Budget cuts – an opportunity within the crisis for testing fiscal management and prudence in R&D spending

The economies all over the world – domestic, regional or national – are dynamic. Testing times are encountered frequently when budgets and plans go haywire for one reason or the other and there is a need to roll-back policies, legislations and to re-assess fiscal estimates, parameters and even forecasts and plans for the future.

A case in point is the budget cut imposed during the first year of the 12th Five-Year Plan, in the science and technology sector. It has been projected that the budget cuts threaten Indian science[1] and this will impact R&D, both academic and innovative. Even a Bharat Ratna awardee has expressed concern at the lack of funds to drive R&D effort in the country[2].

How gloomy is the actual picture? While innovative and path-breaking R&D or research involving high technology may have been the most adversely affected, there may also be instances of manpower retrenchment, roll-back of plan objectives and restrictions on new recruitments along with the usual austerity measures related to travel, conferences, etc. There are few isolated reports of the routine R&D activities to be affected by the budget cuts, but as yet there does not seem to be any national outcry suggesting that there are not yet alarming trends and are perhaps confined to a few institutions.

What does this convey? Some institutions may have found buffers (financial cushions, organizational strengths, external cash flows and other similar factors) that have enabled to keep them not just merely afloat, but to also sustain some R&D work. The institutions that are among the worst affected are perhaps those which lack the favourable factors as above and this begs a question as to why it is so? Could it be a circumstantial situation beyond control, or could it be due to inadequate management safeguards, fiscal prudence and other such issues? The budget cut should in principal have affected all institutions equally, but since this has not happened, it appears that there are indeed institution-specific factors that have determined the outcome of the budget cut on respective institutions. Of all the institution-specific factors, the ones with the greatest influence probably are resource mismanagement, wrong prioritization of requirements and imbalance in accruing resources and expenditure.

Budget cuts will impact undoubtedly on the quantum as well as quality of R&D, but the greatest adverse impact could be more due to disregard of the fiscal prudence, management safeguards and 'rob Peter to pay Paul' principles which are clearly a reflection of incorrect prioritization of the needs. When this happens, it also begs an automatic question of accountability. The need at such times is therefore, for a definite introspection of the policies along with a ruthlessness to do away with the factors that cause the squandering of resources. Do we have the wherewithal to take these steps? Surely there is a lesson somewhere in this situation that can be used for the future. The question is whether this crisis can be converted into an opportunity to cleanse the system and bring in accountability and trust, and therefore, stability in R&D vis-à-vis the union budget and the managerial abilities. Essentially, the crisis is mostly man-made and not due to any calamitous events. Solutions to the crisis must therefore be centric to this fact and the opportunity for finding the solutions is here and now.

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Rationalization of the S.S. Bhatnagar Prizes scheme

The Shanti Swarup Bhatnagar Prize for Science and Technology is awarded annually for outstanding research, in seven broad areas: biology, chemistry, geosciences and environmental sciences, engineering, mathematics, medicine and physics. Since it was first awarded in 1958, the Prize has become the most coveted award in science and technology in India. Up to two awards can be given in each area. This means, that for every two outstanding scientists who are found to be deserving of the award in a field like, say, mathematics in a given year, not more than two such awards can be given in an area like chemistry, even when there may be far more candidates nominated for the award for that year. When the scheme was introduced, there was no way to gather evidence and quantify the integrated impact of the work from a given area in any year. However, today, with the availability of large bibliometric databases like the *Web of Science* (a Thomson-Reuters product), and science performance statistics and bibliometric baselines (field-wise) for comparing the quality of work across fields and disciplines like the Essential Science Indicators (ESI) (http://esi.webofknowledge.com/home.cgi), it is possible to perform due diligence of the impact India has made globally in various areas.

Table 1. Performance of India updated as of 1 July 2013 to cover a 10-year plus 4-month period, 1 January 2003–30 April 2013 and the global baseline citations per paper for the 10-year period

Field	India			Baseline	Before normalization	After normalization	Percentage	
	Papers	Citations	Citations per paper	Citations per paper	(X)	(X*)	X	X*
Chemistry	78,249	596,608	7.62	11.66	4,543,481.24	33,418.86	30.70	21.50
Engineering	35,390	170,404	4.82	5.2	822,194.64	30,406.61	5.56	19.57
Physics	39,901	270,459	6.78	8.6	1,834,185.13	24,799.69	12.40	15.96
Materials science	27,974	171,705	6.14	7.9	1,054,608.61	16,898.07	7.13	10.87
Clinical medicine	37,247	239,566	6.43	12.43	1,539,973.49	9,967.15	10.41	6.41
Plant and animal science	21,878	83,767	3.83	7.68	320,926.19	5,441.05	2.17	3.50
Biology and biochemistry	18,466	157,555	8.53	16.1	1,343,602.78	5,183.45	9.08	3.34
Pharmacology and toxicology	11,244	86,477	7.69	11.93	664,926.31	4,671.89	4.49	3.01
Agricultural sciences	13,361	54,824	4.1	7.24	224,598.41	4,284.79	1.52	2.76
Environment/ecology	9,894	71,781	7.26	11.36	521,488.99	4,041.00	3.52	2.60
Computer science	5,689	18,006	3.17	4.21	57,168.19	3,225.45	0.39	2.08
Geosciences	11,048	57,304	5.19	9.73	297,590.03	3,143.35	2.01	2.02
Mathematics	6,306	14,514	2.3	3.52	33,358.74	2,692.31	0.23	1.73
Social sciences, general	3,907	11,973	3.06	4.76	36,583.59	1,614.63	0.25	1.04
Space science	3,976	33,882	8.52	14.67	288,619.43	1,341.11	1.95	0.86
Microbiology	7,653	45,153	5.9	14.79	266,400.93	1,217.87	1.80	0.78
Molecular biology and genetics	5,496	51,001	9.28	22.81	473,306.73	909.69	3.20	0.59
Neuroscience and behaviour	3,573	26,929	7.54	18.46	203,130.77	596.09	1.37	0.38
Economics and business	1,391	5,473	3.93	6.45	21,483.86	516.41	0.15	0.33
Psychiatry/psychology	923	7,317	7.93	11.22	58,042.76	461.07	0.39	0.30
Immunology	2,291	20,347	8.88	20.65	180,655.43	423.65	1.22	0.27
Multidisciplinary	1,945	4,643	2.39	8.41	11,110.03	157.08	0.08	0.10
					14,797,436.27	155,411.25	100.00	100.00

Table 2. A rationalized scheme for the award of future S.S. Bhatnagar Prizes

Field	Percentage (X)*	Disciplines	Percentage (X)*
Chemistry	21.50	Chemistry	21.50
Engineering and computer science	22.50	Engineering	19.57
		Computer science	2.08
		Space science	0.86
Physics	15.96	Physics	15.96
Materials science	10.87	Materials science	10.87
Medical sciences	10.37	Clinical medicine	6.41
		Neuroscience and behaviour	0.38
		Psychiatry/psychology	0.30
		Pharmacology and toxicology	3.01
		Immunology	0.27
Biology	8.21	Plant and animal science	3.50
		Biology and biochemistry	3.34
		Microbiology	0.78
		Molecular biology and genetics	0.59
Geosciences and environmental sciences	4.62	Geosciences	2.02
		Environment/ecology	2.60
Mathematics	1.73	Mathematics	1.73
	2.76	Agricultural sciences	2.76
	1.04	Social sciences, general	1.04
	0.33	Economics and business	0.33
	0.10	Multidisciplinary	0.10
	100.00		100.00

The methodology is simple. The ESI allow us to determine the research output and impact in specific fields of research. However, as the specific impact is always designated in terms of citations received and papers published, and citations across disciplines can vary greatly according to practices unique to that field, it is necessary to normalize the citations according to the baselines given in ESI.

In the ESI, categories are aggregated into 22 broad fields – 19 in the sciences and 3 in the social sciences. Table 1 shows the scientific activity from India updated as of 1 July 2013 to cover a 10-year plus 4-month period, i.e. 1 January 2003–20 April 2013 and the global baseline citations per paper over a similar 10-year period. Arguably, the most effective way to make comparisons is to use a second-order indicator[1]. Using the data in Table 1, we find that for each major field, data are listed for papers (P), citations (C) and citations per paper (usually denoted by impact $i = C/P$). The second-order exergy indicator[1], $X = iC = i^2P$, is a proxy for research performance in an integrated fashion taking into account both quality (i) and quantity (P). In each field, the value of X is computed as shown in Table 1. Note that no field-wise normalization has been done at this stage. In such an evaluation, chemistry accounts for slightly over 30% of the research done in India and engineering and mathematics account for only 5.56% and 0.23% respectively. This is a result of not normalizing for the fact that papers in chemistry and biology will get far more citations than those in engineering and mathematics. A fairer assessment, from a due diligence point of view will be to propose a normalized second-order indicator, $X^* = (i/I)^2P$, where I is the baseline impact for each field. When this is performed, the results change drastically. Chemistry's share drops to a modest 21.5%. Engineering's share rises to nearly 20%, and if computer science and space science are considered as part of the engineering discipline, the share rises to 22.5%. And mathematics accounts for a respectable 1.73%.

What does all this mean for the institution of the Bhatnagar Prizes? Table 2 shows a re-organization of the data into what could become the new and more rational way of awarding these highly coveted prizes. It is clear that materials science is emerging as an independent field in which the quantum of contribution to India's output is significant. This could be the eighth area in which the Prizes could be instituted. I propose that two prizes be continued every year in chemistry, physics and engineering. Only one needs to be awarded every year in medicine, biology and materials science respectively. The Prize in geosciences and environmental sciences needs to be awarded only once every two years. Mathematics, the queen of the sciences, needs to be crowned only once in five years.

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Uranium exploration

I have read the paper entitled 'Calcrete-hosted surficial uranium occurrence in playa-lake environment at Lachhri, Nagaur district, Rajasthan, India' by Mishra *et al.*[1].

I have been involved in the analysis of geological materials and hydro-geochemical reconnaissance surveys attached with mobile geochemical laboratories in different parts of India for uranium exploration activities of the Atomic Minerals Directorate for Exploration and Research. Based on my experimental work on the analysis of water samples received from different areas/exploration projects, I would like to share some of my observations.

There are two statements in the paper by Mishra *et al.*[1]. (i) There is a one-line statement in the abstract (p. 84) and also in the text (p. 87): 'At Lachhri, the uranium value in the groundwater sample is 333 ppb.' (ii) The other statement (p. 88) reads: 'The high content of uranium in the groundwater samples from Lachhri and adjacent areas and also in the country rocks around Lachhri presents a favourable scenario for uranium mineralization in calcretes of the area.' What is the reliability of the first statement? The details of sampling[2,3], number of samples, detailed composition of samples (major cations and anions, fluoride), time interval between water collection and analysis, and methodology adopted for analysis[4], are not included in the paper[1]. Moreover, there are other important parameters also, such as uranium/conductance ratio which has not been mentioned; this is a significant aspect in ascertaining the potential of uranium presence in hydro-geochemical samples. As stated in the paper[1], the water samples are from the saline zone. However, total salinity values are not given. Total alkalinity values, which are indicators of uranium mobility owing to their role in complexation of uranyl ion (UO_2^{2+}) in aqueous phase, are also not stated. pH values of water samples which are of prime importance in hydro-geochemical movement of uranium and their leaching out from their sub-strata are also missing. The major, minor and trace elements present in hydro-geochemical samples play a major role in characterizing the strata given below the water table. The presence of fluoride may significantly affect the changes in uranium content[5–8].

In general, laser-induced fluorimetry as field technique is used for measurement of uranium in naturally occurring water samples. Since these highly saline water samples require sample preparation, the high uranium content in such samples needs to be validated by conventional fluorimetry technique and level of variation, if any, have been documented. The reliability/quality of measurement results of water samples depends on strict adherence to each step of sampling, preservation of samples, time interval between sampling and analysis for filtered but unacidified water samples, and on the methodology adopted, and not simply analysed by any person, laboratory or technique[5–8].

The higher uranium content in lake water samples may be because of 'evaporative pre-concentration'. All these parameters need to be included and properly documented.

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