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Distinguished Colleagues:

I wish to thank the Academy, in particular its President D. Balasubramanian, and Professor N. Kumar, for the opportunity to speak here today.

Caveats

You may wonder if my choice of the topic today is appropriate, considering that several people in this audience have been thinking about the status of science and mathematics in India; not only are they thinking about it but also, in fact, doing something about it. While there may be some merit to my views because they are formed from a slight distance, but I cannot guarantee total objectivity in the analysis to follow. I can only assure you that I have taken the subject seriously. I will first present some data about Indian science, from which others before me have drawn pessimistic conclusions. I venture to suggest some possible ways to improve the situation. Therefore, my contribution to this discussion ought to be regarded as constructive.

The Indian scene

In fact, over the last few years, a persistent view has been expressed that Indian science is declining. *Current Science*, which is published under the umbrella of this august Academy, has published articles, opinion pieces and analyses on just this topic. International journals, such as Nature, have given some currency to this view as well. Some prominent people within the country have expressed this view. In figure 1, I cite just four such articles: two published within the country and two outside. I hasten to add that I have in fact read most other essays that have appeared on this topic, both in *Current Science* and elsewhere. The starting point seems to have been the observation that while India occupied the eighth place in productivity of scientific articles in early 70s, it slid down to the 13th place in 2000. The status may have improved slightly since then, but the country still ranks below the place it once held---even at a time when the support for science was far smaller than now. This is a matter for concern.

Indeed, in absolute terms, the per capita publications from India is a small number of the order 10 per million people, while it is some three orders of magnitude larger for some OECD countries (figure 2). For understandable reasons, India will measure poorly on this index no matter how much more it improves its share of publications, so one may argue that this is a nonsensical index. But it is this index that creates a certain overall ambience of scientific culture in a country. Further, the improvement in this index over the last 10 years has been far smaller in India than those achieved by some European countries (see figure 2).

The situation with citations is similar (figure 3). India holds the 12th place or so, perhaps commensurate with its publication volume. More disheartening is the fact that a far smaller fraction of the publications (figure 4) produced by Indian scientists fall in the category of top 1%, this fraction being substantially smaller than those authored by the American and European counterparts.

Thus, not only is the volume of publications small but smaller still is the fraction that rises to the top. Of course, this is all based on certain statistics, which have certain biases built into them; further, they do not give any indication of the health of any subfield of science. For these and other reasons, one should not take the conclusions too literally. Nevertheless, they have some qualitative meaning to which one should pay some attention.

Actually, there is another concern in India---and this is the comparison with China. The two countries have historically competed for cultural influence in South East Asia --- before both of them lost out to Islam --- and elsewhere as well, as also for the technological export to the rest of the world. This latter was, of course, a bit in the past. The two newspaper articles cited in the left part of figure 5 merely reflect the concern originated by the data shown on the right of that figure. Another comparison with China is given in figure 6. It certainly gives the impression that Indian science has stagnated while the Chinese science has been exploding exponentially. What amplifies this concern is the fact that other Asian segments such as South Korea, Taiwan, Singapore and Hong Kong, have outpaced India in their rates of publications (figure 7).

The Chinese factor

China is indeed an exceptional phenomenon, especially considering that it started very poorly in the 1980’s, a time which many of us here remember well. I personally know the concerted efforts that China then put into improving its standing in international science. Perhaps a little description of the state of things in China today may help us understand how far China has come (see also figure 8).

I will describe the situation of Peking University but have been told that it is somewhat similar in the top 30 universities. Numbers will, of course, be different.

Peking University has 2400 Faculty members (excluding the medical school), and 50% are from sciences.

The School of Physics works on fundamental physics as well as advanced technology. It consists of 180 faculty members (13 Academicians, 76 full professors, 69 associate professors), and three Research Groups (QCD and Hadron Physics, Femtosecond Optical Physics and Mesoscopic Optics and Biological Network). About 20 Post-doctorial Fellows, more than 80 Ph.D. Students and about 110 M.Sc. Students join the School every year. For comparison, the University of Illinois, which has among the largest physics departments in the US, has about 100 professors (and, I guess, about 250 graduate students). The researchers from the physics department in China publish more than 300 SCI papers annually.

The College of Chemistry has 250 faculty members (9 academicians, 67 professors, 62 associate professors). It is said to be the 9th ranked in the world (though I have not been able to verify it).

The School of Information Technology has more than 300 professors and the School of Mathematics about 100 people on its teaching staff.

A new School of engineering was started about three years ago. The stated goal is to reach 175 teaching faculty in the next five years. The strength now is 80; though 50 of them were acquired as a result of a merger, 30 new people have been recruited, out of whom only 2 are local. The others (all Chinese) came from the US, Europe, Australia and Canada. They were offered, on the average, 60% higher salaries than of those already present. This does create some friction in the early days of the process, but it has been used as a mechanism for raising salaries of everyone; on the average, salaries are now about a third of the US salaries.

Typically, each Chinese professor has about 10 graduate students. The research support for them is roughly 5 to 7 times their salary. Each person has typically two grants. Publication rate is higher than in the US universities. It has not caught up with the US in total because the number of research-oriented universities is still small. The probability of getting funded is 30-50% (which is about 3 times more likely than in the US).

It is possible to do basic work in China but the government is aggressively pushing for high-tech areas and frontier technology. The School of Engineering got 4 million dollars worth of research money in 2 years.

Despite these impressive numbers, people in the know have generally complained that the innovation is not as high as it should be; that old ideas are often recycled; that the quality and originality of work is lower than the US average.

Comparison with the world as a whole

Granted that the Chinese ascendancy is unusual (for reasons which we can discuss at some later point), perhaps not even sustainable in the long run, it is worth taking a look at the rest of the world. Figure 9 shows the break-up among different regions. The Western Europe is enlarging its scientific output and has surpassed Northern America. This was obvious to me more than ten years ago when I was involved seriously in the publishing enterprise of the American Physical Society. In fact, the slight increase one sees in Northern America is perhaps sustained by Canada, not by the US, whose world share has been decreasing slightly (see figure 10). The same figure also shows that the enlarged Europe has also been losing a bit of steam lately. The increase in Asia is essentially due to the Chinese volume. The numbers in Asia are still about half those of the US, say. The rest of the world does not count for much, though Latin America, especially Brazil, and the Middle East, especially Iran (not to mention Israel), have been taking significant strides. Alas, Africa is falling behind in every way. It is a pity that Eastern Europe, which had seen better days, has at best held steady. Russia, in particular, has been losing ground steadily (see figure 5), this being another monumentally sad phenomenon of recent times. The loss of Russian science is not merely one of numbers and Russian loss, but it reflects essentially the dismantling of the backbone of the scientific establishment in that country.

The richer the country, the larger the number of publications

A lot of complimentary remarks have been made about the ICT revolution in India. And much of it is true. It has, however, been both a curse and a boon for basic sciences in India. It has been a curse because it draws the best students away from basic sciences. It has been a boon because anytime the overall economy of a country goes up, by whatever means and in whatever sector, its scientific support goes up as well. This is anecdotally obvious, but figure 11 shows that there is a nearly linear relation between the GDP of a country and its scientific productivity. (I will comment later on the divergences from this linearity.) The statement that it is a good sign for science when the economy booms may have some exceptions (e.g., in Gulf countries), but it certainly holds for countries such as India within which there are eminent scientists who also wield reasonable influence within the political power structure.

The story with ICT, and the coexistence of plenty and poverty

Somewhat as an aside, but mainly to make an important point, I now describe the results of a project in which ICTP has been involved in collaboration with SLAC in Stanford. The project measures the speed of the Internet in different parts of the world by sending a pulse to some chosen stations in the country in question and by measuring the time for the pulse to bounce back. The stations involved in the exercise are shown in figure 12; figure 13 shows the stations in India. The Indian network is not as extensive as one would desire (and may be improved in due course), but it is still geographically representative; in any case, as far as I know, these are the only quantitative estimates available on such quantities. It is clear from figure 14 (especially from figure 15, though it is somewhat old now) that the speed of the Internet is slower in the region by a factor of about 10 compared to the average for Western Europe. Obviously, this conclusion does not apply to institutions such as TIFR (and I use TIFR as an example only because it is better not to use any local institution for the purpose), but is an average statement. Figure 16 also shows that only about 1 in 20 people in the country use the Internet.

Parenthetically, I note that the situation in Africa is getting worse with time.

The findings in these graphs, I think, reflect a larger fact, which is also well known to most people here. That fact is that averages do not count for much in India. In the jargon of dynamical systems, this is a highly intermittent system, where institutions of plenty are few (of the order of 30, say) and those of poverty are many (about ten times as many). As far as I know, institutions such as TIFR have not had any problem with their budgets---the limitation being the ingenuity and initiatives of their faculty and top administration---but the likes of the University of Patna have suffered greatly from want of money. In fact, there is no comprehensive university in the country that is ranked (however imperfectly the scheme) among the top 250. Only one of them is ranked between 251 and 300 and two others in the range between 451 and 500. If one takes averages across the country, one gets what one has seen already. Elsewhere, in an article that was published in *Current Science* earlier this year, I have speculated about the ethos that led to the bimodal system of plenty and poverty in the country. The sad part is that the low level of the large number of institutions drags down the name of even the few best institutions. For instance, everyone here will probably agree with me that a paper of the same quality sent from an Indian address has a harder time getting published in the best journals than the one sent from Caltech or Stanford. The same holds for getting major prizes. The weight of the average drags down the peaks.

Before I go further, perhaps I should establish my credentials somewhat better. In the last five years, I have visited several Indian universities in different parts of the country (parts to which I would normally not have gone); my institution, namely ICTP, receives some 250 post-doctoral level visitors every year from India, and they spend, on the average, about 400 person-months (see figure 17). This is, in fact, a substantial fraction of the total number of visitors to ICTP; indeed, India tops the list. I have talked with many of these visitors, if not all, at least briefly, and have a reasonable understanding that their views roughly correspond to the reality on the ground: and these realities are not good. Of the 375 or so government-run universities in India today, only 20 central universities are funded moderately well; even though they have great potential, even they suffer from lack of infrastructure and good faculty. Indeed, the problem is massive and there have been many discussions within the country about how one might fix the situation. I don't want to add here to this comprehensive discussion: it needs a separate venue and a separate effort. But I shall make some brief suggestions later on.

Reasons for optimism

In spite of this picture, I feel optimistic about science in India. My optimism comes in part because I know firsthand the types of difficulties that other countries face.

1. The greatest reason for optimism is that there is a strong culture of scientific work in India, and science is not alien to Indians. Put yourself in the position of a student from Saudi Arabia who looks for Arabic names in all the text books and papers he studies. You will understand the difference.
2. The scientific leadership, which is of very high quality, has recognized the important fact that greater emphasis needs to be put on science and related activities; and it has convinced the political leadership about its importance.
3. Three new Indian Institutes of Science Education and Research have been created with generous budgets and one or two more are likely to be set up as well. The focus is interdisciplinary areas.
4. The prime minister has recently announced the formation of 30 new central universities, and scores of new private universities are being set up rapidly. This will make higher education accessible to a larger share of the youth and increase its base of knowledge and skills.
5. The annual science budget is expected to grow from $2.8 billion in 2003 to $21.5 billion in 2012.
6. Setting up an autonomous National Science and Engineering Research Foundation with a budget of $1.1 billion is being discussed, making science funding more streamlined and merit based.
7. Many new Fellowships and Awards are being instituted.
8. Areas such as biotechnology are being infused with additional resources.
9. In measures that are normalized by the GDP, India does extremely well in terms of productivity and citations (see figures 19 and 20). While India is low in terms of top-cited publications, it is also the country that has shown the largest improvement in the last few years (figure 21).
10. Countries such as Norway, Finland, Denmark, UK, Australia and Canada are allocating substantial and dedicated funds for bilateral research with India. The National Institutes of Health in the US has been encouraging joint research proposals.

11. The image of Indian scientists as creative and innovative is so strongly ingrained in the world that it is hardly a matter of debate anymore. It was not like this even some twenty years ago.
12. And so forth.

Translating goals into reality

Prime Minister Manmohan Singh recently said, “We are at a point when the dynamics of our population growth can catapult us into a prolonged cycle of rapid economic growth. We need to translate this potential into reality”. Translating the dream into reality is indeed what should concern us. The problem with Indian science has been a long standing one, and only long and sustained remedies will cure it. The problem has to be approached at the level of schools and universities; otherwise, a small number of outstanding groups that exist today will remain unstable and new ones will be difficult to nurture. Developing basic sciences has a considerable incubation period and one should not lose patience at any stage.

Thus, let’s take a look at Indian schools. A recent survey (figure 22) shows that young students, who expressed interest in science perhaps even before they understood what it really meant, lose that interest a few years down the road. The reasons for this shift seem to be the lack of interest in science and the alleged difficulty of science subjects; those who seek to study science cite their interest in science per se and easier job prospects as the reasons (figures 23). Although poor teaching of science does not, in itself, appear as a strong reason for turning off students, it is clear that the lack of motivation from the family as well as teachers, who themselves are not motivated, plays a substantial role in turned students off sciences.

The absolute numbers of students interested in science is quite large. Nearly 1.8 million students enroll for basic sciences at the undergraduate level (figure 24) more if one includes engineering and medicine), but only about 5000 graduate with a Ph.D. degree, and only a small fraction of them keep active in science; yet smaller fraction does science at a competitive level. Even those who go abroad, the number of Indians acquiring Ph.D. in science is substantially smaller than those from China (figure 25).

The real problem seems to be the lack of motivating teachers and the lack of sense that scientific career can be rewarding, both materially and intellectually. Many of us from the middle class chose science because it could open up new vistas and provide mobility of the sort that was unimaginable otherwise. To be a student in a small town, yet be connected intellectually to what was happening in Cambridge (for instance), was an exciting idea. That sort of connection is no longer unique to science; because of globalization, it is perhaps even stronger in ICT or banking or business. Students need examples: in school, they need examples of teachers who are excited by science, in college they should see teachers who are themselves doers of science, later in their career, they must see among them people who have attained some high level. The importance of these proofs of concept can never be underestimated.

How to improve the involvement of university teachers

It is difficult for me to discuss how the school system must be revamped. People with better background than me have spent considerable time on this topic. I do wish to say something about the university system which, though already of immense volume, is more manageable compared to the school systems. To produce students who are capable of creative work in both public and private sectors of the country, it is utmost importance that the university teaching should improve. For reasons that can be defended, but into which I shall not enter here, this task requires university teachers to have direct connection with research, at least for part of the time. Since it is difficult to make every university in India a research university (and this may even be counter-productive), it is useful to think of other ways by which those university teachers who desire to be engaged in research are provided research opportunities for some time of the year, each year. This is the spirit of my discussion.

The proposal is to set up a centre (to be called the Main Center below) in a research-oriented institution (identified as ROI), and set up mirror centers in other reasonable universities across the country. The *eventual* goal is to set up mirror centers in at least one university in each state of the country. It is not enough to set up just one center for the whole country because the magnitude of the problem and the numbers involved are immense. Without enhancing the quality of teachers, one cannot expect to produce creative students. Most of us who are successful will no doubt remember how much we owe to a few teachers.

Let me discuss the Main Centre first. I already said the Main Centre will be created as part of a well-known ROI in the country, as its outreach arm. It will have its own director, its own budget and its own activities, but this will be done in conjunction with other activities of ROI, maintaining formal functional relationships. As its first task, the Main Centre will run a variety of high-level schools, conferences and workshops, through which a set of university teachers come up to speed in various branches of science and mathematics, especially in interdisciplinary areas. The Main Center should organize and run, through the cooperation of a number of interested researchers in premier institutions across the country, some thirty conferences each year on different aspects of science, for each of which some 50 university teachers can be chosen from those who apply. These programs have to be run at a world-class level and broadcast live to universities that show the needed interest. The programs will change from one year to another, just as the people who organize them. These aspects will be determined by scientific needs and the timeliness of the programs. The goal is to provide the needed background for independent research of the participants in certain key areas.

The second function of the Main Center is to provide facilities for a set of medium-term visitors, numbering something like 30 each year, for something like two months each year, extending over a period of some six years, for doing research at the Main Centre, or in the groups of others affiliated with it. The visitors will be chosen on the basis of merit and ability. They will be provided stipend for the few months that they reside at the Main Centre, including accommodation, computing and library facilities; for experimental work, they may be placed in other research institutions in the country where such facilities are available. These visitors will use their time doing research, participating in discussions and seminars, collaborating with local scientists, and so forth.

The two functions need not, and indeed should not, be detached from each other.

The Main Centre should have a dynamic director and should draw upon the permanent researchers of great distinction in the country; it should have a small but strong research base; it would have to create a large network of scientists from all over the world, especially from all first-rate research institutions in the country. Indeed, the Main Centre will have to draw instructors and program directors from this large pool of active scientists. The goal is to mix active researchers with those that are dormant, so there is benefit for each party.

There are additional aspects that can be included, but the basic functions are as described.

Now to the mirror centers: The mirror centers that would be set up in each (or at least some) of the universities in India would be very similar. Each of these centers will be networking with the others loosely, and have some loose affiliation with the Main Center at ROI; should have their own budgets and their own directors who are free to pursue their own agendas, roughly within a broad, stipulated scope. They should receive money in part from the State in question and should, to that extent, be more concerned about the universities in their State. Private money from enlightened business may be solicited. The mirror centers should receive some budget from the Main Center---one of whose tasks should be to raise money---but the underlying idea is to give each mirror center enough flexibility and independence from local politics.

The advantage of the proposal is that it will not detach the university teachers permanently from their institutions. It will usher, on the one hand, the much-needed connection between the elite institutions in the country (whose members will initially be among those who will organize such programs), and the university teachers on the other. It will enable a large number of university teachers to be engaged in research at least for part of the time, so they can impart the feeling of excitement to the students whom they teach. In turn, the students can develop curious minds and take part better in the overall national development.

I think that it is practical to do this. From my private conversations, several universities are ready to consider this action. Indeed, I am led to this conclusion primarily because of the conversations I have had with the university people in the country; I am convinced that there should indeed be more than one such center, and that they should network together in some loose fashion, supporting but not hindering each other.

Develop science of sustainability

I now come to my last major point. Scientific progress has several purposes, one of which is that there is no purpose but the understanding of our universe. There was an occasion on which I surveyed about 1000 people for their impressions of how science is perceived by young people in their countries and what its role would have to be. Three hundred or so of the respondents said that science has lost some of its appeal among governments in part because it has not kept the common man in mind. Thus, especially in a developing country like India, science has a special obligation to contribute to the overall development of the country. There are many such areas to which Indian science is already contributing, but there is one to which I would particularly wish to draw attention. I call this the science of sustainability, perhaps even the science as survival. Please bear with me as I try to explain myself. Let me mention a few of them first and then make a concrete proposal.

Figure 26 lists some aspects of survivability issues that will become increasingly important in due course. Because of the increasing pressures created by the population that is still on the rise, India faces many challenges which cry out for scientific solutions. We don't have the time to go over all of them, but let me comment on a few. The issue of climate change has received adequate notice lately, especially after the IPCC, headed by the Indian scientist Rajendra Pachauri, received the Nobel Peace Prize. I feel that I need not say anything further. India is not so large that it can control the agenda of climate change, but not so small that it has the option of being more than a bystander. Let me, however, discuss a few other items.

Energy needs

India is the 5th largest energy consumer but the 11th energy producer, so significant part of the energy needs have to be met by imports. Without increased source of energy, much of the development will slow down, and there won't be enough money for science, either.

Petroleum resources are meager (India is not in the top 20), coal accounts for more than 50% of energy needs (with consequent pollution problems), and the contribution of nuclear fission is still small, as is the geothermal energy. Even if the new deal with the US goes through, nuclear fission will not meet more than about 7 or 8% of the total needs.

It is clear that the country will need increased energy as increasingly larger fraction of the population aspires for higher standards of living. If India uses as much per capita energy as industrialized countries, the energy demands will go up by a factor of 10. Since India's population is still increasing, it will probably need about half as much again—or a factor of 15 or so than it now does. And the gain of the hard-earned progress made in the last few decades has essentially come to naught because of the additional gain in population.

Increasing energy efficiency will no doubt make a dent in this estimate. Yet, there is no doubt that we will need much more energy than now. We have to ask: where is this energy going to come from?

It cannot be all from oil. Oil wells are slowly drying up. The recent surge in oil prices has already damaged many economies including India's, but it is only a harbinger of tougher times to come—both economically and politically. It cannot all come from coal, either, for environmental reasons. One has perhaps not yet reached the tough situation of modern China, but it is close behind.

The additional energy will not come from nuclear fusion either. A commercial fusion plant is at least 50 years away, even if everything with the ITER project at Cadarache in the South of France, works according to plan and additional up-scaling occurs as expected. ITER will take 20 or so years to work fully and at least one intermediate generation of fusion plants will be needed before commercial success becomes a reality. Fusion will thus play no role at least until 2050—though it may play an important role beyond.

Will it come from hydrogen? According to experts, there are basic problems with hydrogen as an energy source at the thermodynamic and conceptual levels, as well as at practical levels. One should not forget the principal point that hydrogen, though an excellent carrier of energy, is not a source. Thus hydrogen may play some role, but not the dominant one that fossil fuels now do.

What about renewable energy? No one argues against its abundance. The carrot is also that, if we can harness it successfully, one does not need to be constrained by energy conservation! Considerable progress has been made on renewable energies, especially in Western Europe. India is fortunately quite active in this area, but it has not yet well adopted itself to its use. Part of the problem is the "retail" mentality when it comes to renewable energy. The action needed is technology, money, the mindset and politics.

In summary, looking towards the horizon until 2050, say, oil will become less available, the use of coal cannot increase dramatically without doing interminable damage to the environment, fusion will play no role, hydrogen will remain fairly marginal, and nuclear fission can be expected to increase slightly. Renewables will not be able entirely to fill the vacuum created by depleting fossil fuels.

So, what pragmatic approach should the country adopt?

First, the Indian economy is so conditioned on oil and coal that, despite the reservations already expressed, it cannot rapidly switch to anything else. Thus, oil and coal will have to remain in the mix of India's energy portfolio for the foreseeable future.

Second, nuclear fission will play a moderately stronger role than now. Its acceptability seems to have increased also because of the absence of greenhouse effects.

But renewables should play an increasing role, not least because other forms of energy will become more expensive or less available. Some energy consumption is indeed retail, and there is no reason why some household energy cannot come from the Sun, or why wind energy cannot be harnessed more effectively. Equally importantly, one needs to work, with the same level of seriousness as with fusion or fission, on large-scale solar power plants. This task is both high-tech and non-trivial.

To repeat, it would seem that a reasonable portfolio is a three-way mix of renewable energy, fossil fuels and nuclear fission, with others thrown in as minor partners. By 2050, we will surely know more about such things as fusion, hydrogen and the large-scale harvesting of renewable energy (in which category solar energy will figure dominantly), and we will have to adapt ourselves. Continual evaluation and adaptation are the keys to a more secure energy future.

Perhaps one comment is useful. If India follows the same technological path as industrialized countries followed during their ascension, it seems clear that there will not be adequate resources to meet its energy needs. New and alternative approaches require clear awareness of the issues involved, deep understanding of potential technologies and much research and knowledge of science.

Groundwater depletion

It is well known that in India groundwater supplies 85% of the rural water supply, more than 50% of urban and industrial needs and 70% of irrigation needs. Over the years, the undisciplined use of groundwater has made it a scarce commodity in many places. At present, over 1000 geographic blocks out of the 5723 are overexploited. Recharging ground water resources should be a priority for the country but 80% of the water resource budget goes into building big dams instead. More than others, Indian civilization should know the great impact that water resources have on its development.

Himalayan earthquake zone

It is well known that India and southern Tibet are moving towards each other by something of the order of two meters a century. The strain is not deforming the rock much but is accumulating instead; that is to say, the strain is not inelastic but elastic. This will have to be released by some jerky motion of the Himalayas. One or more great earthquakes may thus be overdue in a large section of the Himalayan region. Figure 27 shows the strain accumulated in different parts of the affected region.

Five major earthquakes have struck India in the last decade but the worst may be yet to come. Geologists estimate that earthquakes of magnitude between 8.1 and 8.3 may occur. If they do, up to 50 million people could be at risk across Bangladesh, Bhutan, India, Nepal and Pakistan, and India could take the brunt of this inestimable burden. To illustrate the magnitude of the problem, I show a slide (figure 28) taken from *New York Times*.

Yet, there is not much activity in India on earthquake predictions; nor is there adequate effort on seismic observations in the affected regions.

Ocean resources

The Indian Ocean is of great consequence to the country's climate. Indian Ocean's fish are of great and growing importance to the bordering countries for domestic consumption and export. Fishing fleets from Russia, Japan, South Korea, and Taiwan also exploit the Indian Ocean. Some 40% of the world's offshore oil production comes from the Indian Ocean. Its beach sands are rich in heavy minerals and other deposits.

Analysis and recommendation

The types of problems just discussed are diverse and I am sure that there are various organizations and departments in India that study one or the other aspect. As far as I know, however, there is nothing in India that focuses on these and other issues at a high scientific level. There is nothing that brings these issues to focus at the highest levels of intellectual integrity and under one common umbrella, and carries the scientific conclusions forward through the political system. I cannot argue in favor of such an activity any stronger than by stating that it could, indeed, a matter of long-term well-being of the country and its survival. Indeed, increasing number of these problems will depend on science for their solutions. I think that it is high time that a "center for sustainability science" was set up as part of an institution of high intellectual standards. One should not set up such a center as a stand-alone institution because it is not easy to maintain rigor in one's thinking on these problems because of the easy tendency to politicize them: just look at the issue of climate change or CO_2 emissions. The Centre has to be part of a greater enterprise that examines these issues also from global perspective. In fact, when a huge influx of money came to IISc a few years ago, I had suggested just such a Centre to Professor Balaram. Other possibilities are NIAS and JNCASR. By the way, this Centre is not a substitute for the new Earth Commission (which does overlap on some of these issues), but it should serve as an intellectual complement to that commission and to other existing departments within the government.

I wish to call attention to two other factors and end my presentation.

Increase collaborations with others

From the two tables (figures 29 and 30) it is clear that the scientific collaborations from India have been essentially strong with the US and European Union, just as it is for all other countries. In particular, there is a lot less collaboration with Asain countries. Perhaps this is an aspect to which Indian scientific establishment could pay more attention.

Make strategic choices

My second point comes from the interpretation of figure 31. I put some emphasis on this figure because, I suppose, Indian scientists are not as much worried about the number of publications as they are about the number of high quality publications. In this figure, one sees that among the top ten countries within the 1% category, four countries lie on one line while the others lie above. The common feature among the countries that lie on the line is that they try to everything. Of course, the US is in a better shape because it puts more money into research and there is more manpower, though much of it is not locally born. Japan comes next, but distinctly below, and China and India follow suit. The other countries do better for the same total number of publications. And they manage this feat principally because they select some areas of strength and excel in them. It is not that they ignore others, but they know that they have to maintain supremacy at least in some broad areas. The moral I would draw from here is that it is OK to do everything without making hard choices if one can afford it (as the US has hitherto been able to do), but, otherwise, one has to make some choices and support those chosen activities at a high level. Which areas to pick depends on the traditional strengths, the availability of people, the natural needs of the country, and so forth. For India in its present position, it appears to me that this kind of strategic thinking is a must.

Many thanks for your patience.