Technology policy in a liberalizing economy

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The value of technology

It should be useful to remind ourselves about the importance of technology development before discussing technology policies. Many attempts have been made to estimate the contribution made by technology to economic growth, and a gratifying consensus appears to be emerging[1]. Robert Solow, the Nobel Prize-winning economist, concluded from an early study that 'half of economic growth is due to technological improvement'. An analysis of the US economy by Moses Abramowitz for two periods separated by nearly a century (1869–73 and 1944–53) also found that about half the growth experienced in either period could be directly attributed to technological improvement, including that in human resources. The well-known Stanford economists Boskin and Lau have analysed five major industrial nations, viz. UK, USA, FRG, France and Japan, and found technical progress to be the most significant source of growth—explaining more than 50%—followed by growth of capital input (20%). In Japan, which emerged as an economic and technological power house in about one generation after a catastrophic war, the investment in R&D has exceeded capital investment since 1986; in 1990 it was 26% higher[2]. Another Nobel laureate, Sir Arthur Lewis, has shown by detailed analysis how the poverty of India in colonial times could fundamentally be seen as due to technological backwardness: technology was the engine of growth, and the industrial revolution gave Europe an extraordinary advantage. The fascinating account of Headrick[3], describing the role of technology in the spread of European imperialism in the 19th century, must be read by every Indian engineer and manager: according to him 'It is because the flow of new technologies in the nineteenth century made imperialism so cheap that it reached the threshold of acceptance among the peoples and governments of Europe, and led nations to become empires.' In a way, therefore, India became a colony not just because of Robert Clive and Warren Hastings, as history books tend to suggest, but also (indirectly) because of Isaac Newton and James Watt.

The nature of technological knowledge

A brochure issued on the occasion of the 7th Indian Engineering Congress (Bangalore, February 1993) declares that 'It is the codification of knowledge that becomes the directive of innovation'. It is therefore useful to understand the nature of technology as knowledge. There is a widespread tendency to think of technology as indistinguishable from science, or as being at best applied science. However, while there is nothing more practical than a good theory, and while scientific knowledge is most valuable for and increasingly more often can lead to technology development, technology is not mere applied science; it is enormously richer, and indeed autonomous in many ways, for technologists will and must develop new artifacts for human use even when all the 'understanding' that is the motivation for science is not available to the satisfaction of the true scientist. Science has to do with understanding nature, and with explaining and predicting phenomena with the fewest possible independent hypotheses. (When Napoleon, looking at Laplace's book called *The System of the World*, asked him how a book with such a title made no mention of God, Laplace said, 'Sire, I find no need for that hypothesis'.) In other words, science has to do with intellectual economy. The objective of technology, on the other hand, is to make new products or artifacts—things never made before—to meet human needs, and to make them in the most (financially) economic way possible. (Sometimes the existence of those needs is recognized only after the product meeting them is available!) In doing this scientific knowledge is a powerful ally, and increasingly more so with time. Such developments as the transistor or nuclear power have critically depended on scientific breakthroughs. Nevertheless, as the Japanese in particular have demonstrated, new products can be made and considerable wealth generated by an accumulation of incremental improvements none of which in isolation can be said to involve a breakthrough.

Quite often the technologist takes on tasks in which there is no scientific understanding yet, and may even have to create new science in the process. An example from the 19th century is steam engines, whose development led to the invention of thermodynamics. (In my undergraduate years the engineering course that used to be called 'Heat Engines' was fashionably renamed 'Applied Thermodynamics'. From a historical point of view, however, the subject of thermodynamics can be more accurately called 'Applied Heat Engines'—i.e. heat engines applied to understand nature.) An example from this century is (electronic) computer technology. Its genesis was an instrument put together by Eckert and Mauchly in the University of Pennsylvania for making ballistic calculations; it was von Neumann and Fermi who saw its scientific possibilities[4]. A much more familiar example—one that is shocking to most people—is the elementary problem of hydraulics: conveying water from point A to point B. While this is a routine task for the plumbers, the basic problem of predicting any characteristic of the kind of turbulent flow that occurs in most pipes used in practice, based on first principles, is unsolved as science.

Surprising as it may sound, the nature of technological knowledge has received little attention till recently, presumably because engineers are so immersed in getting ahead with their immediate tasks that they have little time for self-analysis and even less for articulating their views. Some historians of technology have recently devoted much attention to the subject[5], and Prof Vincenti[6], reporting several analytical studies from aeronautical history, makes some fascinating points in his book *What Engineers Know and How They Know It*. We first recall that, as G.F.C. Rogers points out, 'Engineering refers to the practice of organizing the design and construction of any artifice which transforms the physical world around us to meet some recognized need'; knowledge is not an end in itself in engineering. And engineering is a subset of technology, which includes not only the science but all the arts, skills and craft involved in production and operation of the artifact. Vincenti concludes that the growth of engineering knowledge has essentially three elements: (i) introduction of variations, (ii) selection among the variants; (iii) preservation or propagation of selected variants. Thus, most aircraft flying today are monoplanes with aft tails. This configuration has survived from a large number of variants tried out earlier this century: biplanes, canard configurations, tandem wings, pusher and tractor propellers etc. We see the same selection process at work in automobiles: the current generation has a surprisingly uniform appearance irrespective of country or company of origin, all the other diverse variants that used to be seen even as recently as twenty years ago having fallen by the wayside. In other words, technological knowledge has more to do with (a

Darwinian type) selection among a variety of technically feasible but suboptimal solutions, rather than with the concepts of falsifiability, consensus etc. that characterize science.

In summary, technology moves ahead with whatever information it has—from science, craft, testing, intuition, experience, computation—whatever is feasible. As the pioneering electrical engineer Heaviside pointed out early in this century, one does not wait to understand the process of digestion before starting to eat. However, the search for that understanding proceeds apace in parallel, the aim of what we call 'engineering science' being precisely to expand the scientific component of technological knowledge; invariably this leads to all those incremental improvements that quite often accumulate in the triumphs of engineering, such as for example putting a man on the moon.

The connection with commerce

Having argued how technology is not the same as science but needs it, we must now introduce the third element: business or commerce, because commercial success (or at least widespread adoption) is the final test of new technology. Briefly, concepts and understanding come from science; technology makes artifacts, develops them into useful, affordable, needed products, business puts them on the market or commercializes them, and generates wealth. New science is not the sole origin of innovations: commerce is often a fertile source as well. And the bulk of the investment in introducing a new product does not go into research, but into later stages of development. On an average, US experience on expenditure on any product breaks down as follows:

Fundamental research	5%	15%
Exploratory development	10%	
Advanced development	20%	85%
Engineering development	50%	
Operational systems development	15%	

In India, industry unfortunately has hardly any tradition of R&D, although there are some notable exceptions (e.g. chemicals). According to the Department of Science & Technology (DST)[8], Central and State governments support 72.8% of our R&D budget, and industry 23.2%, roughly equally shared between the public and private sectors (spread over more than a thousand generally small R&D units).

The technology policy statement

It should be clear from the above discussion that successful technology has (especially in India) to act as a bridge between science and discovery at one end, and business, commerce, economics and sociology at the other. When we examine or formulate a technology policy, therefore, we have to keep in mind all these other factors and harmonize them to be able to achieve our goals.

Now India adopted a Scientific Policy *Resolution* in 1958, and issued a Technology Policy *Statement* in 1983 (raising the interesting question whether we could not muster the same *resolution* on technology as Panditji did on science). Parliament passed the former, but the latter was just handed out at a conference. The very first aim of the Technology Policy Statement was:

> Attainment of technological competence and self-reliance to reduce vulnerability, particularly in strategic and critical areas, making the maximum use of indigenous resources.

There were several others, but one is left in no doubt about the primacy of strategic considerations. Given the history of Western dominance over India (and indeed over the East as a whole) during the last few centuries[3,7], and the experience of continual conflict even during the first four decades of the Republic, the emphasis of the Technology Policy Statement is understandable. It is therefore no surprise that, even in 1991–92, of the sum of Rs. 4830 crores invested in R&D, more than 54% went to defence, space and atomic energy[8]. Transport, communications and energy together accounted for only 10.3%, i.e. about US $160 million, which is of the same order as what one would have to pay for one aircraft of the Boeing 747 or jumbo class. While the concern about the strategic sectors is, as I said, understandable, what is wholly ununderstandable is how the country expects miracles in sectors which have clearly been considered secondary, and not worth much investment. Even the funds sanctioned in these sectors have not often been fully utilized, so the question is a matter of mindset and not just resources. Clearly, as a result of encouragement by the state, the best technical and managerial talent has migrated towards the strategic rather than the wealth-generating sectors.

So our infrastructure remains weak; not surprisingly, many foreign investors (particularly the Japanese) have been hesitant about opportunities in India precisely because of this weakness. It has been said[9] that sectors like energy, housing, transport and communications should not be seen as national headaches, but rather as extraordinary opportunities for technology and wealth generation in a vast market; till our mindset changes, progress here will at best be halting. Recent studies in aviation[10] and other transport sectors[11] show the phenomenal growth that has already taken place, and the inadequacy of current policies to deal with this growth. For example, the number of two-wheelers on our roads grew by two orders of magnitude between 1951 and 1989, is currently growing at 17.6% p.a., and between 1990 and 2000 will have multiplied five-fold. But roadways are growing only at 4.4%. Our clogged roads and crowded railways, and the frustrated wait-listed passengers in our airports and the long queues for telephones, are clear indications of market needs that have not been positively and aggressively tackled.

We must realize that economic development is also part of national security. Without the creation of sufficient wealth, we will be unable to defend ourselves. Japan has constitutionally limited itself, for a long time, to spending no more than 1% of gnp on defence; but its defence budget is rapidly growing, because the gnp is growing.

The point that I wish to make is that it is essential to increase investment in the non-strategic sectors and to create an environment there that will attract talented scientists and engineers.

An illuminating case-study of how success in commercialization does not depend only on the excellence of the technology or management, but crucially on technology policies, is presented by Bhojwani and Lal[12] and is strongly recommended to the engineering reader. Recounting the story of methyl chlorosilane, a basic material in the manufacture of silicones, (used widely in several lubricants, coatings and pharmaceuticals and in food-processing and water softening technologies), they find:

> The technology and product were demonstrably superior. It was offered as a fully-proven and guaranteed technology package... However, commercial success is not simply a function of technological excellence (but) is critically dependent on the national policies and the way they are applied to create national advantage... None of the provisions of the TPS were even remotely upheld...

We shall return to this issue, but it is necessary at first to ask how the New Industrial Policy announced in July 1991 is likely to affect technology development in India.

The new industrial policy

The new policy welcomes foreign investment and technology collaboration to 'obtain higher technology, to increase exports and to expand the production base', but at the same time promises to encourage 'self-reliance and development of domestic technology through investment in R&D'. In spite of first appearances these are not necessarily contradictory aims, but their simultaneous realization will call for an extremely finely tuned set of policies, and a kit of well-honed tools for implementation of those policies; neither of these appears to be available in India, going by the example quoted in the previous section. Nevertheless, that the objectives of the policy are not impossible to achieve is demonstrated by the experience of many Asian countries, in particular Japan and Korea. A White Paper published by the Japanese Science & Technology Agency in 1982 (ref. 13) noted how Japan was the largest producer and exporter of automobiles in the world, possessed the most efficient steel technology and had become the dominant source of consumer electronics: in all of these areas it had a major presence in the international market. But while this was being achieved Japan's *technological* trade balance (i.e. in ideas or knowledge, as represented by patent fees, royalties, technology purchases etc.) was adverse: it paid eight times as much to the US as it got from them. At the same time it was spending furiously on domestic R&D, at a rate higher than the US; a recent study has found that more than 99% of the patents used in Japan are domestic, a higher proportion than in any other country (including the US)!

It seems clear from the above numbers that even the *use* of foreign patents demands a vigorous industry and R&D: Japan had clear ideas about the products it was developing and the technologies it was mastering, generated its own knowledge base but bought whatever it needed. The role that the Ministry of International Trade and Industry played as the presiding deity in the transformation of Japan to an economic superpower has been too well-documented to need elaboration here.

Similarly South Korea has transformed itself in one generation[14]. In 1962 its economic vital statistics were the kind still all too familiar to us: $482 gnp per capita, 2.9% population growth rate, $335 million trade deficit; in 1987 the figures were $4968 gnp per capita, $4.6 billion trade surplus. While during the first half of this period the growth was chiefly due to use of cheap labour on imported technology, massive investments began to be made later in R&D, which amounted to over 1% of gnp in 1983, and to nearly 2% in 1989 (half of the latter incidentally coming from industry). These transformations took place through six consecutive five-year plans, and strong state intervention, but with industry generally in private hands.

The conclusions we wish to draw from the above examples are that economic liberalization, especially to foreign capital or technology, does not imply a smaller investment in domestic R&D, nor does it imply that the state plays no role in technology and industrial policy. What seems clear is that direct investment by the state in (public sector) industry has generally not been successful anywhere in the world. In contrast, the state has been, directly and indirectly, a successful *agent* in technology development, certainly in the East recently; and in many areas of strategic concern in both East and West, including India[15]. A policy that leaves *everything* to the market place will not, at least at the present stage in India, lead to healthy technology development. Even the US is now realizing that in certain key areas, e.g. manufacturing and computers, the state would have to take initiatives if the US is to maintain its international competitiveness or leadership[16]. In many products the US position has been eroded because of the aggressive role that the state has played elsewhere in the world in assisting technology development (e.g. France in aerospace, leading to the emergence of Airbus Industrie as the second largest player in the international airliner market, next only to Boeing, and of Arianespace as a major provider of satellite launch services; Japan in supercomputers, producing the most powerful sequential machines in the world).

There has actually been much debate on these issues in that very temple of free-market economics, the US. The well-known economist W. W. Rostow, after a survey of the competitiveness of US technologies[17], concluded that:

> aeronautics and chemicals fared best, because of close linkage to both R&D and production; electronics was mixed: computers did well, but consumer electronics was lost; automobiles were a disaster.

Hans Mark, analysing aeronautics, found three reasons why it has done well:

(i) The Federal Government made a consistent investment in the development of aeronautical technology for more than 70 years, and spends even today about $2 B/yr on research.
(ii) There is no adversarial relationship between Government and the aerospace industry.
(iii) There is good technology transfer from R&D to manufacturing.

In spite of worries about the growing prowess of Airbus Industrie, the US aircraft industry is doing relatively well (it had a trade surplus of $23 B in 1990) because of this 'coalition' between R&D, Government and industry.

In India however the situation appears to be that the Government has identified the new industrial policy with a relative *reduction* in its S&T investment; a recent publication by the Department of Science & Technology[8] discloses the alarming fact that this investment has declined over the last three years, from 0.96% of gnp in 1988-89 to 0.89% in 1990-91. In most advanced countries the figure is 2-3%, and rises to nearly 6% in the ambitious countries of east and south-east Asia. In absolute terms the Indian expenditure on S&T is about 1% of Japan's. Furthermore the Central Government is the major supporter of R&D in India, accounting for 69%: industry (public and private), as we already saw, accounts for only 23%, whereas in Japan the figures are nearly switched. Finally, we have to recall the nature of the investment required in technology if product development is the objective: US experience (already cited) shows that, on an average, for every dollar spent on fundamental research and exploratory development, nearly six dollars have to be spent on the later stages of product development. Many projects in India stop at the first stage for lack of support for the second.

The concern among scientists and engineers about these new policies is serious and genuine. Six distinguished colleagues of mine have recently considered the status of basic science in India in such fields as physics, chemistry, engineering, biotechnology and earth sciences[18]. And their conclusion is unanimous: we have a long way to go still, and this is not the time for Government to wash its hands off S&T.

Aviation: a case study

I have considered elsewhere the subject of a civil aircraft industry for India[10], so it is unnecessary to present the argument here in detail, but some of the major conclusions drawn there are relevant to the present paper.

The number of passengers carried by Indian Airlines is doubling every 7.5 years. The overall growth rate is about 10–12%, which is much higher than the world average; elementary models and experience both suggest that the potential rate of growth is about twice as high. There is evidence that the growth of aviation in the country has been curbed, presumably on the ground that it is a net *consumer* of wealth, not creator. The outlay on civil aviation reached a peak of Rs. 930 crores in the Sixth Plan, and is Rs. 780 crores in the Eighth Plan. Of this the capital outlay is about Rs. 500 crores, much of it in foreign exchange. However the airlines bring in about Rs. 400 crores in foreign exchange, leaving a deficit of about Rs. 100 crores. This is about a tenth of the earnings in foreign exchange from tourism (still very small in global terms: India attracts only 0.3–0.4% of the world's tourist traffic). These figures clearly show that the problem is by no means formidable, and indeed suggest solutions that can make civil aviation a net source of wealth.

Before we propose a set of policies for civil aviation, it is first necessary to recognize that there have been three dramatic changes in the aircraft industry scene in the world in recent decades.

The first is the emergence of an increasingly confident and powerful second rank of aeronautical powers. For a decade after the end of World War II, the industry was dominated by USA, UK and USSR. The position is now vastly different.

Beginning with Brazil, many countries have entered as competitors on the international scene and have begun to carve a niche for themselves in the market place. Small Brazilian aircraft, including the well-known Bandeirante, are now familiar in many parts of the world. The Indonesian aircraft industry is another fascinating study: it was realized that aviation has many natural advantages as a means of transport in that vast archipelago. From licence manufacture (which is where India also started—in the 1940s), Indonesia has moved in less than 15 years through joint to independent design and production of its own civil aircraft.

The second dramatic change is the increasing internationalization of the aircraft industry. In the 1980s more than half of the aircraft projects in the major European countries (France, Germany, UK, Italy and Spain) were international. Part of the reason for this development is that the aerospace industry is technology-intensive, and R&D costs tend to be very high (15.4% of sales in the US), so they have to be more widely shared. Furthermore, internationalization increases the market and brings advantages of economy of scale. Collaboration in Europe has of course been encouraged by the urge towards economic union, but this is clearly not a sufficient explanation, for the US is also now actively looking for partners, both in Europe and Asia. India has till now spurned all foreign suitors (of which there have been several), although the human resources of this country, our relative familiarity with an alien tongue, and our own dire need for a civil aircraft industry that can earn foreign exchange should make us natural partners.

The third dramatic change in the world scene is the enormous growth of the aircraft industry, and of the volume of air traffic. As of October 1990, some 3500 jet transports were on order, and there are an additional 2000 options. Although there may be some doubt whether all these aircraft can be filled with passengers, aviation in Asia and the Pacific Rim is growing very rapidly, and if economic development in the Asian giants—India and China—picks up pace, the market can be huge indeed. A US National Academy of Engineering report[19] estimates that the current international fleet of 9000 subsonic aircraft will expand to about 20000 by the year 2020. While China, along with Indonesia, S Korea and other Asian countries, is exploiting this growth for establishing a presence in the international civil aircraft industry scene, India is conspicuous by its absence.

Keeping these factors in mind, a possible policy-framework for civil aircraft manufacturing programmes would be as follows:

- Institute a carefully tailored programme of controlled deregulation, promoting a small number of domestic national carriers, and a much larger number of regional and fourth-level airlines, using them also for community aerial services and air-taxi operations.
- Encourage (through a scheme of financial incentives) consortia/joint sector ventures between private industry and national laboratories for design, development and manufacture of light aircraft (maximum take-off mass upto 5700 kg).
- Establish co-development and co-production between foreign and domestic industry for aircraft in the 30–100 passenger category, through private or public industry.
- For all substantial purchases of a given series of aircraft (and engines) by the airlines, wide-body and other, insist on offset arrangements.

It is clear that the emphasis of the Technology Policy Statement on strategic technologies may have blinded us to opportunities for profitable investment in civilian aeronautical technology—opportunities that on the other hand have been seized by countries like Indonesia and South Korea, although their human resources and infrastructure have been much less impressive than India's. Apart from smaller aircraft, for which the market in India should be large (given how primitive and inconvenient surface transport still is in India), the possibilities for co-development and offset production have been studiously ignored in the country.

Policy at the macro level

More generally, in the light of what has been said before, what should Government's role in technology development be?

Single-issue, simplistic solutions are not likely to work. Primarily, we have to identify real technological opportunities and promote their exploitation. We should begin with the wide availability of well-researched documentation on techno-commercial opportunities, and provide detailed information on the market, technology and investment. The Technology Information, Forecasting and Assessment Council (TIFAC) has already made a good beginning in this direction, and should be encouraged to involve and reach a wide circle of scientists, engineers and businessmen. We need a class of 'technology scouts' who can smell good commercial propositions. The agency that promotes such scouting, like TIFAC, will need the long-term commitment of people and organization, so that we may put experience to best use.

The exploitation of such opportunities must be encouraged by a scheme of incentives over a period of years: to industry in terms of tax concessions on R&D expenditure, which should be increased to the original 133% at least, and something like 150% if contributed to a consortium or network; to R&D through joint funding with industry; to scientists and engineers by recognizing publicly contributions to technology development and creation of wealth. We must remember that organizational behaviour is not an invariable trait but rather a symptom that can respond to policies. If Indian industry does not invest in R&D it is surely because it is an unnecessary risk in a protected market; profitability does not need R&D with the present technology policy. Similarly if our R&D institutions have to generate more resources for themselves, they must also be freed from the many regulations that now restrict their operations. For example they will need schemes for providing greater rewards to their more productive scientists and engineers, and for retiring non-productive staff; and mechanisms by which, when occasion demands it, they can operate in a more flexible and enterprising mode, through companies that they can establish or promote. We cannot expect national laboratories to run like race-horses while keeping them in bureaucratic shackles. These issues have been discussed by me elsewhere[20].

Government must further encourage, or even create, consortia and networks. Different agencies must be brought together, if necessary by applying economic pressure, using methods that have been perfected by the Japanese; and by *reversing* the methods that have often been used in India to *discourage* technology development.

Finally, on identified opportunities we must see what the critical gaps are, and fill them the best way possible, utilizing the expertise of academia, national laboratories, industry, private enterprise or voluntary agency.

In general, Government has to set the national agenda on technology and formulate strategies; it must act not as a leading player, but as patron, umpire and manager. As it has been the experience of many technologists that small and medium scale industry (often run by aggressive technocrats rather than cautious traders) have greater skills and success rates in the development of indigenous and innovative technology, a special initiative by Government for small-scale technology-intensive industry is most desirable.

At the time of the turn of the 20th century India has a unique opportunity, because a strange technological revolution may be taking place[17]. If the 19th century unleashed steam, and early 20th century electricity and the internal combustion engine, since the 60s and 70s technology is being driven by microelectronics, information technology and genetic engineering. But this revolution appears different from the previous ones on several counts. It requires that scientist, engineer, businessman and worker all operate in partnership. It will affect *every sector in the economy*, including the traditional ones: from tea and jute to agriculture, pharmaceuticals, livestock, steel, automobiles, aircraft, medicine, banking, etc. It is therefore immediately relevant to India if only we can absorb, adapt or develop the technology. And it is unlikely to be dominated by a single country—as Britain did with textiles to the disadvantage of India in the 19th/20th centuries, or as the US did in automobiles till the 60s.

Here therefore is our opportunity. If industry, R&D and government can act as a coalition, I believe there are no limits to what we can do.

Policy at the micro level

At the other end of the scale, we can ask what micro-level policies could foster technological innovation and development in the country for the creation of wealth. Such policies should in my view start from the basic premise that our greatest resource is human: a skilled workforce is available at much less than international costs. Exploitation of this resource is however not always easy. Many leaders of East Asian countries have claimed in recent years that their economic success is to be attributed to a Confucian ethos[14]. The establishment and promotion of a culture of work and discipline is undoubtedly of paramount importance in India, but this takes us to questions in management and sociology that are outside the scope of the present paper (but they need to be tackled intelligently and with urgency).

Short of a cultural revolution, what policy measures can one adopt?

On each opportunity identified as earlier discussed, a working group consisting of scientists and engineers from universities and national laboratories and representatives of industry and financial institutions should make concrete action plans and monitor progress. In particular, a separate budget should be created to fund joint proposals from R&D and industry, with industry contributing at least 20% (say) of the project cost (and obtaining appropriate tax concessions as already discussed for the contribution). This will enable industry to benefit from R&D work without taking unduly high risks, and will give them experience in utilizing R&D institutions; the latter will correspondingly gain from direct contact with industry and learn to develop and transfer technology in commercially viable ways. The chief role of government agencies will then be to provide the rest of the funding, to monitor progress, and generally to preside over the technology generation and transfer process (rather than doing both themselves). Such funding of joint projects should emphasize the later stages of the product development cycle, which in many areas is now a weakness in the country. A suitable source for the required Government investment in such R&D would be the Technology Development Fund (TDF): such a fund has been much discussed, and although the Industrial Development Bank of India apparently gets its resources from the TDF, the size of the fund and the manner of its current utilization are not widely known. Does the Fund envisaged by the Technology Policy Statement of 1983 exist? How much is collected from a cess on technology imports, and where does it go? The confusion regarding the Fund reflects the mindset I mentioned earlier: a clear statement of policy on TDF is now essential. In particular, I propose that TDF should be run by several autonomous councils in key technological (e.g. chemicals, materials, aerospace) or geographical (north, south, east etc.) areas, consisting of engineers, scientists, businessmen and secretaries of the concerned departments in government, with special treatment reserved for the confident and aggressive technocrat running his own small or medium scale enterprise.

For specific technologies at a slightly earlier ('exploratory') stage of development several small Technology Development Cells need to be set up, in R&D and academic institutions, when special expertise has been developed or is seen to be an attractive proposition. Once again such Cells should be partially supported by industry whenever possible. These Cells should have time-bound programmes around an identified expert, and should invariably be closed down after the objective is achieved. They should in particular have only a very small core of permanent staff from the parent organization, but should supplement this staff by a large number of students, fellows, contract staff and engineers deputed by the sponsoring industry, and get as much done on sub-contracts as possible.

In general, there should be a preference for cooperative grants and awards, joint projects and funding, multiply supported development teams and cells etc. As mobility of personnel between industry and R&D is still very poor, perhaps a prestigious Fellowship (—it would be appropriate to name it after Visweswaraya), meant specifically to encourage transfer of people on agreed technology development projects for periods ranging from weeks or months to years, should be instituted. A special feature of such a Fellowship must be the particular attention paid to ensuring that the movement of personnel involves no hassle, both at organizational and personal levels.

It is essential that those who contribute to technology development and wealth creation this way are suitably rewarded. At the very least they should have, *at their disposal*, a personal account for professional use, which would be constituted from funds won and be available for utilization on any professionally worthwhile activity that will promote their own technology development projects: expenditure on this account should not need approval from any other authority. Other incentives can also be visualized. Eventually, we should move towards a system where scientists and engineers, in national laboratories and universities, are encouraged to set up their own businesses. This will raise academic eyebrows in India, but it is already happening elsewhere, and we can learn from such experience. What is important when such a system is set up is that there should be strict control on time spent on regular duties (which need not be full time, so salaries will be reduced accordingly), and strong enforcement of appropriate conflict-of-interest clauses. This might well be the quickest and most efficient way of ensuring strong links between work done at the laboratory bench and production on the shop floor, and of throwing open the skills and resources of R&D organizations to the rigours of the market place. To use an American phrase, we have to empower the doer.

Conclusion

These thoughts also suggest that a thorough re-examination of our educational system is now long overdue. We have adopted and stuck to a late Victorian model borrowed from England; both social and industrial conditions in India of the late 20th century are vastly different from those of England in the late 19th century, but we have made no effort to look at our problems and devise our own solutions. I must here refer to a discussion of these problems elsewhere: time does not permit a longer analysis here[21].

In summary, the following policy initiatives are suggested: Encouragement of non-strategic technology sectors; a vigorous mechanism for identification of techno-commercial opportunities; joint funding of proposals by R&D organizations and industry; incentives to industry supporting R&D; the decentralization of liberalization of the national R&D agencies; the encouragement of technology-intensive small and medium scale enterprises; enhancement of the Technology Development fund and its full exploitation by a set of autonomous councils; a system of incentives to scientists and engineers in R&D organizations contributing to technology development, including the possibility of their operating (under suitable controls) their own enterprises. In particular, there is need for a 'new coalition' between scientists, engineers, businessmen and bureaucrats. If we are not to become a technological client of more disciplined nations, government cannot abdicate its role as an effective agent for promoting technology development.

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Intellectual property rights in India—some suggestions for a new strategy

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The issues around India's stance on Intellectual Property Rights have been written about and debated so extensively that I do not intend to cover old ground. Suffice to say that the Indian Patent Act of 1970 was a landmark in legislation, not only for India but as a model for Third World countries. It paved the way for the manufacture of a range of pharmaceuticals and agrochemicals in the country at affordable prices. It also fostered the growth of small-scale chemical units suited to the domestic demand volumes of the time.

Without listing detail, the salient variance in the Indian Patent Act from the intellectual property protection available in other countries is the inadmissibility of protection for chemical products and the limitation of patents to only methods of manufacture. The period of protection even then is relatively shorter than in other countries. Compulsory licensing in the event of the patent holder not working the patent in the country is practised elsewhere as well as India with different degrees of emphasis.

The seminal relevance of the Indian Patent Act of 1970 derived from its recognition that, for an underdeveloped economy, process innovation aiming at cost competitiveness tends to be relatively more important than product innovation which is more crucial in a developed and competitive market. This legislation has strongly influenced the changing shape of the chemical industry in India particularly in terms of the rapid growth of its pharmaceutical and agrochemical sectors which today account for about 15% of the estimated Rs 40,000 crores total chemicals market in India.

However, as the country has travelled along the path of development since 1970 and industries such as pharmaceuticals and agrochemicals have come of age, it is now opportune to review the further role of the Indian Patent Act, particularly for the large remainder of the chemical industry other than pharmaceuticals and agrochemicals which tends to be neglected in such debates.

Legislation around protection of intellectual property has to be viewed with pragmatism. The Indian Patent Act 1970 fulfilled a signal requirement in the economic and social development of India in the subsequent two decades. With India's economic policies undergoing dramatic change, the question is whether the same service to the nation from this Act can be expected in the decades to come.

The new industrial policy removes many of the barriers protecting the Indian chemical industry with a promise of further liberalization in the future. The Indian chemical industry will thus be required to be competitive not only in the domestic market but against global competition both at home and abroad. Factors not especially pertinent till now of economies of scale, energy efficiency and waste generation will often play a pivotal role.