King C, Ma N. *Global Research Report China: Research and Collaboration in the New Geography of Science*. Leeds: Evidence Ltd; 2009.
4. Satyanarayana K. India & China: Time to catch up. *Indian J Med Res* 2006; 124 : 597-600.
5. *Think smart: R & D and innovation in China*. London : Thomson Scientific and Health care, The Economist Intelligence Unit; 2006.
6. China rapidly catching up in research impact. Available from: <http://www.physorg.com/news/180269823.html>, accessed on December 17, 2009.
7. Adams J. Get ready for China's domination of science. *New Scientist* January 6, 2010.
8. Cyranoski D. China moves to help high-tech firms. *Nature* 2009; 462 : 149.
9. Stone R. China plans \$3.5 billion GM crops initiative. *Science* 2008; 321 : 1279.
10. Qiu J. Publish or perish in China. *Nature* 2010; 463 : 142-3. doi:10.1038/463142a.
11. Anon. Stem cells in China - Wild East or scientific feast? *The Economist* January 14, 2010.