Indian science slows down – V: The slack in the university sector

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One of the reasons for the poor performance of Indian science since Independence has been the slack in the university sector. In this commentary, some hard evidence is collected to show how the university sector is performing relative to the other sectors in the S&T enterprise.

There has been anecdotal evidence for some time that one of the reasons for the poor performance of Indian science since Independence has been the slack in the university sector. The most recent editorial in *Current Science*[1] addresses this point.

It will be interesting to collect hard evidence to see how the university sector in India is performing in basic research compared to the autonomous research institutions of the Government sector and the industrial (or corporate) sector.

In a communication to SIGMETRICS@listserv.utk.edu, Loet Leydesdorff has given an update for 2002, of the figures he had provided for 2000 in his paper on what has come to be called Triple Helix Dynamics; the role that university, Government and industry play in furthering research and development[2]. To the best of my knowledge, these are the best data we have so far which try to assign numbers to the relative activity of the three major sectors that contribute to basic research, based on the number of published research papers in the *SCI* database (Table 1). The next step is to compare the various sectors for their share to the total scientific output and then normalize this with respect to the world norm. This is best done as shown in Table 2 using the Index of Activity (IOA) approach. In Table 2, the data in the first row (for all countries) are obtained as a percentage share of the various sectors. This is taken as the benchmark. The IOA for each sector in a country is then obtained by comparing the percentage share of that sector for that country with the global norm. The IOA for sector *A* in country *X* is defined as:

IOA_{AX} = (Papers from sector *A* in country *X*/Total papers in country *X*)/(Papers from sector *A* in the world/Total papers in the world).

This allows us to draw, as David King noted[3] in his study, which was done for various disciplines, now, in this instance, an indication of sectoral strengths and weaknesses based on international comparisons, through this national and sectoral disaggregation process. Comparing one sector across different countries is more meaningful than comparing sectors only within a country, and once the IOA is obtained, it is easy to compare sectors within a country. A value of 1 for the IOA indicates that the emphasis for that sector in the country is in line with the prevailing world norms. The numbers in Table 2 convey most of what is needed to be said. It is clear that in Russia, France and India, the Government sector does far more basic research than is expected of the world norm. Curiously, Japan stands out from the rest as a country where the industrial sector does a disproportionately large share of basic research, and upon closer examination of the inter-sectoral interaction figures, it is seen that this is obtained because Japan shows far greater inter-sectoral co-operation (UI, IG and UIG) than any other country.

To those who are more comfortable with pictures than words and numbers,

Table 1. Raw data for the number of papers published in *SCI* journals in 2002 provided by Leydesdorff (a communication to SIGMETRICS@listserv.utk.edu on 12 August 2004)

SCI 2002	Total	University (U)	Industry (I)	Government (G)	UI	UG	IG	UIG
All	683222	556370	41840	234843	17095	116782	4626	5664
USA	238676	206813	18193	68835	7274	40650	1777	2732
EU	250395	204531	11011	99830	4586	54617	1400	2187
UK	66544	53972	3617	26673	1569	14263	360	763
Germany	59630	50319	2925	24364	1181	14986	405	703
France	39973	26663	1826	25721	431	12214	422	585
Scandinavia	30437	26283	1431	13064	592	8757	170	411
Italy	29795	26680	956	10863	374	7609	79	321
The Netherlands	17865	15927	859	6762	328	4663	78	307
South Korea	14931	13163	996	4904	533	3115	118	183
Japan	68338	57345	9892	22776	4303	13297	1113	1481
People's Republic of China	28913	24328	728	11103	381	6408	111	173
Taiwan	9572	8608	295	3757	183	2772	15	59
Singapore	3411	2978	202	1085	110	622	16	53
Russia	20723	11486	443	15960	81	6637	134	157
India	12570	7140	459	7486	109	2180	92	67
Brazil	10888	9584	386	3368	189	2054	45	81

Total is obtained as U + I + G – UI – UG – IG – 2UIG.

Table 2. Index of activity comparison for various countries

SCI 2002	University (U)	Industry (I)	Government (G)	UI	UG	IG	UIG
All	0.8143	0.0612	0.3437	0.0250	0.1709	0.0068	0.0083
USA	1.0641	1.2447	0.8390	1.2180	0.9964	1.0996	1.3807
EU	1.0031	0.7181	1.1599	0.7320	1.2761	0.8258	1.0536
UK	0.9960	0.8876	1.1661	0.9423	1.2540	0.7990	1.3831
Germany	1.0363	0.8010	1.1887	0.7915	1.4703	1.0031	1.4221
France	0.8191	0.7459	1.8720	0.4309	1.7876	1.5592	1.7653
Scandinavia	1.0604	0.7677	1.2487	0.7773	1.6832	0.8249	1.6288
Italy	1.0996	0.5239	1.0607	0.5017	1.4941	0.3916	1.2996
The Netherlands	1.0948	0.7852	1.1012	0.7338	1.5270	0.6448	2.0729
South Korea	1.0826	1.0893	0.9555	1.4267	1.2205	1.1672	1.4784
Japan	1.0305	2.3637	0.9696	2.5165	1.1384	2.4054	2.6142
People's Republic of China	1.0333	0.4112	1.1172	0.5267	1.2966	0.5670	0.7218
Taiwan	1.1043	0.5033	1.1419	0.7641	1.6942	0.2314	0.7435
Singapore	1.0721	0.9670	0.9254	1.2889	1.0668	0.6928	1.8743
Russia	0.6806	0.3491	2.2406	0.1562	1.8737	0.9550	0.9139
India	0.6975	0.5963	1.7326	0.3466	1.0146	1.0810	0.6430
Brazil	1.0809	0.5789	0.8999	0.6938	1.1037	0.6104	0.8974

Data in the row for 'all countries' are obtained as a percentage share of the various sectors. This is taken as the benchmark. The index of activity for each sector in a country is then obtained by comparing the percentage share of that sector for that country with the global norm.

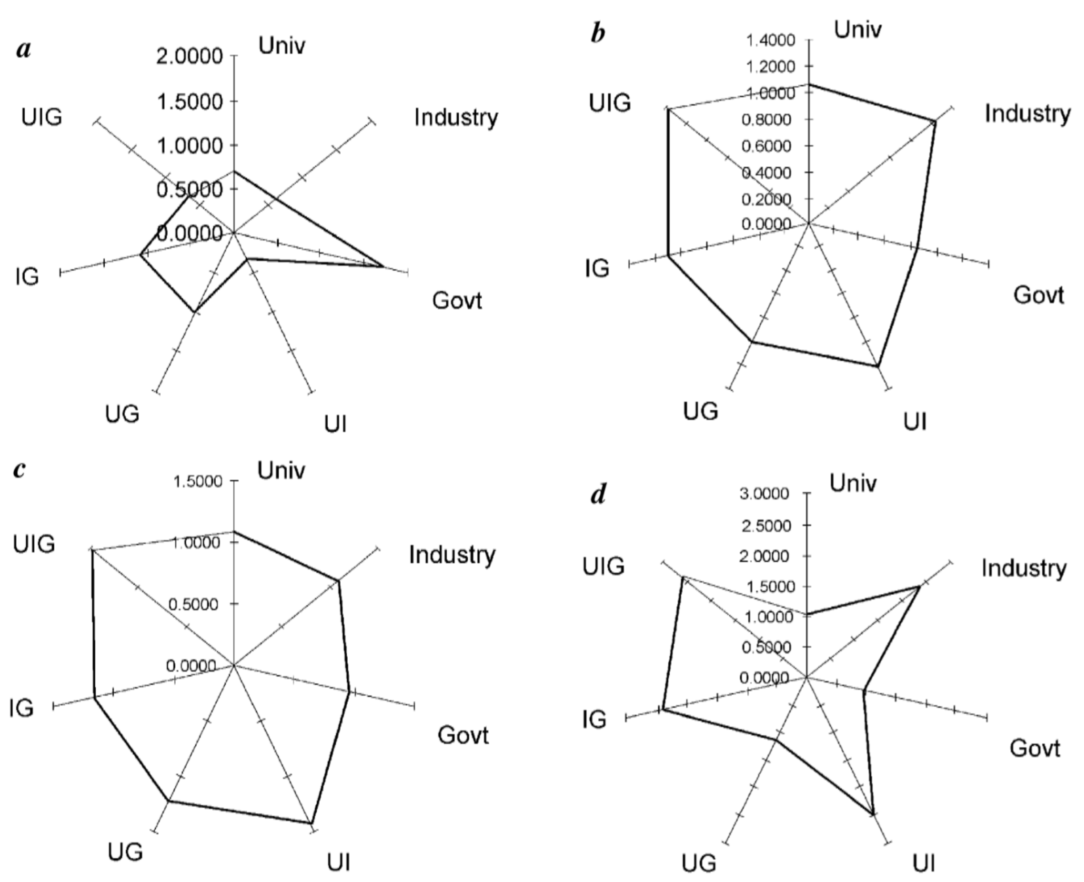

Figure 1. ***a***, Footprint for India shows clearly that there is an imbalance with the polygon, departing considerably from the circle of radius 1. ***b***, Footprint for USA shows a fine balance with the polygon closely corresponding to a circle of radius 1. ***c***, Footprint for South Korea shows, as for USA, a fine balance with the polygon closely corresponding to a circle of radius 1. ***d***, Footprint for Japan shows a fine balance within the university and Government sector compared to the world norm, and a healthy imbalance with the industrial sector leading through cooperation with one or both of the other two to produce output far in excess of the world norm.

we can display the same information using what are called footprint or radial plots. Figure 1 *a–d* shows the footprint plots for India, USA, South Korea and Japan. Figure 1 *a* shows that for India there is an imbalance, with the polygon departing considerably from the circle of radius 1. The Government sector is doing far more than is expected from the world average and the university and industry sectors and the university–industry cooperation leaves much to be desired. In Figure 1 *b* and *c*, the footprints for USA and South Korea show a fine balance with the polygon closely corresponding to a circle of radius 1. Figure 1 *d* reveals that Japan has been able to achieve a remarkably fine balance within the university and Government sectors compared to the world norm, and a healthy imbalance with the industrial sector leading through cooperation with one or both of the other two to produce basic research output far in excess of the world norm.

Balaram's fear that 'a large fraction of work in our network of national laboratories is academic in nature', is clearly brought out from this study. However, considering the fact that India is doing far too little research overall for its size, the logical step is to increase significantly the amount and quality of research done by the university sector, without disturbing the good work done by the Government sector.

1. Balaram, P., *Curr. Sci.*, 2004, **87**, 273–274.
2. Leydesdorff, L., *Scientometrics*, 2003, **58**, 445–467.
3. King, D., *Nature*, 2004, **430**, 311–316.

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SCIENTIFIC CORRESPONDENCE

Shock waves can enhance bacterial transformation with plasmid DNA

Shock waves appear in nature whenever the different elements in a fluid approach one another with a velocity larger than the local speed of sound[1]. Shock waves are strong perturbations in aerodynamics that propagate at supersonic speeds independent of the wave amplitude. Such disturbances occur in steady transonic or supersonic flow during explosions, lightening strokes and contact surfaces in laboratory devices. The typical thickness of the shock front in air is $\sim 10^{-7}$ m, very small compared to other characteristic lengths in fluid flow. Physically, the occurrence of shock waves is always characterized in a fluid flow by instantaneous changes in pressure, velocity and temperature.

On the other hand, shock waves can be generated in a controlled fashion in the laboratory and the nearly instantaneous changes in the fluid velocity and the pressure produced by shock waves can be used for innovative applications in various fields such as medicine[2], biological sciences[3] and industry[4]. In the present study, we report a novel shock-wave-assisted bacterial cell transformation technique.

An underwater electric discharge device has been designed, fabricated and successfully used for creating spherical micro-shock waves[5] in the Shock Waves Laboratory at the Indian Institute of Science, Bangalore. Figure 1 shows the schematic representation of an underwater shock-wave generator. Spherical micro-shock waves (few millimetres radius) are generated in water, by instantaneously depositing electrical energy (100 J) between two stainless steel electrodes (1 mm apart) for about 0.35 μs. Peak overpressures up to 100 MPa can be generated for about 10 μs. The water between the electrodes is instantaneously vaporized, creating a tiny vapour bubble. This bubble grows in size and subsequently bursts creating the spherical micro-shock wave. The high voltage applied between the electrodes can be varied to generate shock waves of requisite strength. A high-precision mechanical traverse system is used to hold the eppendorf tubes containing bacterial cells with naked plasmid DNA above the

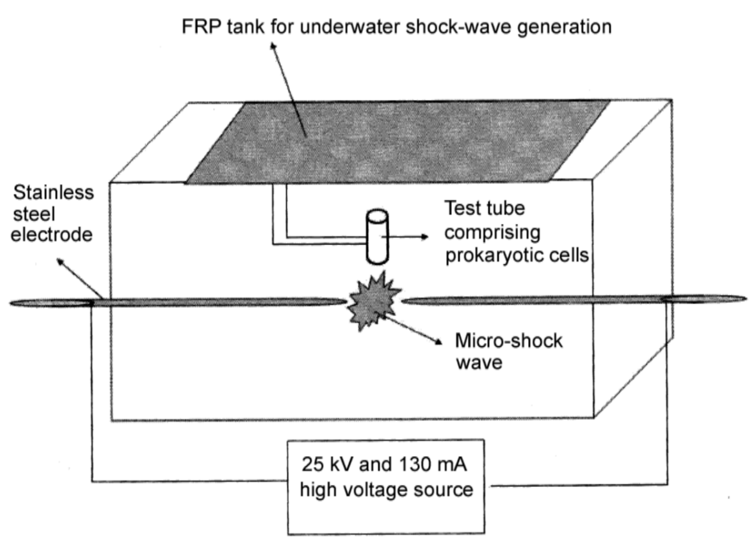

Figure 1. Schematic diagram of underwater shock-wave generator used for bacterial cell transformation.