Final Version

10th Zuckerman Lecture

Nation Building through Science & Technology
A Developing World Perspective

By

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1. I feel truly privileged to stand before you this evening. The invitation to deliver the 10th Zuckerman Lecture is one of the greatest honours of my life. I want to thank the Office of Science and Technology and Lord Sainbury for doing me this honour. It is also a very special privilege to pay a tribute through this lecture to Lord Zuckerman, who was one of the most distinguished scientists of the 20th Century. He left such a huge imprint on science in this great nation. I feel overwhelmed when I look at my nine predecessors; all of them were men of such great eminence. I must also add that last year, when I was sitting in the audience in the front row listening to Sir David King, who gave the 9th Zuckerman Lecture, little did I realise that we would be swapping places this evening! Sir David's brilliant and stimulating lecture is still very vivid in my memory. He brought such a wonderful new perspective to this vital issue of science of the climate change. His will be a very hard act to follow but I'll do my very best. I do hope my best will be good enough for this evening.

2. The topic that I have chosen for the tenth Zuckerman Lecture is **'Nation Building through Science & Technology: A Developing World Perspective'**. I come from a developing country, namely India. India’s civilization is one of the world’s oldest civilizations. It has had very rich traditions of science and technology. Science in India was always very closely intertwined with culture and philosophy. It was also tempered with very unusual wisdom. India’s contributions to astronomy, to mathematics, to medicine etc. in the millennia gone by have been truly phenomenal.

3. Today we look at the modern India that was built after independence. We must give credit to Pandit Jawaharlal Nehru, our first Prime Minister, who had such a deep faith in S&T as a powerful tool of socio economic transformation. He helped us take the first definitive steps in nation building. His deep commitment to S&T can be seen from his

famous statement "It is an inherent obligation of a great country like India with its traditions of scholarship and original thinking and its great cultural heritage to participate fully in the march of science, which is probably mankind's greatest enterprise today". India has benefited immensely from this enthusiastic participation in 'the march of science'. Sustained investments made in higher education and science and technology have helped build a new nation, which has now an aspiration to reach a developed country status by 2020. Drawing from the Indian experience, I would like to share with you my own perspective of how the nation building process can be accelerated through the powerful tool of S&T in a developing world scenario.

Positioning the Developing World in a Global Landscape

4. Let me begin by looking at a global landscape. I will attempt to position the developing world in this landscape. We can, in a simple minded way, position all the countries in a single diagram (Fig.1) in terms of their relative economic strength and their indigenous S&T capacity. In the top right hand corner you have developed nations such as USA, Eroupe, Japan, etc. They have a very high indigenous S&T capacity and a very high economic strength. In contrast, in the lower most left hand quadrant, we have the least developed countries, including sub-saharan Africa, where indigenous S&T capacity as well as economic strength is low. In the top left hand quadrant are countries, which by the strength of their natural resources, have attained very high economic strength (such as the oil rich Middle East countries). But they do not have any significant indigenous S&T capacity. The interesting quadrant is the one in the lower right hand quadrant with high indigenous S&T capacity but relatively low economic strength. This includes India, China, Brazil, Argentina, Chile, South Africa, etc. The positions of developing nations in this diagram are not static. Different countries in different times of history occupied different positions on this map. For instance, not too long ago, Korea belonged to the lower right hand quadrant. But they have moved upwards to attain the status

that OCED countries enjoy today. After all, Korean companies like LG and Samsung dominate global markets and compete with the best in the world today, something that did not happen thirty years ago!

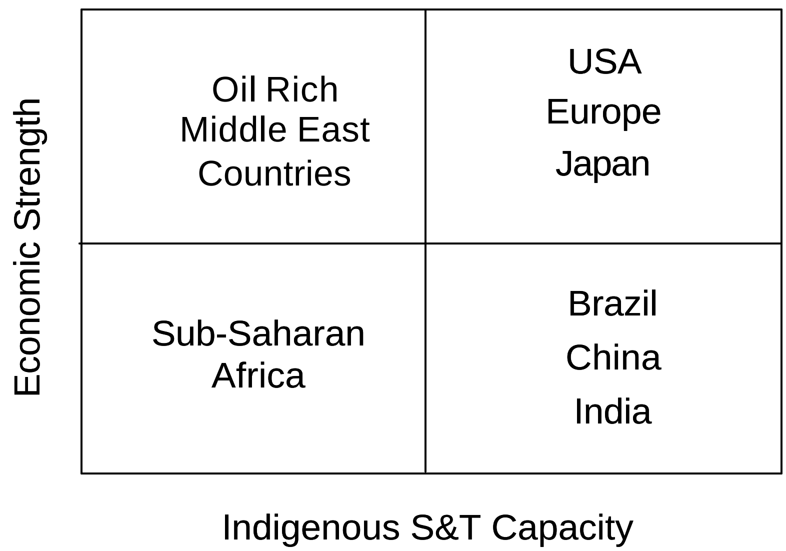

Fig. 1

5. There is an interesting equilibrium between countries in these different quadrants. For instance, countries like India and China are providers of huge human capital to USA. However, these countries are becoming global research and design development centres today. Leading industrial enterprises from USA and Europe are physically setting up their R&D centres in these countries, something that they did not do a decade ago.

6. There is also a subtle but definite tension that gets created because of the strength of these scientifically advanced developing countries. For example, it is the capacity of these countries to create cheaper versions of generic drugs, or indeed to copy new molecules in a protected intellectual property regime, as it had existed in India, that have led to fierce intellectual property rights debates in recent times. When multinational companies offered an anti-retroviral cocktail of HIV/AIDS drugs for an year's treatment for $ 10,000 in South Africa, it was CIPLA, an Indian Pharma Company, that offered it for a mere

$350. This case created a major public debate. The issue of TRIPS and public health was brought forward in the DOHA Declaration. This in turn raised a new awakening in terms of the issues involved in access to medicines for the poor and the rights and obligations of the big pharma companies.

7. We also have a new dynamics on cooperation and competition amongst these countries positioned in different quadrants. Take, for instance, the issue of the recent break out of SARS in China. When this happened, research on SARS started not only in China and Hong Kong but also in US, Canada and Germany. There was the race to sequence the SARS genome. Canada won the race. We thus have a new equilibrium in this new global setting, which provides a peculiar driver for cooperation and competition.

Benefits of Investment in S&T in the Developing World

8. It is well known that the success of today's advanced industrialised countries is due to their history of innovation along different dimensions which include the creative use of science and technology to add value to their natural resources (physical as well as human), combined with strong institutions, trade and organisation. However, many times a question is asked as to whether the scarce resources of a poor developing nation should be invested in S&T. It is important to realise that investments in S&T are investments in the future. Further, time and again, it has been shown that a dollar invested in a developing country may go very far. It could create international competitiveness as well as socio-economic development.

9. One can cite many examples from around the world to illustrate the point. In what follows, because of my greater familiarity with the Indian scenario, I will cite examples from India. But generic lessons drawn from these examples are valid across the globe.

10. Take a specific example of the Indian space research programme. The R&D budget for this programme was US $ 450 million in 2002. The R&D budget for General Motors was around 7 billion dollars in the same year. What is it that the India's space programme has achieved for such a small budget that is equivalent to 7% of single company in USA? Today, India has developed a strong capacity to design, develop, test and fabricates its own launch vehicles and satellites. India has moved from one sophisticated launch vehicle to another - that is from SLV to ASLV to PSLV to GSLV. It has done this without any help from anyone, since for love or for money, no one was willing to give the technology in these strategic sectors. India has launched 35 satellites so far, of which 17 are Indian launches, 23 are in orbit and 14 are geo-stationary. India has also launched satellites of its foreign customers too and these include Germany and Korea.

11. India has achieved international competitiveness in remote sensing with these small investments. Tina Cory, the Director of Application and Training of Eosat, which is a US based satellite imagery marketing firm, recently said "Indian Remote Sensing (IRS) series of remote sensing satellites is a 'jewel in the crown'." It is predicted that India's IRS series may actually capture 30 percent of the global market in remote sensing.

12. The real impact of Indian space programme has been in terms of nation building through accelerated socio-economic development by impacting on problems ranging from education to drinking water.

13. Thanks to India's progress in space research, one is able to 'reach the unreached' in distant villages, valleys, hilly areas and so on. Just as there was a 'green revolution', India is witnessing a 'connectivity revolution' today that is bringing this vast nation together. Primary, secondary and tertiary education is reaching vast masses through the use of distance learning devices as well as remote access to diverse educational resources.

14. Space research is impacting on other human needs such as, for instance, drinking water. This problem is acute in India. I still remember Rajiv Gandhi telling us something striking in one of our meetings of the Science Advisory Council to the Prime Minister (SAC-PM). He said that John Kennedy had a dream to land a man on the moon; his equivalent dream was to take drinking water to 180,000 villages, which had no access to it. India's space program has been able to draw hydro-geomorphological maps across the country. This scientific source finding approach has meant that the success rate for groundwater targetting has moved from 45% to more than 90%. Around 160,000 villages with drinking water problem have got benefited from this.

15. Lives of the poor fishermen have been impacted too. Through the satellite IRS P-4, potential fishing zones were identified. Information on the locations of these zones is communicated to the fishermen through radio and internet. The catch in potential fishing zones in higher than the normal catch by approximately 100% to 500%!

16. Lack of cyclone warning in the coastal regions of Andhra Pradesh used to wipe out entire villages in the aftermath of a cyclone. The early warning systems now ensure that this is not the case any more. It is clear that whether it is a poor nation or a rich nation, investment in S&T does play a key role in nation building.

.***Making Technology Work for the Poor***

17. Developing nations are besieged with several burning problems. Let us look at some disturbing figures in the year 2000. Look at education. There were 854 million illiterates in the world. 325 million children went out of the school at primary/secondary level. There were 968 million people, who had no access to drinking water. 2.4 billion people lived without access to basic sanitation. There were 2.8 billion people living on less than 2 US dollars per day. Can technology help in making a

difference and changing this statistics, both quantitatively and qualitatively? Again the answer is a positive one, if only the technology is directed appropriately on problem solving for the poor.

18. Let us take just one example of illiteracy. In India, we have about 200 million adults, who cannot read or write. There are huge constraints of trained teachers. The use of conventional methods of learning from alphabets to words requires 200 hours of instruction. This leads to a number of dropouts. India's illiteracy today is reducing only at the rate of 1.3% per annum. At this rate, India will need 20 years to attain a literacy level of 95%. Can we do it in less than 5 years by using technology?

19. The great doyen of Indian IT industry, F.C Kohli believes that this can be done through his recent breakthrough. He has developed a unique Computer-based Functional Literacy (CBFL) method. It is based on the theories of cognition, language and communication. In this method, the scripted graphic patterns, icons and images are recognized through a combination of auditory and visual experiences by using computers. The method emphasizes on learning words rather than alphabets. While the method focuses on reading, it acts as a trigger for people to learn to write on their own.

20. Based on this method, Kohli's team has developed innovative methodologies using IT and computers to build a reading capability among the adult illiterates. This experiment was first conducted in Medak village near Hyderabad. Without a trained teacher, the women started reading the newspaper in Telugu in 8 to 10 weeks. Thereafter, Kohli's team has carried out more experiments in 5 states and in 5 languages. 40,000 people have been made literate in these pilot experiments so far.

21. Kohli is an engineer. He believes in pragmatic and affordable solutions. His team ran these lessons on Intel 486s and the earlier versions of

Pentium PCs modified to display multimedia. There are around 200 million of such PCs in the world that are obsolete. They have been discarded. They can be made available free of cost. By using these PCs, the cost of making one person literate would be less than Rs.100, slightly over one British pound. With CBFL, Kohli says he can increase literacy in India to 90 to 95% within 3 to 5 years, instead of 20 years.

22. Kohli was invited in South Africa to demonstrate the prowess of his CBFL. He dealt with a group, whose ages varied from eighteen to eighty. All of them started reading a newspaper in eight to ten weeks. Kohli narrated to me a remark by one of the participants, who said 'I used to go to the church every Sunday morning. I used to hold the Bible in my hand - pretending to read but not understanding a word of it. Today I understand what I am reading'. How touching! Kohli's CBFL can help 854 million illiterates in the world -- such is the power of this technology.

23. Technology is a many spleandoured endeavour. There is a low technology and there is a high technology. Both can be used for solving the problems of the poor. The prestigious medical research journal Lancet referred to the greatest medical break through of the twentieth century. That breakthrough was a simple oral dehydration therapy. Tens of Thousands of children from the developing world used to die in the laps of their mothers because the mothers did not know as to how to treat diarrhea. The normal treatment through intravenous injections cost $ 50 per child, which is an impossibility for some one who earns less than $ 2 a day! The simple sugar salt solution in the right proportion was found to increase the intake factor by twenty five. This saved millions of children. But this was a simple technology. What about the use of advanced technology? 11 Million children around the world die before reaching their fifth birthday. The major cause of infant mortality is infectious diseases such as pneumonia, measles, malaria, etc. Molecular diagnostics involving rapid DNA based diagnostic

methods present a powerful set of tools to arrest child mortality. Can we make it cheep enough so that it benefits the poor? The answer is yes, we can, provided we make an effort.

24. Sometimes scientific advances will create solutions - but adopting them to the developing world conditions can pose a challenge. Vaccines for killer diseases such as measles, whooping cough, diphtheria, tetanus, etc. were developed because the antigens to tackle these diseases were known for a long time. But they required sterile conditions and reliable cold chains. Transporting them to village health centres thousands of miles away was a challenge. Technological advances leading to freeze dried and more heat heat stable vaccines that do not require refrigeration made a big difference.

25. How does one set up a telephone exchange in a village in the Rajasthan desert in India, where temperatures with go beyond 50 C and the sand storms create unmanageable dusty conditions. It was Centre for Development of Telecommunications (C-DOT) in India that designed the rural exchanges, which could withstand these aggressive conditions.

26. Our real challenge seems to be to get the 'best minds' around the world to engage themselves in providing solutions to the problems that can make a difference to the humanity. Every thirty seconds, a child somewhere dies of malaria. Can you imagine the impact if we had a good vaccine for malaria? HIV/AIDS is ravaging nations today. Can you imagine what impact will a new vaccine on HIV/AIDS have? Electric power generation and grid delivery were first developed in 1831 but they are still not available to a third of world's people. Can you imagine what impact a break through on low cost fuel cells and photovoltaics for decentralised power supply can have? We must find ways and means by which the best scientific minds in the world could be first ignited and then united to tackle these challenges. May be a high profile and massively funded 'Millenium Challenge Initiative' could

just do the trick! May be it should be funded through a Global Science Fund.

27. While new technological solutions can solve the problems of the poor, the public concerns at the risk of new S&T also need to be handled with care. The challenge before many poor countries with vast populations is simply to get "more from less." That means more food production from less arable land per capita, less water per capita, less environmentally damaging inputs in agriculture, etc. This means judicious use of emerging technologies such as information technology, space technology, biotechnology, etc. When it comes to new biotechnology, the risk assessment of genetically modified crops immediately emerges as a key issue. Different nations have adopted different approaches. They are either promotional or protective or precautionary or totally preventive. It is obvious that we need to adopt a precautionary but promotional effort, which is based on sound and transparent scientific methods of evaluation, with full public participation. If this does not happen, then the benefits of technological revolutions such as these will bypass precisely those parts of humanity, which can benefit the most from these.

28. The Millenium Development Goals pertain to eradicating extreme poverty and hunger, achieving universal primary education, promoting gender equality and empowering women, reducing child morality, improving maternal health, combating HIV/AIDS, malaria and other diseases and ensuring environmental sustainability. Judicious investments in S&T and the consequent development of indigenous technological capacity can help us reach each of these goals possibly even before 2015, only if we build the technological capacity in developing nations. But how can we achieve this?

Building Indigenous Technological Capacity

29. The critical factors which help in building indigenous technological capacity are shown schematically in Fig.2. These factors include a conducive policy environment, entrepreneurship, promotion of a culture of innovation, access to technology through international technology transfer, endowment that is achieved through an educated and skilled work force, and finally a thrust on indigenous efforts involving 'learning by doing'. The critical role paid by many of these factors is too obvious to need further elaboration. However, the importance of a conducive policy environment is not that obvious. Let me illustrate its importance.

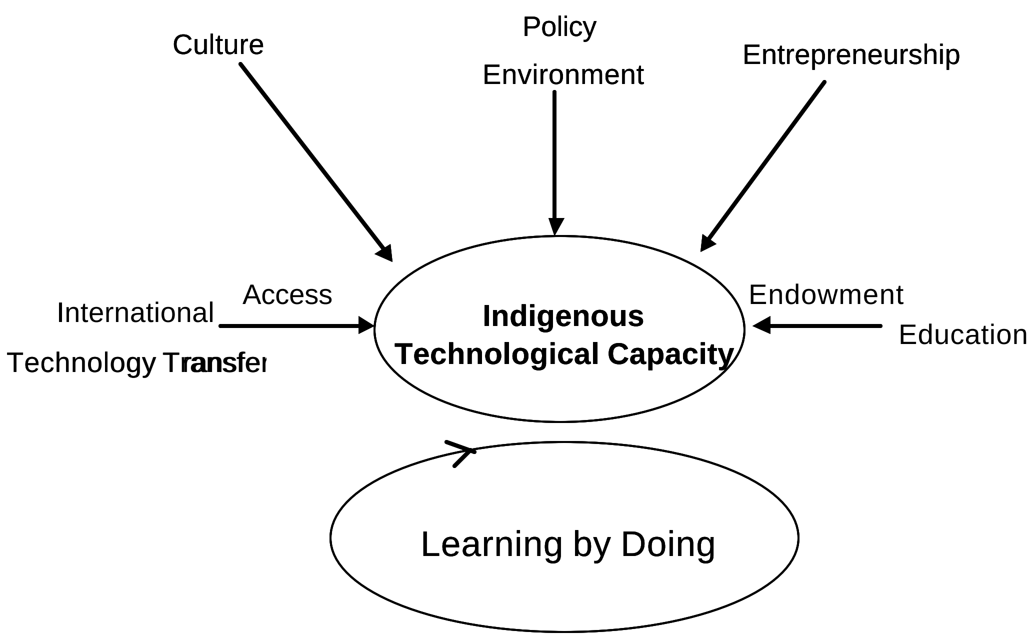

Fig. 2

30. A policy environment influences the innovative capacity of the firms, the society and indeed that of the nation as a whole. Let me illustrate this by a striking example from India. As I stand here in London, I am reminded of the way the car industry has changed in India over the years. In the last fifty years, the wheel has turned the full circle. It was British Morris Oxford, which was sold as an Indian Ambassador on Indian roads some fifty years ago. Today it is an Indian Indica, i.e. an

Indian car, designed and built in India, that is being sold as City Rover on London roads! This transformation was entirely due to a policy change. I remember the legendary Indian industry leader JRD Tata saying in desperation in February 1978 that Telco, which was his company, was not allowed to develop a car. It was only in July 1991, that India changed its industrial policy by liberalisation and opening up. It was in 1993 that Ratan Tata, who succeeded JRD Tata, was allowed to make a car. He gave this challenge to 700 engineers, who had never designed a car before in their life. He spent only one tenth of what major auto manufacturers would have invested to design and develop a new Indian car, Indica, that was world class. The creative ability of his 700 engineers from Telco was always there for all to see, but it got 'expressed' only when the government policy changed through opening up and liberalisation.

31. Creativity gets nurtured in a flexible, competitive and dynamic economic environment. In a developing country context, this means building on reforms that emphasise openness to new ideas, new products and new investments. For instance, telecommunication laws that favour government monopolies will isolate countries from global network and retard growth. The recent experience in India has shown that competition among providers of information and communications technology has led to increased investment, increased connectivity and better service. It has also heralded the age of new technological breakthroughs.

32. But only open markets and competition will not be enough. Expanding human skills to meet the challenge of relentless technological change becomes critical. Advanced skills developed in secondary and tertiary schools become increasingly important. Vocational and on-the-job training becomes important. For firms to remain productive and competitive, they will have to make massive investments in building the quality of human capital. Then only can the indigenous technological capacity be sustained at adequate levels.

33. Consider now the impact of international technology transfer on indigenous technological capacity shown in Fig. 2. Facilitating the access of the third world countries to technologies required by them constitutes one of the key elements in accelerating the pace of their economic and social development. Such access is generally the result of licenses and technology transfer agreements. The prospective technology seekers in developing countries face serious difficulties in their commercial dealings with technology holders in the developed countries. These difficulties arise for a variety of reasons. Some arise from the imperfections of the market for technology. Some are attributed to the relative lack of experience and skill of enterprises and institutions in developing countries in concluding adequate legal arrangements for the acquisition of technology. Some arise due to government practices, both legislative and administrative, in both developed and developing countries, which influence the implementation of national policies and procedures designed to encourage the flow of technology to, and its acquisition by developing countries.

34. There are concrete examples to show that technology transfers to the developing world have not taken place when they were needed most. The 1990 Montreal Protocol on Substances that Deplete the Ozone Layer ran into conflicts over commitments to ensure fair and favourable access for developing countries to chlorofluorocarbon (CFC) substitutes protected by intellectual property rights. The 1992 Convention on Biological Diversity aims to ensure fair and equitable use of genetic resources partly through technology cooperation, but its technological provisions have received little attention. The 1994 TRIPS agreement calls for technology transfer to the least developed countries, yet that provision has scarcely been translated into action.

35. There are additional difficulties too. Scientifically advanced developing nations are not necessarily considered as a bottomless pit of demands

by the firms in the developed world any more. Technology buyers from such countries are being seen as potential competitors in the world market. Therefore technology sales are being conditioned with marketing territory restrictions. The age of straightforward technology licensing agreements is also over. It is giving way to technology-cum-market, technology-cum-stakeholding, technology-cum-product swap, etc. Technology is available to a buyer only if it fits in with the supplier's global scheme.

36. The most important factor in developing indigenous technological capacity in Fig. 2 is that of 'learning by doing'. This requires investment in local R&D. Some developing nations have remained mere 'assemblers' rather than becoming 'smart assimilators'. Japan is a classical case in point. It invested heavily in international technology transfer, but then moved forward aggressively through strong local R&D to create globally competitive products. Cleverly designed national policies do stimulate this drive towards 'learning by doing'. Innovative ways of linking universities and industry, creating fiscal incentives to promote R&D by private firms, venture capital financing, etc. are just some of the proven ways to promote this process.

Bridging the Development Divide

37. The development gaps between the rich and the poor nations are truly striking today. The richest 1% of the world's people received as much income as the poorest 57%. In 1998, 29 OECD countries spent $ 520 billion on R&D - more than the combined economic output of the world's 30 poorest countries. These countries had 91% of the share of the new patents issued in 1998 - meaning thereby that the remaining 81% of the people had only 9% of the share. Can we ever dream of bridging this divide? What needs to be done?

38. Let us just take one sector, namely Information and Communications Technology (ICT) as an example. ICT revolution can provide powerful

new tools for a major socio-economic transformation of the poor people. But can they really benefit from this revolution, so huge are the asymmetries in ICT infrastructure! Whereas one in two Americans is on line, only one in 250 Africans is on line. More strikingly, one out of the two citizens of this world has never had the luxury of making a telephone call! Entire Africa has only 14 million telephone lines, which are less than those in Manhattan alone. 15% of the people in the world do 90% of the global spending on IT. An average OECD country has 40 times more personal computers, 110 times more mobile phones and 1600 times more internet connectivity than in Africa.

39. However, there is a good news. Rapid advances in technology are bringing down the costs dramatically with an attendant increase in speed and quantity. Transatlantic cable was laid in the late 1950's. The cost of one minute voice communication was then $ 2.44. Today it has plummeted to less than one cent. The processing power of computer by 2010 is expected to be 10 million times more than that in 1975. The prices for providing bandwidth are crashing due to fibre optic network technologies.

40. We need to take advantage of these breathtaking advances to provide economic access of new technologies to the poor. We also need to focus more on creating technologies specially suited to the poor. As an example, look at the Indian development of 'simputer' done by Indian Institute of Science (IISc) in Bangalore. It is a handheld internet appliance costing less than $ 200. It is based on the Linux open source operating system. The intellectual property rights have been transferred for free the non-profit Simputer Trust, which is licensing the technology to manufacturers at a nominal fee. Simputer provides Internet and e-mail access in local languages with touch-screen functions and microbanking applications. Speech recognition and text to speech software for illiterate users has been provided. This is a technological advance that can reduce the divide.

41. Let us look at the development at Indian Institute of Technology in Madras. It has created a low cost internet access system that needs no modem and eliminates expensive copper lines. The technology is based on a wireless local system, which is ideal for providing access to low income communities throughout India and beyond. Licensed to manufacturers in India, Brazil, China and France, the technology is already in use internationally, in Fiji, Yemen, Nigeria, Tunisia, etc.

42. There are two lessons to be drawn here. The first is that both these above initiatives were supported by public funding and incentives. The second is that they came from two of the most elite institutions from India, namely IISc and IIT. Scientists in such institutions are often times accused of working on problems that will fetch them peer recognition from the western scientists, rather than working on problems that can make a difference to the country. These brilliant exceptions prove that with proper support and encouragement, we can do a directional change that can eventually benefit the humanity at large. After all, there is a hope to bridge the divide

Creating Wealth through Traditional Knowledge

43. Many developing countries are described as rich countries, where poor people leave. Their richness lies in their traditional knowledge, biodiversity, etc. This traditional knowledge relates to such diverse domains as geology, ecology, botany, agriculture, physiology and health. There is a great potential to create wealth through such traditional knowledge. This opportunity has remained largely untapped so far.

44. One of the concerns of the developing world is that the process of globalization is threatening the appropriation of elements of this collective knowledge of societies into proprietary knowledge for the commercial profit of a few. These knowledge systems need to be protected through national policies and international understanding

linked to IPR, while providing its development & proper use for the benefit of its holders To encourage communities, it is necessary to scout, support, spawn and scale up the green grass root innovation. Linking innovation, enterprise and investment is particularly important.

45. New experiments are beginning to emerge on benefit sharing models for indigenous innovation. An experience in India is worth sharing. It relates to a medicine that is based on the active ingredient in a plant, trichopus zeylanicus, found in the tropical forests of southwestern India and collected by the Kani tribal people. Scientists at the Tropical Botanic Garden and Research Institute (TBGRI) in Kerala learned of the plant, which is claimed to bolster the immune system and provide additional energy, while on an expedition with the Kani in 1987. These scientists isolated and tested the ingredient and incorporated it into a compound, which they christened "Jeevani", the giver of life. The tonic is now being manufactured by a major Ayurvedic drug company in Kerala. In 1995, an agreement was evolved to share the license fee and 2% of sales of the product as royalty, that was receivable by TBGRI, will be shared on a fifty-fifty basis with the tribe. This marks perhaps the first time that for IP held by a tribe, a compensation in the form of cash benefits has gone directly to the source of the IP holders.

46. The grant of patents on non-original innovations (particularly those linked to traditional medicines), which are based on what is already a part of the traditional knowledge of the developing world have been causing a great concern to the developing world. It was CSIR from India that challenged a US patent that was granted for the wound healing properties of turmeric. In a landmark judgement, the US Patent Office revoked this patent in 1997, after ascertaining that there was no novelty; the findings by innovators having been known in India for centuries.

47. Yet another case of revocation followed in May 2000. The patent granted to W.R. Grace Company and US Department of Agriculture on

Neem by European Patent Office was squashed again on the same grounds that its use was known in India. India filed a reexamination request for the patent on Basmati rice lines and grains granted by the USPTO in 2000. Ricetec Company from Texas decided to withdraw the specific claims challenged by India and also some additional claims. In a further action, the examiner decided to disallow seventeen of the twenty claims.

48. To mitigate this persistent problem, the Indian Government took steps to create a Traditional Knowledge Digital Library (TKDL) on traditional medicinal plants and systems, which will also lead to a Traditional Knowledge Resource Classification (TKRC). Linking this to internationally accepted International Patent Classification (IPC) System will mean building the bridge between the knowledge contained in an old Sanskrit Shloka and the computer screen of a patent examiner in Washington! This will eliminate the problem of the grant of wrong patents since the Indian rights to that knowledge will be known to the examiner

49. Eventually the creation of TKDL in the developing world would serve a bigger purpose in providing and enhancing its innovation capacity. It could integrate widely scattered and distributed references on the traditional knowledge systems of the developing world in a retrievable form. It could act as a bridge between the traditional and modern knowledge systems. Availability of this knowledge in a retrievable form in many languages will give a major impetus to modern research in the developing world, as it itself can then get involved in innovative research on adding further value to this traditional knowledge; an example being the development of an allopathic medicine based on a traditional plant based therapeutic. Sustained efforts on the modernisation of the traditional knowledge systems of the developing world will create higher awareness at national and international level and will establish a scientific approach, that will

ensure higher acceptability of these systems by practitioners of modern systems and public at large.

Intellectual Property Rights and Development

50. An ideal regime of intellectual property rights strikes a balance between private incentives for innovators and the public interest of maximizing access to the fruits of innovation. This balance is reflected in article 27 of the 1948 Universal Declaration of Human Rights, which recognizes both that "Everyone has the right to the protection of the moral and material interest resulting from any scientific, literacy or artistic production of which he is the author" and that "Everyone has the right ...... to share in scientific advancement and its benefits". The burning question seems to be balancing the interest of the inventor and that of the society in an optimum way.

51. Intellectual property rights are being harmonised worldwide. As per the obligation under the Trade Related Intellectual Property Systems (TRIPS) agreement, developing countries are now implementing national systems of intellectual property rights following an agreed set of minimum standards, such as twenty years of patent protection; the least developed countries have to do so. One of the developing world concerns is that while a fully harmonised system of IPR is being advocated, today's advanced economies had refused to grant patents throughout the 19^{th} and early 20^{th} centuries. They formalized the enforced intellectual property rights gradually as they shifted from being net users of intellectual property to bring net producers. Indeed, France, Germany and Switzerland, who are leading developed countries today completed, what is now standard protection, only in the 1960s and 1970s.

52. In the developing world, the impact of TRIPS will vary according to each country's economic and technological development. Middle-income countries like Brazil and Malaysia are likely to benefit from the

spur to local innovation. Countries like India and China, which are endowed with a large intellectual infrastructure, can gain in the long term by stronger IPR protection. However, least developed countries, where formal innovation is minimal, are likely to face higher costs without the offsetting benefits.

53. I was privileged to be a member of the UK Commission on Intellectual Property Rights. The Report of the Commission addressed the issue of IPR and development, as it pertained to public health, access to food, information, education, etc. The sum and substance of the report can be briefly summarised as follows. For too long, IPRs have been regarded as food for the rich countries and poison for poor countries. It is not as simple as that. Rich countries can get indigestion from overindulgence. And poor countries may find them a useful dietary supplement, provided they are accommodated to suit local palates and not force-fed. The appropriate diet for each developing country needs to be decided on the basis of what is best for its development. It is this guiding principle that should help the national governments and international community to arrive at rational decisions, which can help integrating intellectual property rights into a balanced development policy. But reaching that balance requires a real understanding between the global players. The sooner we reach it, the better will it be for the mankind.

Technoglobalism and the Developing World

54. Just as globalisation of trade is growing at a rapid pace, there is a globalization of research and technology also. A new term 'Technoglobalism' has been coined in recent times to describe this phenomenon. The term "Technoglobalism' means a strong interaction between the internationalisation of technology and the globalisation of economy. Technoglobalism has created a widening of cross-border interdependence between individual technology based firms as well as economic sectors. Technoglobalism provides both challenges and

opportunities for the developing world, especially scientifically advanced developing nations.

55. Take India's case as an example. India is rapidly becoming a global R&D hub. More than one hundred major companies around the world have set up their R&D centres in India just during the last five years. The biggest would be the R&D centre of General Electric (GE) at Bangalore. Its current size of 1600 employees will increase to around 2400 employees, making it the second largest R&D centre of GE in the world. It is not India alone. Similar phenomena are in evidence in China, Korea, Singapore, Taiwan, etc. Specialised clusters are coming up in Philippines, Malaysia, etc. Many leading enterprises around the world are building innovation platforms through multi-sourcing of innovations.

56. Why has multi-sourcing of innovations gained prominence? There is an increasing pressure on shortening international market penetration times for new products, on shortening R&D times, and on decreasing the market life times for new products. Innovations are beginning to have multiple geographical and organisational sources of technology with increasingly differentiated and innovation specific patterns of diffusion. R&D in high-technology industries such as biotechnology, microelectronics, pharmaceuticals, information technology and new materials has become highly science based. The costs of doing R&D are also increasing phenomenally.

57. There has been a progressive weakening of the strategic position of corporate central laboratories within large firms. The firms around the world are becoming very selective with internal developments focused on critical products and processes. They complement their internal efforts with external technology acquisition on a global basis.

58. Creation of seamless laboratories around the world is also being helped by the evolution of global information networks. Indeed, these

networks are allowing the real-time management and operation of laboratories in any part of the world. Thus, companies are gaining a competitive advantage by using the global knowledge resource and working with a global time clock. The trend is also being fuelled by the shortage of R&D personnel in some emerging high technology areas in industrialised countries. The companies have to bridge that demand-supply gap in skills by external outsourcing. Obtaining access to high-quality scientists, engineers and designers is on the top of the agenda of many major companies now.

59. The impact of the severity of the shortage of R&D personnel can be seen by citing an example from European Union (EU). For EU to meet the goal set at the Barcelona Summit to raise R&D spending as a share of GDP to 3% by 2010 will require 700,000 new researchers. Obviously, there will be a great demand - supply gap. It is not surprising that there will be a greater draw on 'third world researchers' as one of the EU representative put it recently.

60. The demographic shift in the developed world means that developing countries with relatively favourable demographic profile with a large proportion of working and talented young people can become global innovation hubs, from which not only outsourcing of innovation will be done, but in which R&D based innovation centers will be set up by the companies from the developed world. This progressive shifting of the R&D location from the developed to the scientifically advanced developing nations is likely to have strong social, cultural, political, economic and strategic implications. Increased local demand on high quality science and scientists as also a competition between local institutions and industry on one hand and foreign R&D enterprises on the other hand for access to superior human capital will be some key drivers of change. Shifting of the 'centre of gravity' of knowledge production to these scientifically advanced developing nations will have strategic implications in the long run. Such shifts will also lead to a

gradual reversal of brain drain due to the increased opportunities in the country of one's origin.

Brain drain to brain gain

61. Let us take the issue of brain drain in a broader context. Why does brain drain take place in the first instance? I found the answer one day. I was involved in the process of interview for the Chief Innovation Officer of National Innovation Foundation in India. I found that the individual that we were interviewing was an expert in branding a product. I said ‘I want to brand India. How would you do that?’ He was puzzled. He had branded a soap, a refrigerator, but he wondered as to how he could brand a nation. I said ‘I will make it easy for you. Let me tell you as to how other nations brand themselves. For instance, US brands itself as a land of opportunity’. He immediately replied ‘I will brand India as a land of ideas’. Now here is the problem. India is a land of ideas but it is USA that is a land of opportunities. That is why young people with aspirations go to USA, which provides them an opportunity to reach their own potential.

62. I believe that for the young people, it is not the 'physical income' but it is the ‘psychic income’ that matters much more. Their incentives are not just financial. The fun of creation, admiration received from their peers, the excitement and glory of taking part in the process of creation of something new and exciting matters to them much more. That is why a computer engineer in India works on the challenge of the Param computer in Centre for Development of Advanced Computation (C-DAC) in India on a salary that is a small fraction of what he would get from IBM in India. That is why a space scientist in Indian Space Research Organisation works on the indigenous satellite launching vehicle GSLV rather than joining NASA. That is why I came back to India in 1976 on a princely salary equivalent to 140 British pounds per month, and so did many of my colleagues. The problem is that it is a small fraction.

63. Brain drain is not just a developing world phenomenon. It exists in the developed world too. The Italian scientist Riardo Giacconi, a Nobel Laureate in Physics, summed it up beautifully, when he said "A scientist is like a painter. Michael Angelo became a great artist, because he had been given a wall to paint. My wall was given to me by the United States". Italian, English and German scientists have also migrated to the United States; just as the Japanese scientists have done. A recent US National Science Foundation report (2002) shows that the percentage of Japanese Ph.D.s, who remained in USA, increased from about 35% in 1995 to over 70% in 1999. However, the damage that brain drain does to the developing world is far greater than in the developed world. Let me provide an analytical perspective to this argument.

64. Ecology of the intellectual process throws up outstanding scientists and inventors in a pyramidal and power-law fashions. The distribution of scientific productivity was analyzed by A.J. Lotka of the Metropolitan Life Insurance Company in 1926. The result of Lotka's investigation [Journal of the Washington Academy of Sciences, **16**, (1926) 317-323] was an inverse square law of productivity, which states that the number of people producing n papers is inversely proportional to n^2. This means that for every 100 authors who produce one paper in a given period of time, there are approximately $100/2^2$, or 25, who produce two papers. Simultaneously, there will be $100/(10^2)$ or one, who will produce ten papers, and so on. Interestingly, the same law applies to patents too. Francis Narin and Anthony Breitzman [Research Policy, **24** (1995) 507-510)] analysed the data on patents in semiconductor technology and showed that Lotka's law applicable here too.

65. It certainly appears that scientific and technological creativity and productivity lies in the minds and abilities of a relatively small number of highly talented individuals. Developing world continues to lose them

to the developed world. For instance, the cream of the cream from Indian IITs, which are India's premier institutions, leaves the Indian shores, year after year. India comforted itself by saying that if it lost a small number, it did not really matter. After all, it is a country with one billion population. But India did not realize the implications of Lotka's law, that it was these few individuals, who made a huge difference to those economies abroad. India did not realize that when it lost 1% of its top talent, it also lost 90% of its intellectual energy. A recent UNDP report estimates that 100,000 Indian professionals leave the country every year to take up jobs in United States. It estimates the resource loss of $ 2 billion per year for India. However, one needs to look at the potential economic gains these exceptionally talented people could have made in India and then one realises that the losses are even higher!

66. Different developing nations have used different means to handle this issue of brain drain at different times in their history. For instance, the strategies in Taiwan, Korea, China and India have been distinctly different. I saw somewhere a compendium of 110 different initiatives that have been taken. Taiwan set up National Youth Commission to encourage return. Korea upgraded its research institutions and offered salaries competitive with overseas incomes. Both Korea and Taiwan succeeded. Africa set up The Return of the Qualified African Nationals Programe run by the International Organisation for Migration. Over the past twenty years, around 100 persons per year returned. Considering the high level of brain drain in Africa, this is negligible. On the other hand, the Indian experience is recent years is striking. The data collected by NASSCOM in India shows that over 25,000 professionals have returned over the past three years. These first faint signs of the reversal of brain drain in India are due to increased opportunities in the IT sector and also in the new multinational R&D centres. Reversal of brain drain will only take place, when there are improved opportunities in one's chosen field and improved economic conditions - this is true universally.

Global Knowledge Pool for Global Good through Global Funding

67. Are we doing enough to fund those areas of research, which will benefit the poor? I am afraid not. Let me illustrate this by dealing only with the issue of diseases of the poor. Today, there is a problem about creating the drugs for treating the diseases of the poor. For instance, in 1998, the global spending on health research was $70 billion, but just $300 million was dedicated to vaccines for HIV/AIDS and about $ 100 million to malaria research. Of 1,223 new drugs marketed worldwide between 1975 and 1996, only 13 were developed to treat tropical diseases and only 4 were the direct result of pharmaceutical industry research.

68. It is obvious that there is a pressure on large drugs and pharma companies to provide the maximum value to their shareholders. Their research portfolio is obviously heavily slanted towards drugs, which bring in maximum profits to the firms and not towards the drugs for the poor. Incidentally, this is true of the pharma companies in India too! Even though there is an orphan drug law, the developed world does not have an incentive to work on diseases, which do not affect at least some part of their own population. Therefore, there is no substitute to creating new drugs for the poor excepting through public funding (national as well as international) and also through meaningful public private partnerships.

69. Can new drugs be effectively developed by public funding? Two issues arise here. First, the track record of the government in commercializing research is generally poor. Secondly, the governments of the developing countries will not have adequate R&D budgets of their own for supporting research for diseases of the poor, especially the tropical diseases. These problems can be circumvented by using successful models like the ones that have been used in agriculture. Research in agriculture was supported through public

funding. It has given immense benefits to the developing countries, heralding green revolution in several countries.

70. The solution is to create a **global knowledge pool** for **global good** through **global funding**. The global fund should be created and managed by an international body. The funding should be given for creating new knowledge and products for identified diseases of concern to the poor. The research agenda can be set and programmes monitored by this body. The norms for sharing the intellectual property arising out of this could be decided in such a way that access at affordable prices to the poor is ensured.

71. There are three ways of funding. The first is to create new world-class R&D centers in countries, which have the intellectual capacity to deliver. These centers could be specially fenced, structured and managed. The second is to fund already existing public institutions in developing countries, who have a successful track record, and whose performance could be bolstered with additional & directed funding. The third is to create a global knowledge network with partnership between the public and the private as is being done, for example, by Medicines for Malaria Venture (MMV) or International AIDS vaccine Initiative.

72. It has been repeatedly demonstrated that supporting R&D for the poor in the developing nations can bring rich benefits. India's Central Drug Research Institute produced a drug to treat cerebral malaria. Themis, an Indian pharma company sells it under the brand name E-Mal to 48 countries at affordable prices. These include the poor nations in Africa. India's Shantna Biotech came out with a recombinant DNA vaccine (Shanvac) on Hepatitis B. This vaccine was being sold for US $ 15 per dose. Thanks to the entry of Shanvac, the prices of the vaccine kept on tumbling till they came to less than a dollar per dose. Shanvac is supplied to UNICEF for 50 cents today! The message is that strengthening S&T and manufacturing capacity in the developing world can benefit the poor of the whole world. Global funds directed towards

this goal can accelerate the process of providing access of medication to the poor.

Global Funding for Global Public Goods

73. How can global funding for creating global public goods be created? UNDP's Human Development Report (2001) on 'Making New Technologies work for Human Development' provides some striking statistics. It suggests that the developed nations should take seriously the agreed standards for official development assistance of 0.7% of GNP. Doing so in 1999 would have increased the official development assistance from $56 billion to $164 billion. Dedicating just 10% of that to technology would have generated more than $16 billion.

74. In 2000, the official debt service payments by developing countries amounted to $78 billion. A swap of just 1.3% of this debt service for technology research and development would have raised over $1 billion.

75. A handful of foundations (Welcome Trust, Melinda and Bill Gate Foundation, Rockfeller Foundation, Ford Foundation) have made exemplary commitments to investing in long-term research. World Bank, through its Industrial Technology Development Programmes (ITDP), over the past twenty years invested over 4 billion dollars in improving the intellectual infrastructure in developing countries such as Korea, India, Philippines, Turkey, Chile, etc. These efforts are laudable but not fully adequate. It is estimated that an input of at least $ 10 billion per year will be required to push the R&D agenda on public good creation.

76. While we can seek help from around the world, can the developing countries help themselves? In 1999, the governments of sub-Saharan Africa dedicated $ 7 billion to military spending. Diverting just 10%

would have raised $ 700 million, more than enough to support the HIV/AIDS vaccine research program.

77. It is not that only the Developed world has billionaires. The developing world has these too. In 2000, Brazil had 9 billionaires with a collective worth of $20 billion, India 9 worth $23 billion, Malaysia 5 worth $12 billion, Mexico 13 worth $25 billion, Saudi Arabia 5 worth $41 billion. Foundations set up by such billionaires from the developing world could make important contributions to regionally relevant research agendas will they respond to these calls?

78. With its financial, intellectual and research resources, industry could make an invaluable contribution by committing a portion of profits to research on non-commercial products. For instance, in the pharmaceutical industry alone, if the top nine Fortune 500 companies had dedicated just 1% of their profit, to such research in 1999, they would have raised $275 million. In this context, it is refreshing to see the setting up of Novartis Institute for Tropical Diseases (NITD) by the Swiss pharmaceutical company Novartis in Singapore or that of Astra Zeneca Research Centre by the Swedish pharmaceutical company Astra Zeneca in Bangalore in India for research in tuberculosis. We need to multiply these efforts several fold.

Lifting the Submerged Past of the Iceberg

79. Let me end the lecture by sharing a recent experiment done by one of our laboratories, namely Central Salt & Marine Research Institute (CSMCRI) in Bhavnagar in India. In Kutch in Gujarat, we had a major earthquake. There was no electricity and no drinking water for those poor people in the villages. CSMCRI had developed the reverse osmosis technology for drinking water. But to operate this technology required a pressure of around twenty atmospheres. Without electricity, how would one generate such a pressure? The villages had no electricity but they had bullocks. The scientists made the bullocks go

around and using a cleverly designed helical gear system, generated the required pressure to run the reverse osmosis device. A village with around 300 families got the drinking water. The Intermediate Technology Group in Rugby in England was so impressed with this feat that it featured it in the New Scientist issue of 10 May 2003. While applauding this feat, the article said "The device holds a great promise for 1.2 billion people, who lack electricity and clean water, but who have plenty of oxen".

80. I see both a good news and a bad news here. The good news is that the compassionate Indian scientists, touched by the sorry plight of the poor villagers, created an 'appropriate technology' by using the odd combination of the motion by bullocks and the high technology of reverse osmosis. The bad news is that the remarks in the New Scientist article implies that we assume that 1.2 billion people in the world will continue to be without electricity and drinking water! This is not simply acceptable. Continuing with such disparities will cause a global fracture.

81. The substantial disparities between the developing and the developed world are major cause of concern for us today. But they exist within the developing world also. For example, large nations like Brazil and India suffer a national scale poverty, but also hide large sub-regional variations in social and economic fortunes. East and Southeast Asia have huge regional crests and troughs. Myanmar, Laos and Cambodia have not enjoyed the same economic growth as in other East Asian Countries.

82. The same situation persists in India. Today we have 50% Indian children that go to school, 30% of them reach upto 10^{th} standard and 40% of them pass. Multiply these percentages and you will find that 6% of the children go past the 10^{th} standard – as against 65% to 70% in Korea. Yet India is projected as an emerging IT Superpower. 600,000 software professionals with an average age of around twenty six

generated 20% of our exports last year. By 2008, they will generate 35% of our exports and contribute to 7% of our GDP. But 600,000 professionals constitute only 0.06% of our population. This is a tip of the iceberg. For this tip of the iceberg that is shining, there is a huge part of the submerged iceberg, which constitutes the 'have nots' and the 'underprivileged' that is in the dark. What worries me is how we are going to lift that iceberg.

83. It is rather strange that I am delivering the 10th Zuckerman Lecture here in London. I belonged to that submerged part of the iceberg in India. I was born in a very poor family. My father died when I was six. My mother, who was uneducated, did menial work to bring me up. I went barefoot till I was twelve. I studied under streetlights. I remember that after my Secondary School Certificate Examination in 1960, although I had secured eleventh rank among 135,000 students in the state, I was about to leave the school, because my mother could not fund my college education. And I remember Sir Dorab Tata Trust coming in with a scholarship of 60 rupees per month. They supported me until my graduation. This support was less than one British pound per month. That 60 rupees added so much value to my life but it did not subtract any value from the Tatas.

84. What are the lessons that I draw from my own life. There are three factors that helped me. First, I was given an opportunity to study in a municipal school that was run through Government funding. This education was free. Second, there was the philanthropy of the house of Tatas. This unique public-private partnership, if you like, made it possible for Mashelkar to complete his education. Third, as a young man in early thirties, I was invited back to India and given all that I needed to do my research in polymer science and engineering. This invitation was a part of a special initiative by the then Prime Minister to reverse the brain drain. I was given an opportunity to rise to my own potential. But for that one Mashelkar, who is standing here, there are millions of Mashelkars around the developing world, who need to be

helped. If they are similarly helped, then they will not remain confined in that submerged part of the iceberg. They will themselves rise to become a part of that shining tip of the iceberg. They will also help lift that submerged part of the iceberg. Ladies and gentlemen, I'd like to conclude by saying that we must do everything to lift this iceberg. Science and technology has that power of lifting that iceberg as I have repeatedly demonstrated in this lecture. We can all do it **together** and make it into a better tomorrow -- not just for a lucky and privileged few but for the entire humanity.