Speech

SCIENCE, TECHNOLOGY AND DEVELOPMENT *

Bimal Jalan

I am grateful to the Indian Institute of Science, unique Institute committed to advanced research and education on Science and Technology for asking me to deliver this lecture in the memory of Sir Vithal N. Chandavarkar. As a non-scientist, I feel specially privileged to be invited to address this distinguished audience in this famous institution. Sir Vithal Chandavarkar, a barrister by profession, was a towering personality in Indian public life. The University of Bombay and the Indian Institute of Science, Bangalore were among the two major educational institutions with which he was closely associated. I am happy to join you in the tribute we are today paying to the memory of a truely dedicated and inspiring personality.

2. My subject today is 'Science, Technology and Development'. Obviously, this is too vast an area to be covered in a single lecture. I will, therefore, have to be necessarily selective in dealing with only some aspects which seem to me to be of particular relevance at the present juncture in the development of our country. I hope you will forgive me if I have neglected some other aspects which may be of equal or even greater importance to some of you.

Introduction

3. The ultimate purpose of science is social. Its relevance lies in its contribution to the well being of the society. Science performs this role in many ways. In an intellectual sphere, science perhaps embodies a way of life – a rational thinking process. But in the material sphere its societal contribution is primarily transmitted through its application to the production of goods and services. In this process the scientific knowledge is transformed into applied technology. Technology, by changing the production techniques, results in improved productivity and it is through this increase in productivity that societies have achieved rapid strides in economic growth.

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4. History has shown that modern economic growth has been inspired by a rapid and persistent upgradation of technology and scientific know-how. It is estimated that from one-third to one-half of the growth experienced by the industrially advanced countries has come from technological progress. Thus, technology has emerged as the principal driving force for long-term economic growth. Economic growth results both from slow and steady improvements in technology and from knowledge embodied in physical and human capital as well as from the "breakthrough" inventions. Breakthrough inventions are, however, unpredictable and such inventions may at times change the direction of the entire industrial structure.

5. What is the relation between science and technology? How do they influence growth trajectories of the world economy and well being of the people? What should be the relative roles of state and market in ensuring the blooming of scientific knowledge and its culmination into technological know-how? What do the successful country experiences teach us in this regard? Today I would like to share with you some thoughts on some such questions that concern us all.

Relation between Science and Technology: Invention, Innovation and Diffusion

Invention and Innovation: A Schumpeterian Paradigm

6. From an economist's viewpoint, the relation between science and technology reminds me immediately of the great twentieth century Austrian economist Joseph Schumpeter. Schumpeter made a fundamental distinction between the invention, which is the discovery of new techniques, and innovation, which consists of the practical application of an invention in production for the market. Invention is performed by the inventor while innovation is the task of the entrepreneur.

7. The classic example of this is perhaps the 18th century industrial revolution in Britain. The success of the then Britain did not merely lie in the invention of scientific tools, which may be primitive by modern standards, but also in their commercial adoption. Thus James Watt is not only remembered as the inventor of steam engine but also as one who put it to commercial use. It is this commercial adoption that Schumpeter referred to as innovation. Many of the inventors of modern software too fall into this combined category of inventor-innovator rolled into one. Bill Gates is often portrayed as not only the pioneer of MS-DOS and Windows but as one who marketed it successfully. However, often the entities of innovator and inventor are distinct, and in such normal situations it is the intimate interlink between invention and innovation that marks the interrelationship between science and technology.

8. In Schumpeter's analytical structure there is a third stage of the twin process of invention-innovation, viz., diffusion, which occurs only when the scientist and the entrepreneur join hands. The invention and initial innovation of any product or process may be the property or outcome of an individual or company effort. But how are they made popular? What ensures their cost-reduction and universal adoption? It is only through proper diffusion of the scientific knowledge embodied in the marketable form of a particular product or process that it gets universalised. Technological history is full of examples of such diffusions, or knowledge spillovers.

Interlink between Science and Technology: The Question of Basic vis-à-vis Applied Research

9. Once we recognise the interlink between science and technology as the prime force behind economic progress, the question comes about the optimal mode of interplay between them. Put differently, often the question arises what kind of research is more necessary: pure or applied? The issue becomes all the more important in the context of funding science programmes. However, like many of the fundamental choice problems of human life, there is no standard model that can be universally pursued. At a conceptual level, nevertheless, one can have a two-way classification of the agencies involved with scientific research, viz., knowledge generation agencies and knowledge application/diffusion agencies. While the former includes universities or technical schools, big science national networks like CSIR or various corporations are examples of the latter. A related question would be: what kind of research we need more? Would the research paradigm of the scientific pursuit be dictated solely by utilitarian consideration and accordingly subjected to social controls?

10. All economies in the world faced this dilemma at some time or the other. In fact, the issue can be traced earliest in a public debate that took place in Great Britain during the 1930s between Michael Polayani and J.D. Bernal. Polyani stressed the need for autonomy and self-governance for the scientific community, while Bernal expressed his preference in favour of societal and government regulation over research agenda. Thus, often one finds a tension between, what is called an 'open' science with an 'appropriable science'. Such dichotomy, in my opinion, arises from a confusion between private and social rate of return of scientific pursuit. The immediate social rate of return out of an otherwise esoteric research programme may be low – but over the longer run it could have the potential of being appropriable. The contribution to science and technology comes from both these two kinds of research and often the degrees of success in the field of technical capabilities depend on the degree of cohesion that these two kinds of scientific paradigms have. In this regard, it may be noted that in many fields of today's world of scientific research, like modern biology, the distinction between basic and applied science is increasingly getting blurred. One is, in fact, reminded of Louis Pasteur, who used to say, "There is nothing like basic research and applied science. There is only science and its application". The distinction, developed by the European Commission is instructive in this respect. They have adopted a three-way classification of knowledge-based research, viz., a) fundamental research, b) basic industrial research, and c) applied research and development (R&D). It is my firm belief that India, as nation needs all the three kinds of research and makes an endeavour to maintain a symbiotic relation between them.

Impact of Science and Technology on Development

11. Enhanced labour, capital and technical progress are the three principal sources of economic growth of nations. The distinction between capital and technical progress in economist's terminology is often a matter of degree. While increase in capital is interpreted as the quantitative change in the existing capital stock of any country, technical progress refers to qualitative changes in the production technique. However, the term 'capital' needs to be taken in a rather broad sense, so that it encompasses the three distinct

kinds of capital viz., physical, financial and human. Accordingly, the domain of the concept 'technical progress' gets extended to all these three kinds of capital. This basic broad definition of capital is central to our understanding of the impact of science and technology on economic well being. Moreover, the contribution of science and technology on economic growth comes both in the form of capital and technical progress.

Relation between Technology and Growth: Schumpeter's Notion of Creative Destruction

12. What is the process through which these technological innovations get transmitted to higher growth trajectory? Let me turn to Schumpeter once more. Schumpeter describes this process as one of creative destruction; in his own words,

> "The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new…goods, the new methods of production or transportation, the new markets, the new form of industrial organization the capitalist enterprise create…(These) illustrate the same process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly, destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism."[1]

13. Recent theories of endogenous growth stress two facts of innovation. First, it is the engine of growth, and secondly, it is endogenously generated by competing profit-seeking firms. The key feature of the process is that knowledge acts as a public good and creates economy-wide increasing returns. The public stock of knowledge that has accumulated from the spillover of the previous inventions is a crucial input in the technology to generate new ideas. Recent empirical findings establish that while the rate of knowledge obsolescence rose from 2-3 per cent early in the century to about 10-12 per cent per year at the end of the 1980s, the rate of knowledge diffusion was even faster. In fact a study for U.S.A. found that 70 per cent of product innovations were known and understood by rivals within 12 months of the innovation, and only 17 per cent took larger than 18 months. There is also evidence of increasing patent-research input ratio (as measured by R&D expenditure) for a number of developed countries.

Growth, Total Factor Productivity and Incremental Capital Output Ratio (ICOR)

14. However, the crucial impact that science and technology imparts on the economic growth of a nation is through the kind of broad-based technical progress that I have referred to earlier. Traditionally this is done through growth accounting in which the total growth of a nation is decomposed into relative contributions of labour, capital and technical progress. The influence of technical progress in growth process of any economy is referred to as total factor productivity growth (TFPG). There have been various studies on growth accounting in a number of countries. A recent contribution for the G-7 countries and the Netherlands, for the period 1947-73, finds that the annual growth rates for TFP for these countries were substantial ranging from 1.4 per cent in the U.S.A. to 4.0 per cent in Japan.[2] TFPG accounts for over

1. J. Schumpeter: *Capitalism, Socialism and Democracy*, New York: Harper.

2. Robert Barro and Xavier Sala-i-Martin: *Economic Growth*, New York: McGraw Hill, 1995.

one-third of the overall growth rate in all these countries. Interestingly, the same study finds a rather low growth of TFP in the high growth nations of East Asia, where capital contributed the lion's share to the growth process. There is, however, no riddle in this finding; after all from measurement standpoint a small variation from earlier technique may still be defined as one of change of capital. As already mentioned much of the technological capabilities of the East Asian countries came either from technological licensing agreements or from foreign direct investment.

15. Let me now turn to the Indian performance in the productivity front. Because of inherent measurement problems of TFPG, estimates by different researchers differ quite substantially in Indian context. As for example, Professor B. N. Goldar of Delhi University estimated TFPG for 1960-80 to be 1.3 per cent per annum for India.[3] On the contrary, Professor I. J. Ahluwalia of Centre of Policy Research, New Delhi found that there were considerable inter-industry differences insofar as TFPG was concerned; in fact, her calculations indicated that TFPG for India was in the range of (-)0.6 – (+)0.3 per cent per annum during the sixties and the seventies.[4] Nevertheless, researchers found a positive turnaround in Indian TFPG since the early eighties.

16. Productivity performance may alternatively be measured by how much incremental output investment has generated in different time-periods. This, in economists' tool-kit, is termed as "incremental capital output ratio" (ICOR). The ICOR that exhibited an ever-increasing path during the first three decades of post-independence period started reducing since the early eighties. During the post-liberalisation period (i.e., 1992/93 – 1996/97) there had been further decreasing trend in it, indicating some productivity gains in the Indian economy in recent years.

Employment Potential of Technology-induced Growth

17. An important issue governing the impact of science and technology on the well-being of a nation is the employment potential of any technology. An oft-expressed fear associated with the emergence of any technological innovation is that it is labour displacing. The crucial issue in this context is the employment elasticity of an innovation-induced growth. Though *per se* the innovation of a new technology may be labour saving, but the development of ancillaries or related products may give rise to newer employment opportunities; it is the net employment absorption that determines the employment-elasticity of growth. There is strong evidence that so long as technology helps to widen the resource base of the production system of the economy, there is no a priori reason for technological innovation to be employment reducing in an aggregate sense. East Asian example is a case worth considering on this issue. It is now widely accepted that notwithstanding the proportions of factor-utilisation of any production process, there has to be ample emphasis on labour for ensuring the welfare of the working class. East Asian governments used many such policies - land reform in Korea and Taiwan, housing subsidies in Hong Kong and Singapore, credit targeting for small business and investment in rural infrastructure in Indonesia and Malaysia. Accordingly, despite varied degree tolerance

3. B. N. Goldar: *Productivity Growth in Indian Industry*, New Delhi: Allied, 1986.

4. I. J. Ahluwalia: *Productivity and Growth in Indian Manufacturing*, New Delhi: Oxford University Press, 1991.

of labour unions, wages increased as fast as Gross Domestic Product (GDP) and unemployment decline in all of the East Asian countries.

Policy Framework to Foster Innovation and Technology Development

Options in Technology Upgradation

18. International experience is full of success stories with different kinds of innovation. In fact, internationally there are four different forms of technology transfer, viz.,

a) acquisition of a share of the equity of the technology producing firm,

b) license agreement,

c) outright purchase of equipment, know-how or blue print, and

d) flow of human resources.

There are success stories in all these modes of technology upgradation. As for example, countries like Japan, acquired patents from outside, and then took recourse to their indegenous assimilation, and further development, so as to finally export them. Similarly, many of the high-growth East Asian countries have little original technological inventions – bulk of the technological capabilities came from licensing agreements or direct foreign investment.

19. Technological activity in developing countries, accordingly, tends to be almost of the "incremental type" rather than of "Schumpetarian-frontier-moving-type". Numerous case studies of such experiments can be cited from the Indian experience. Some examples include adopting imported designs of power plant equipment to suit local quality of coal and changes in the designs of tractors, vehicles and a variety of consumer durables to suit local conditions of production of components.

20. It must, however, be recognised that success stories of "in-country research" leading to output growth are exceptions rather than the rule. We have had our constraints. The time lag between 'effort' and 'results' in any innovation activity is large. An economy has to "afford" it. And an economy, that is pursuing a pattern of investment (such as infrastructure development), where projects have long gestation periods, may not find it very easy to allocate large resources to innovative activities where gestation lags are even larger than these infrastructure projects. Besides, there are the risks associated with innovation effort.

21. Thus, the principal elements that should be taken into account in drawing up a framework of policies to facilitate science and technology development effort are :

1. the trade option in technology,

2. the time lag between 'efforts' and 'results' and the associated risks,

3. the areas/industries to be given priority,

4. the institutional framework, the role of public sector, particularly the Governments in

   * facilitating innovation,

   * the direct role of Government in R & D effort, and

   * the institutional set-up for science and technology.

22. Looking at science and technology in the context of its contribution to production of goods and provision of services to the people, the objective is maximisation of output. If the needs of the society are to be fulfilled at the lowest cost, the 'make' versus 'buy' issues become important i.e., the trade option has to be kept in view. While the commodity markets may tend to be 'perfect', technology markets, even if they exist, are characterised by their 'imperfectness' marked by inadequate information and exclusive rights acquired through patents or otherwise. In the Indian situation, we are frequently compelled to acquire technology through imports. Firms trade in 'technology' not as a commodity but as a 'perceived' economic advantage for a stream of returns in the future. International political considerations cannot also be ruled out in technology trade. Licensing by Governments of developed countries is a common feature. However, when it comes to bargaining regarding technology transfer, the issue of indigenous availability often becomes extremely important. As for example, it has been observed in India that the prices quoted by foreign firms for capital goods and equipment drop when a distinct alternative supply possibility emerges. This has been the experience in a number of industries like electric power equipment, telephone exchange equipment and machine tools. Hence, to appropriate the benefits of the trade option in technology, the nation needs some effort at technology development, which generates a supply alternative. Consequently, the efforts towards development of indigenous technological capabilities make immense commercial sense and makes the path of getting the right kind of technology at a right price in an otherwise global village.

Financing of Innovation Activities

23. There are two fundamental issues that are central to any policy governing science and technology. First, what is the funding process of innovation activities? Secondly, if the diffusion of technological innovation is indeed fast what is the incentive of the innovator? Often there is a wedge between the commercial successes of a new innovation and the profits appropriated by the innovator – the problem becomes all the more important in view of the fact that in a number of cases innovative activity have substantial fixed cost. A number of solutions are practised in different degrees in various countries. Use of subsidies or tax-concessions for R&D expenditure, adoption of co-operative R&D venture and national champions, and detailed patent laws are the major policy instruments adopted in this regard. I shall take up the issue of patent later; for the present let me look into the funding process.

Some Cross-Country Trends in R&D Expenditure

24. As regards funding of R&D expenditure is concerned, considerable differences exist even among the advanced economics. While both Japan and U.S.A. spent 2.8 per cent of their GDP on R&D in 1989, 20 per cent of total Japanese R&D come from Government as against 50 per cent in U.S.A. Nevertheless, public expenditure on technology development for civilian industrial application accounts for a small share of public R&D budgets in the industrial economies. Interestingly, a number of studies found that effects of direct Government funding on the productivity performance of the recipient firms are smaller than privately financed R&D investment.

25. How does Indian expenditure on R&D compare against these statistics for developed countries? Based on official statistics, released by Department of Scientific and Industrial Research (DSIR), it had been pointed out that India spends roughly 0.7 per cent of her GDP to R&D. Furthermore, it was observed that the ratio had shown remarkable stability over the years. However, it needs to be noted that these statistics cover only those industrial units who chose to get registered with DSIR. Considering the fact that, over the nineties there had been substantial reduction in the number of units registered with DSIR, Professor Y.K. Alagh hinted at the presence of some underestimation in these numbers.[5] Interestingly, out of this rather meagre amount of R&D spending, more than three-fourth comes from Government; thus, the possibility of underestimating R&D expenditure could be present only in the rest one-fourth. Hence, even if we had accounted for the extent of underestimation, Indian R&D spending would hover around 1 per cent of her GDP. On the other hand, in the RBI sample of 1,720 public limited companies, there had been some marginal increase in the proportion of R&D expenditure to total expenditure – from 0.23 per cent in 1992-93, it became 0.24 per cent in 1993-94 and finally to 0.27 per cent in 1994-95. However, these numbers do not tell the full story. After all, one should not forget that presently in India there are 200 universities, nearly 400 national laboratories, and 1300 in-house R&D units of industries.

Venture Capital

26. Financing of innovative activities with private sector initiative, as I have already pointed out, is indeed problematic. Gone are the days of individual entrepreneurs, capable of financing uncertain, risky but full of profitable potential, new technological innovations. On the other hand, stock markets also may not be forthcoming in financing these high growth but risky ventures. To get rid of this finance constraint 'venture capital' comes in, which is essentially equity investment in companies that are not mature enough to get access to capital market but have high growth potentials to compensate for the uncertainties inherent in such ventures. There are a number of success stories of such venture capital financing in the developed world; successful corporations like Apple Computers or Genetech producing bio-medical products would not have born without active venture capital participation.

27. The guidelines on 'venture capital' issued by the RBI in 1988 recognised their role in the Indian conditions. A number of venture capital institutions came up in due course – the Technology Development and Investment Corporation of India (set up by ICICI). Technology Development Fund (set up by IDBI), Equity Development Scheme (set up by SBI Caps and Canara Bank), to name a few. For the year ending December 1997 the number of active members of the Indian Venture Capital Association (IVCA) went up to thirty-three. From Rs. 317 crore in 1993, the investments of various venture capital funds became more than double at Rs. 673 crore in 1996. Despite this growth, we still have a long way to go in the field of venture capital. However, since IVCA does not have the foreign equity companies as their members, the actual investment by venture capital firms may be somewhat higher than the quoted figures. The nature of the venture capital has an element of country specificity. It depends on the state of development of an economy. In this context the recent Draft Regulation for

5. Y. K. Alagh, "*Technological Change in Indian Industry*", Economic and Political Weekly, January 24, 1998, pp.181-184.

Venture Capital Funds issued by SEBI is expected to go a long way.

Science and Technology: The Indian Policy Environment

Indian Technology Policies: The Early Era

28. Nationalist leaders recognised the importance of science and technology in national development in as early as 1939, when a National Planning Committee was constituted under the chairmanship of Jawarharlal Nehru. Indian Science and Technology Policy was greatly influenced by Pandit Nehru's vision, who from early days had an abiding interest in application of science and technology to development. Commenting on his interest in science, Nehru said,

"Though I have long been a slave driven in the chariot of Indian politics, with little leisure for other thoughts, my mind has often wandered to the days when as a student I haunted the laboratories of that home of science, Cambridge. And though circumstances made me part company with science, my thoughts tuned to it with longing. In later years, through devious processes, I arrived again at science, when I realised that science was not only a pleasant diversion and abstraction, but was the very texture of life, without which modern world would vanish away. Politics led me to economics, and this led me inevitably to science and the scientific approach to all our problems and to life itself."[6]

Scientific Policy Resolution, 1958

29. India was perhaps one of the first countries of the world to create a ministry of Scientific Research and Natural Resources in 1951 for organising and directing scientific research for national development. The Scientific Policy Resolution presented in March 1958 stressed the following objectives of Indian Scientific Policy:

- to foster, promote and sustain, by all appropriate means, the cultivation of science, and scientific research in all its aspects - pure, applied and educational;
- to ensure an adequate supply, within the country, of research scientists of the highest quality, and to recognise their work as an important component of the strength of the nation;
- to encourage, and initiate, with all possible speed, programmes for the training of scientific and technical personnel, on a scale adequate to fulfil the country's needs in science and education, agriculture and industry, and defence;
- to ensure that the creative talent of men and women is encouraged and finds full scope in scientific activity;
- to encourage individual initiative for the acquisition and dissemination of knowledge, and for the discovery of new knowledge, in an atmosphere of academic freedom; and,
- in general, to secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge.

6. Nehru's address to Indian Science Congress - quoted from Dorothy Norman (ed), Nehru: The First Sixty Years, New York: The John Day Company, 1965, Vol.I, p.550.

Technology Policy in Indian Science Congress at Tirupati, 1983

30. Active pursuit of these policies bore fruits and educational institutions and scientific laboratories were established so as to reap the benefits of scientific progress. The next major landmark in the policy domain was announcement of the technology policy of the Government of India at the Indian Science Congress, Tirupati held in January 1983. Apart from reinforcing the above objectives, the resolution specifically called for developing internationally competitive technologies with export potential, energy saving technologies and technologies, which will recycle waste material. As far as the priorities of technology policies are concerned, it called for special consideration to be given to the aspects like employment, energy, efficiency of activities, and environment. In the field of acquisition of technology, though it called for a selective role for import of technology and foreign investment, it specifically stressed the need for absorption, adaptation and subsequent development of imported know-how through adequate investment in R&D to which importers of technology were expected to contribute.

CSIR: Some Policy Issues

31. In the context of the efficiency of the invention-innovation process, the role of CSIR is of paramount importance. Much has been written on the strengths and weaknesses of the CSIR. In this context, I found the Report of the CSIR Review Committee (1986, Chairman: Shri Abid Hussain) to be highly interesting. The Report found that presence of multiple objectives, sub-optimal scale of operation, lack of sustained and meaningful interaction between the CSIR and its actual and potential users, and lack of suitable incentive support had in the past limited the usefulness of CSIR in the Indian economy. Nevertheless there were exogenous factors, beyond the control of such scientific institutions, that were responsible for its limited usefulness. Lack of industry support and a regulatory regime had hindered their proper functioning. Often the reasons for lack of smooth functioning of institutions like CSIR were interactive and consequently the responsibility became collective. In future, the objectives of such science-technology interaction would be a proper blend of different situation-specific modes, like technology missions, technology programmes, sponsored research, basic research and societal science programmes.

32. In this context, it is encouraging that CSIR has recently issued a White Paper, CSIR 2001: Vision and Strategy. Among other things, it set up the goal to achieve self-sufficiency in financing by 2001, primarily through development of some niche areas in globally competitive technologies, holding of patent bank, and releasing 10 per cent of operational expenditure from intellectual property licensing. Moreover, as a strategy for achieving these goals, it has called for development of an effective marketing system and adoption of a stimulating intellectual property oriented outlook.

Recent Changes

33. The major changes in the industrial sector initiated in July 1991 introduced a new policy for technology transfers. Automatic approval for foreign technological agreement to high priority industries up to a lump sum payment of Rs. 1 crore was granted. The automatic approval was also granted to other industries provided they did not require the spending of free foreign exchange. For hiring foreign technicians and foreign testing of

indigenously developed technologies, all prior clearance have been done away with.

34. In recent past, Indian Government, apart from giving a number of tax concessions for R&D purposes, has undertaken a number of policy measures with far reaching significance in the field of science and technology. A Technology Development Board has been established in 1996 with a three-fold strategy, viz., (a) facilitating development of new technologies, (b) assimilation and adaptation of imported technologies, and (c) providing catalytic support to industries and R&D institutions to work together. In the budget for 1994-95, a new fund called Fund for Technology Development and Application was created wherein 5 per cent cess on payment for royalty for imported technologies was credited. The budget for 1996-97 strengthened this fund further and released Rs. 30 crore. Furthermore this proposed a matching one-time grant for the modernisation of laboratories of CSIR and ICAR. Every commercial rupee that the CSIR and ICAR earn incrementally will be matched by another rupee from the budget.

35. Recently released Draft Ninth Five Year Plan Document has emphasised the role of science and technology in Indian development process to a great extent and proposed the adoption of a multifaceted approach. Among the specific issues that have been raised in the Draft Ninth Plan, which call for closer attention are:

- Creation of a conducive environment in the R&D institutions for minimising hierarchical bureaucracy;
- Emphasis on human resource development and motivation as an element of qualitative growth; maintenance of proper balance between fundamental research and applied research;
- Development of a 'consortia approach' in which one of scientific laboratories acting as 'nodal' institution forms a consortium with the industry and other departments;
- Effective implementation of science and technology for societal development.

Realisation of this vision through adoption of operationally viable strategies, I am sure, will go a long way to enhance Indian technological capabilities.

Trends in Indian Technological Capabilities

Composition of Capital Formation in India

36. In the post-independence period India followed a fairly broad-based technological development. The sectoral composition of gross fixed capital formation (GFCF) at constant prices may illustrate our evolution of technological capabilities. The share of 'machinery and equipment' in GFCF has gone up substantially, with a per contra reduction in the share of 'construction'. During the first five year plan period (i.e., 1951-52 to 1955-56), 'construction' occupied a share of nearly 62 per cent of GFCF as against 'manufacturing and equipment's share of 38 per cent. On the contrary, in the nineties the trend is just the reverse, with a 35 per cent share of 'construction' in GFCF as against the share of 'machinery and equipment' at 65 per cent.

Some Examples of Indian Technological Capability

37. Some examples of the benefits obtained from "technological change", in our own country during the past three decades,

illustrate the impact of science on growth. The sharp increase in "agricultural productivity" experienced in the last two decades can be ascribed mainly to the shift to high yielding varieties. Agricultural scientists working in laboratory condition no doubt developed these. But their successful adoption was supported by simultaneous efforts utilised for infrastructure development. The sharp improvement in the life expectancy since the forties reflects a successful effort at improved health care service realised largely through control of epidemics using modern medicine. Many other examples from the areas of transportation and energy exist.

38. India has had a long history of 30 to 40 years of manufacturing capital goods. Both kinds of capital goods, the special purpose equipment for the process plants (for chemicals, metals, minerals, consumption goods, electric power, etc.) and the general purpose machines amenable to mass production (machine tools, transport equipment, consumer durables) have been produced in our factories. In the process of vertical integration of manufacture – from assembly stage backward to individual components – a wide production base has been created. However, the capabilities to design and further improve upon the product have not been developed for many kinds of capital goods. In the case of some equipment, our domestic market compares well with those of developed countries. Examples are – consumer durables (two wheelers, refrigerators etc.), tractors, machine tools, power generation equipment and textile machinery. Some capabilities have been developed in light commercial vehicles, and two wheelers. Such instances are, however, 'firm specific' and not general across the industry. The lack of designing capability has inhibited the ability to adjust the designs to changes in the requirements of the customers and industrial user, resulting in the import of product designs frequently. In the case of capital goods used in the processing plants, such design know-how is built through the designing of 'processes'. However, in India the 'process design capabilities' have not grown. The initial effort in certain areas was promising. In the fertiliser industry, the then FCI and FACT and in steel industry, the then Hindustan Steel had their in-house engineering and design establishments but later as independent companies, competed for jobs in their own mother companies against the international process consultancy companies, and were generally unsuccessful. More recently, the successful design work done on an experimental high voltage direct current (HVDC) project, under the BHEL, and in telecommunication, under C-DoT have been widely quoted. But these still await contracts by the user sectors. In recent years, the 'process consultants' have generally been foreign firms, and they have sourced their equipment supply, frequently, abroad. The technology for the capital goods production can, therefore, mature only in exceptional cases. Such instances are found in products and processes where technologies have stabilised but the product markets have lacked dynamism. A successful capital goods manufacturing structure can thrive only on a sturdy base of designing capabilities.

39. Technology helps to widen the resource base of the production system of the economy. In India, the major areas where this has taken place are the energy and agriculture sectors. This has occurred also in relation to the provision of certain basic needs such as drinking water. The successful shift in the technology of oil exploration from on-shore to offshore opened up vast resources of oil and natural gas for use. At present 63 per cent of our oil production comes from offshore operations which did not exist 15 years ago.

The utilisation of natural gas for fertilisers and petro-chemicals has been possible only because of the shift to offshore production. Natural gas today supports more than 40 per cent of nitrogenous fertiliser output and about 50 per cent of petro-chemicals. The latter in turn has enabled a shift in the material base in terms of common usage, from timber and metals towards plastic based materials. Thanks to our technological advancement in some industries like catalysts and pharmaceuticals, India could become a net exporter. Electrification of villages enabled the exploitation of ground water potential for agriculture. The period of 80's when value added in production in agriculture increased at about 3 per cent per annum was associated with a sharp growth in electricity consumption by agriculture. It is largely through the shift in water lifting technology that paddy could be produced in the north and north-west. Even the changes in simple techniques of lifting the ground water have helped to solve drinking water problems in water scarce villages. The technology mission on drinking water owes its success to a considerable extent to the new types of deep well hand-pumps introduced in the country some 15 years ago. Besides, our achievements in space, defence and atomic energy have indeed been momentous.

Challenges for the Future and Possible Policy Directions

40. What is the future of science and technology in India? Against the above background, let me now turn to some of the challenges and burning questions of the future. From rather long menu of issues, I shall largely deal with two issues in particular.

Effective Patent Laws and Intellectual Property Rights

41. I have already pointed out that innovative activities often turn out to be risky from the standpoint of the financier. Existence of an effective and speedy patent-legal framework goes a long way to solve the incentive problem associated with any innovative venture. Though the Indian Patent Act, 1970 was indeed a breakthrough from the earlier archaic Indian Patent and Design Act of 1911, still much needs to be done. The following example may illustrate the point. During 1994, whereas in India 4,000 patents were filed, China in the same year had 70,000 patents.[7] After all, a slow process of patenting not only hurts the interests of the innovator but also discourages the potential ones. Existence of loose patent laws or its violation, like those prevalent in software piracy, thus, makes me extremely anxious.

42. Nevertheless, as a far-reaching extension to above argument, the global regime represented by trade-related-intellectual property rights (TRIPs) tilted the balance of benefits of innovation in favour of the private innovator. As a signatory to the 1994 Uruguay Round of Multilateral trade negotiation of the then General Agreement of Tariff and Trade (GATT), India is bound by the regulatory framework of the recently created World Trade Organisation (WTO). This may have consequences on the oft-adopted modes of industrial research in India like imitative research or reverse engineering. We need only to stress more innovative research but also to develop the intermediaries like patent agents and patent attorneys, who will bridge the gap between

7. R. A. Mashelkar, Making Economic Sense of Science: The Emerging Indian Challenge, Foundation Day Lecture at Inter University Centre for Astronomy and Astrophysics, Pune, December 29, 1995.

the market and the scientists. This apart, as the Draft Ninth Plan pointed out, we need to take new initiatives to, "secure a more favourable deal at the impending review of the TRIPs agreement in the WTO" (p. 1059). This is going to be a serious challenge of the future.

The Role of the State in Technological Development

43. What is the role of Government in advancement of science and technology upgradation in a liberalised market-friendly atmosphere? At this point of time, the issue may apparently seem to be old-fashioned. Often in popular parlance, liberalisation in equated to a withdrawal of state from the economic domain. However, science and technology is a field where such popular notion may turn out to be fallacious. It is widely argued that there are three sources of market failure, viz., indivisibility, uncertainty and externalities. Knowledge generating activities like R&D suffer from all three types of market failure. Moreover, when there is a wedge between private and social profitability, like that existent in pure research, private finance may not be forthcoming. Thus, even in a deregulated regime the state will have three specific and selective roles in fostering science and technology, viz., financier of fundamental research, provider of infrastructure, and regulator of property rights. The Approach Paper to the Ninth Five Year Plan (1997-2002) rightly pointed out,

"Experience of many developing and industrialised countries suggests that a rapid acceleration of industrial technology development call for a deliberate 'strategy', in the sense that it requires the Government to co-ordinate and guide an essentially market-driven process. Free markets suffer from various kinds of 'market failures', they may not throw up the appropriate amounts of infrastructure, skill, information and institutional support, and mere exposure to market forces, while getting rid of inefficient policies, may not suffice to create the technological dynamism that continued industrial growth needs" (p.37).

Epilogue

45. During the fifty years of independence, India has come a long way in her quest for scientific pursuit, both in material and intellectual sphere. The winds of change that have been blowing in India since the last few years has changed the scenario a great deal. It has posed new challenges and opened up newer opportunities. True, there is still much to be done in the policy and legal sphere. But the directional indications are right. In the liberal environment, let thousand ideas of science and technology bloom and let these be transcreated into innovative ventures by our entrepreneurs. India has the talent, the skills and the resources to be in the forefront of technological revolution that is taking place in the new sectors of growth in the global economy. The future is truly exciting and we in the scientific, industrial and financial community must make it possible for our young men and women to take maximum advantage of the opportunities that lie ahead.