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M. L. SHARMA

Agricultural Research Station, PB-7
(Rajasthan Agricultural University)
Ummedganj
Kota 324 001, India

OPINION

Role of technology and relevance of self-reliance

S. C. Tiwari

Global economy and new world order

Rapid economic liberalization during the last two years, though projected as well thought out, and the continuation of Nehruvian policy in the changed world order to lead India into becoming an economic giant, may indeed turn out to be a pathway to economic slavery. My apprehension is likely to sound naive when most vocal elements of society starting from politicians to intelligentsia have been mesmerized by the charm of World-Bank and IMF loans and the lure of high-tech life style with the modernization of Indian industry through multinationals. Inconvenient questions are not raised, disturbing issues not debated, and deeper long-term implications of the new market-driven adhoc economic measures are not appreciated. I think the role of scientists and technologists is much more profound than merely undertaking a bargaining exercise for more funds. I intend to share my thoughts and experiences with the readers in the context of technological self-reliance.

Though political and social changes occur in complex ways, some observations may help to understand the present world scene. Technological advances are responsible for the super power status of a few countries, and the prime impetus for major technologies has been the war-cloud rather than the welfare. Holton[1] noted that 'a current symptom is the popular identification of science with the technology of superweapons'. In USA, the share of basic research was only 7% out of 10 billion dollars spent on scientific research, and only 15,000 out of 7,50,000 scientists and technologists were involved in any basic research around 1958. According to a 1983 report[2], 75% of the satellites were for military use and USA spent 1.5 billion dollars on antisatellite weapons. High technology is primarily a military technology which needs huge non-profitable expenditure of the governments. In view of the secrecy involved the outdated military technology is transferred to the industry as advanced technology. Industry has to devise a method for its commercialization, and most often by introducing perverted usage and complex solutions to simple problems of the society. Sustenance and growth of advanced technology is entirely dependent on the artificial and questionable notions of progress and needs. Mass production of consumer articles requires world market and continuous supply of raw materials to the industry. The diminishing quality of raw materials in technologically advanced countries increases the energy cost of extraction of pure materials, hence the energy crisis and search for cheap raw materials. The so-called developing countries provide raw materials at throwaway prices in exchange for manufactured goods, and in the name of modernization consumerism spreads in these countries. Imported outdated industrial technology and race for modernity are perpetual processes for economic deprivation in the poor countries.

In the cold war era, whereas American industries provided vital economic support to military technology by exploiting world market and American people, the closed system in USSR permitted a limited access to world market. Moreover, in contrast to American consumerism society, in USSR the high tech lifestyle was relatively nonexistent. Nevertheless USSR was competing with USA in the arms race even in antisatellite weapons and third generation nuclear weapons[2]. Bankruptcy of the USSR and weakening of the American economy was a foregone result. Once USSR collapsed, the only way open to USA and the Western powers for retaining their superiority was through economic domination forcing market-driven economy in the rest of the world, and dumping the obsolete technologies in the so-called developing countries. I suggest that advanced technology is not economically viable in the long run, and therefore the collapse of the American system is also inevitable.

India's post-independence period could be broadly divided into three major phases in terms of the outlook of Western powers. The period until 1970 was marked by general apathy. Nuclear and space research programmes and establishment of a large pool of S&T personnel created a sense of alarm during the next 15 years or so. It was during this period that Indian political leadership showed strong commitment to self-reliance in S&T and provided unqualified support for S&T. Seen in this light one may understand the reason for the attention Indian science received in reputed US and UK science journals. In fact, a detailed survey on

Indian Science carried out by *Nature* was published[3] in 1984. Since 1985, in the third phase marked by the policy of allurement, there has been a determined effort to turn Indian society into a high-tech consumerist society.

Political leadership has failed singularly to comprehend the real import of this sort of modernization which may ultimately ruin the country. Though our achievements and performance in S&T have been dismal, these are not the reasons for the recent upheavals in S&T policy. These are used as a *posteriori* arguments to justify fund cuts and reversal of the policy of self-reliance. It is quite likely that the entry into the much talked about 21st century may witness the fall of the American system, and therefore to follow USA is highly unimaginative. Is it advisable to rush for global marketism thoughtlessly even if my assertion is taken with scepticism? The necessity of self-reliant technology and the radically new approach to development are most relevant today if we have to survive as an independent nation.

Science and technology

Science is universal and transcends national boundaries. Men of science may become secretive and possessive of knowledge, but nature is open to reveal its secrets to anyone who meditates for it. Therefore, self-reliance in science is not a meaningful term. At best one could say that a nation should have sufficient strength of scientifically-trained manpower who are an asset for a nation aspiring for self-reliant technology. Unfortunately since the days of Bhabha the role of science in technology and the distinction between science and technology have not been understood, and the misplaced emphasis on pure science has resulted in confusion. Contemporary research in pure science is mostly done in high-tech laboratories termed as big science.

Science is therefore seen closely related with technology, however the aim of science is more in consonance with that of philosophy[4]. Besides observations on natural phenomena, the empirical knowledge created in laboratory experiments is the basis of modern science. Research activity aimed at understanding nature is pure science or experimental natural philosophy. A scientist is not concerned with the use of this knowledge, though application of scientific knowledge for devising better experiments to probe the nature has been a continued process. It is also remarkable that depending on their philosophical thinking scientists may differ on the perception of objective reality[5]. Earlier small laboratories and inexpensive experiments could ensure freedom for a scientist to pursue the search for truth. Now heavily funded big science has naturally led people to ask: Why should society support such an activity?

The question is most relevant in India, because with meagre resources it is unjustified to invest heavily on such pure science. But the proponents of pure science argue that an economy based on modern science and technology is essential for development; Bhabha[6] underscored the need for modern science 'as a live and vital force'. Menon[7] viewed basic research to be 'at the frontiers of science on a competitive international basis', and recently Rao[8] has also pointed out the importance of basic research. An alert reader would easily discover that the outlook of Bhabha on basic research, centres of excellence and 'proper appreciation and financial support' for a talented few has guided the top science managers till to date, and that there is nothing new in what Menon[7] or Rao[8] have said. Ironically they have argued for support for basic science precisely for reasons which Bhabha gave, though Bhabha had assured us in 1966 for returns within the next few years. The same arguments have been repeated time and again, and the gap between promises and achievements has been widening since then. Does this not suggest a basic flaw in S & T policy?

Let me first discuss basic science. Highly talented people are necessary not only for science but in every sphere of life. What one needs is a natural urge to understand the nature and an aptitude for science in an individual for scientific research. A personal encounter with Raman recounted by Daniel[9] is illuminating. Centres of excellence cannot be created by funds and buildings; rather than specially favoured select institutions, there should be the institutes committed to science and the values which support and encourage any curious mind. It must be remembered that Raman or Dirac are not produced by the system; therefore policies are not made for such original minds. The system should be able to train and support committed professional scientists, and recognize and encourage rare cases of a few original idiosyncratic minds.

To base science policy for a few indispensable talented scientists, and create institutions around them is not only unscientific but is fraught with practical problems. A highly original scientist may not necessarily be a good science administrator and organizer of institutions. Secondly, concentration of power on policy matters in a few individuals may adversely affect the system due to their personal weaknesses. In our country, anyone who does a bit of original work immediately aspires for an administrative post. Why should scholarship be recognized and rewarded this way? I am not aware if Dirac and Einstein ever held any administrative position. Much has been written on Raman, but I think he failed to understand his limitations as a science administrator and wasted his talent and time on petty matters. The preference of Bhabha for scientists trained abroad and of Saha[10] for his own students has led to the present situation such that practically all appointments are made with these criteria relegating merit into the background. Basic research also suffers due to personal prejudices. To take two recent examples on basic research, proton decay experiment required heavy funding but due to Menon's interest it easily got financial support. Menon[7] quoted Karl Popper's view on routine research i.e. merely compilation of empirical data, and criticized most of the basic science done in India for this reason. Does proton decay experiment not fall into the category of Popper's fable? High temperature superconductivity research got extensive support from government mainly due to the interest of C. N. R. Rao and his influence in the government. In the absence of institutional norms and 'genuine' science policy there is no method to evaluate the desirability and success of such heavily funded researches. The idea of 'front-line research' and 'international competitiveness' to justify such routine basic science creates confusion, and retards real progress of science by neglecting small projects. Can't we emulate the examples set by J. C. Bose and Raman for basic science?

Bhabha[6] illustrated the role of indigenous technology using an analogy with the aircraft flight; however, it is only recently that the distinction between science and technology has been realized[11]. Mashelkar[12] makes an important point that though the necessity of applied research for development is felt, basic research is accorded superior place at a national level. Technological advancement demands foresight in leadership, spirit of teamwork, and innovativeness, skill and experience in an individual. The method of science, effective use of scientific techniques and application of scientific knowledge enhance the capabilities of a technologist, and have become crucial in sophisticated technologies; but in the absence of technically-oriented minds these by themselves are of no use. Working style and outlook of a technologist considerably differ from that of a pure scientist. A professional scientist doing what is termed as routine research work is most suitable in technology development. Enterprising and imaginative leadership which could make use of pure scientists and technologists is crucial for advanced technology. Development of vacuum tube amplifier, and discovery of electron diffraction by Davisson illustrate the role of basic research. To take another example, during 1945, Kelly of Bell lab concluded that a study group for new device technology be set up, as vacuum tubes might not be useful for high switching speeds. Fisk and Shockley proposed semiconductors as possible materials for new devices. A group consisting of Bardeen, Shockley and Brattain (who were to get Nobel prize after Davisson from this lab) was formed by Kelly to carry out research in electronic processes in semiconductors. This effort culminated in the invention of transistor in December 1947.

Why advanced technology?

Saha had unconditional commitment for the nation and believed that only science and industrial development could improve the living conditions of the people. Visible affluence in the West greatly influenced his thinking, and I think his sharp criticisms of government policies played a significant role in shaping the S&T policy at that time. Saha[13] rightly pointed out that 'when cheap factory goods began to pour in Indian market, most of the artisans lost their jobs and became peasants'. He advocated rapid industrialization, and though his views were similar to Bhabha, for political reasons he remained antagonist to the government. Is it true that modern technology and industrialization lead to material prosperity for all?

Socioeconomic studies in West show that unemployment and poverty are rising in the technologically advanced countries. Pockets of affluence, the enormously widening gap between rich and poor, and environmental pollution are becoming synonymous with advancement in technology. It seems that the tremendous psychological impact of modernity has been in transforming sensitive minds to arrogant robot-like objects thereby reversing the process of scientific enlightenment. George Brown, chairman of the Science, Space and Technology Committee, USA has argued[14] that market-driven technology is not needed for satisfying basic human needs; his views have been highlighted in a recent *Science* editorial. If we wish to gain from this experience then we must revise the development approach adopted so far based on modern technology.

A more poignant argument to reject advanced technology stems from the historical fact that India was most prosperous in the medieval age with indigenous technology. We had a great tradition of science and technology in the spirit of what today is called peaceful uses, but essentially for this reason we were enslaved by foreign invaders. A treatise on history of technology[15] is a recommended reading, but I would quote few sentences from Singer's epilogue: 'In skill and inventiveness, during most of the period treated in this volume (700 B.C.–1500 A.D.) the near East was superior to the West, and the far East superior to both. . . . For nearly all branches of technology the best products available to the West were those of the near East. . . . Technologically, the West had little to bring to the East. The technological movement was in the other direction. . . . Thus from Persia and China, and to some extent from India, materials, wares, techniques and ideas filtered through the main approaches to the West'. This is not intended to harp on past glory, but only to show that there does exist compelling historical evidence proving the superior status of Indian technology.

The only justification for advanced technology is defence. Evidently so long as scientists and technologists are a party to the stupid arms race, every enlightened thinker would face a moral dilemma. However, military superpowers are not benevolent nations, and their concern for humanity, justice and morality is, to put mildly, superfluous. Therefore, we need self-reliance in advanced technology for defence, and there can be no dithering on this.

Ground realities

Passing events occasionally jolt us, loud proclamations are made, and then follows the state of slumberness once again. Shortcomings and failures are not critically analysed, and usually there is no attempt for improvement. In 1981, Sanghvi[16] brought out the salient features of self-reliance, and the 69th session of the Indian Science Congress in 1982 had the focal theme on basic research in self-reliant S & T. Despite the Interministerial Task Force, national debate and focal themes, we still find the same arguments as those given by Bhabha[6] when advanced technology is denied to us. This is not the first time that the problems faced by working scientists have been pointed out, however, the recent debate[17] must be given serious consideration. Harsh but realistic analysis given by Bhargava[18] has made public what was known in private circles since long regarding the top science administrators. Ironically he himself is not much different from others, if we reflect on his past writings[19], and remarks in *Nature*[3]. Nevertheless, lack of integrity, commitment, honesty and scientific vision among scientists in power, and the absence of a mechanism to impose accountability highlighted by him deserve utmost attention of the policy-makers.

The phrase 'reinventing the wheel' to criticise self-reliance in technology[20] is misleading, and unfortunately no technologist has effectively countered this. Transistor was invented in 1947, but transistor technology requires ingenious and sustained effort over a long period of time. Electron gun technology cannot be developed without first demonstrating the old Child–Langmuir law. Developing something is always reinventing by oneself, and that is what makes it interesting.

Mashelkar's point mentioned earlier is also operative within a laboratory. For example, in the Central Electronics Engineering Research Institute, Pilani in the late 70s and early 80s the development work on microwave tubes was considered inferior to semiconductor device technology by the then Director. In recent years joining superconductivity research and pushing semiconductor technology into the background by CEERI was most unimaginative. Project leaders and directors regard publications in foreign journals as superior research retarding the development of creative technological work. I think with encouragement and proper support CEERI would have by now become a pioneering research lab in the advanced technology of gyrotron and free electron laser.

The indigenous development of technology is often blocked at implementation level by vested interests. In March 1979, the Department of Electronics, New Delhi sanctioned a project on high power microwave tubes at the Electronics Engineering Department of Banaras Hindu University. Due to lack of technical competence of the project leadership after the sad demise of the first Chief Investigator, the dubious role of the Monitoring Group in misdirecting the efforts of the project team, and foreign collaboration of the production agency ultimately led to the failure of this project. Despite sophisticated equipment and excellent laboratory facilities not even the technology of a single subassembly of microwave tube has been developed, though the Centre has been made permanent.

Mashelkar[12] did well to highlight the strengths of CSIR and suggested how it can play an important role in the post-liberalization era. While I concur with him on the former, his suggestions do not reflect imaginative and bold response. To put the performance and the role of CSIR in perspective, Bhabha's unreasonable criticisms[6] of CSIR, and Bhatnagar's pragmatism[10] need to be recalled. Pre-eminence of basic scientists and their dominant role in policy making has from the beginning been disadvantageous to CSIR. Moreover, CSIR leadership has always adopted the submissive and misplaced pragmatic approach. Faced with criticisms, the need for publicizing the achievements was felt by G. S. Sidhu in 1983 (ref. 3). Today we find substantial resources being wasted on publicity. Idea generators and providers of new concepts, and marketing efforts recommended by Mashelkar would further misdirect the efforts of CSIR. Market-oriented activities should be left to the public sector units like CEL.

Few comments on the universities are also in order. Big research projects and centres of excellence have in reality corrupted the university system, and teaching and institutional values have suffered most. Costly equipment are inaccessible to students, and a few influential professors with bureaucratic mind-set usually head more than one big project. If industries start funding directly the research projects, the condition will deteriorate further. In this connection I refer to a very revealing report by Dickson[21] and quote from its preface: '. . . Some insert fabricated data into published research papers as a substitute for what companies want to keep secret. . . . A study carried out at Harvard University in 1986 showed that University scientists who worked with industry funds were four times as likely to keep their research secret as their colleagues; two-thirds of them felt they were being pressured to spend too much of their time on commercial activities'.

Suggested new approach

The best system in a society is that which provides ample opportunities for an individual to satisfy natural interests and to develop mind and body, while at the same time making use of personal traits and abilities for collective good. How can we establish such a system? In the light of foregoing discussion I would make the following suggestions:

Minor Policy changes. (1) the scheme of centres of excellence and heavily funded research projects in Universities/basic research institutes should be abolished, (2) financial support for Ph.D. and post-doctoral students should be the responsibility of UGC, and CSIR should stop JRF/SRF/RA scheme, (3) M.E./M.Tech. courses should be discontinued, (4) Science and engineering papers should be deleted from the IAS and other civil service examinations, (5) it should be mandatory that no single person holds more than one administrative post at one time, (6) government funding for participation in symposia-conferences abroad, and for holding them in India should be stopped at least for the next five years, (7) CSIR labs should allocate some grants to explore the areas of ancient Indian technology for R&D, and (8) R&D work carried out in CSIR labs should be published as internal reports or in some cases in Indian journals only.

New Policy. This should broadly recognize the difference between pursuit of knowledge for the sake of it and application of knowledge with specific materialistic objectives. Universities and fundamental research institutes in one category, and S&T agencies like CSIR, DOE, AEC, Space Research Organizations, etc. in another category require independent policies. Bare minimum funds necessary for the first category should be provided by the government, and there should be total freedom for schools of thought evolving in these places of learning. On the other hand rather than wasteful expenditure on administrative structures of as many as a dozen government agencies/departments, all these should be dissolved, and a small, autonomous agency, let us call it National Science and Technology Commission should be created. Policy formulation, recommendation for fund allocation in broad disciplines, and performance evaluation would be the responsibility of NSTC. It is suggested that the membership of this commission should be limited to 4–5 scientists and technologists, two government representatives and one elected representative each from national political parties.

Professional engineering/technical institutes should be delinked from the University system. The National Engineering Education Board should be created to govern these institutes. I think the training school programme at BARC has been quite successful. NEEB and NSTC should devise suitable schemes on the pattern of BARC training school and UPSC for selecting and training S&T personnel for various laboratories and research organizations. Rather than Ph.Ds, the intake should be mainly B.Tech./M.Sc.

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S. C. Tiwari is in the Department of Physics, Banaras Hindu University, Varanasi 221 005, India

COMMENTARY

Science & technology in India—An evaluation

Sumit Bhaduri

The spate of articles and letters in recent issues of *Current Science* and in other publications including newspapers has raised a number of issues such as the health and future of Indian science and its societal relevance. Serious concern has been expressed about inadequate Government support and the mechanism for the utilization of the available meagre resources.

It is instructive to note that this is by no means a unique Indian phenomenon. Seven years ago, about fifteen hundred British scientists paid eight thousand pounds of their own money for half a page in *The Times* to express their deep concern about the state and 'management' of British science. More recently, *Time* magazine in an article has bluntly summed up the way a large section of American society views scientists and their profession: they are—'the new villains of Western Society ... engaged in building toys for the rich'.[1]

Though the problems and questions agitating the minds of scientists, technologists, the public, and fund-giving authorities the world over have some common characteristics, they do differ significantly in matters of detail between nations. In fact the differences could be so deep and wide-ranging that, to be effective, the plausible remedial actions and policies would have to be different.

The purpose of this article is to assess the interdependencies and inadequecies of science and technology in the Indian context. However, to begin with, it is necessary to delineate some of those common characteristics of technology and its science base that cut across national boundaries.

A few general points

While science is certainly not identical with technology, the social dimension of science is manifested to a large extent by the level of technological advancement of a given society. Progress in basic science, evolution of superior technology, and economic prosperity are therefore often imagined as following one another in a mechanical and automatic manner. This, however, is not true in today's world: the relationships and interdependencies between the three are exceedingly complex.

First of all, the path from scientific discoveries to commercially useful products or processes—the fruits of *innovation*—is one with lots of bends and curves, and not a linear one as is often assumed. The 'linear model' of innovation is of little relevance in today's world for many reasons, an important one being the highly elastic and arbitrary time span between a given discovery and its final use.[2]

Secondly, while technology development and its successful commercial use definitely require a strong science-base, the converse is not necessarily true. A strong science base does not automatically ensure technological innovations. Most of the 'how' questions of technology could be satisfactorily answered, if and only if, due attention is paid to a crucial set of associated 'why' questions, i.e. if the underlying science is understood and established to a reasonable extent. However, a 'how' question has often been known to lead to a new set of 'why' questions, thereby opening up unexplored areas. The synergistic relationship between science and technology—an aspect often ignored by the 'linear model', needs to be fully appreciated. Technology could feed the engine of economic growth only when this relationship is selectively and consciously nurtured.

The survival and sustainable growth of science and technology require crucial inputs from the socio-economic environment. In most cases it is the nature, extent and mechanism of such inputs that determines the success or failure of a 'science and technology policy'.

It should also be remembered that ideologies and political compulsions play an overwhelmingly important role in determining a nation's socio-economic priorities and goals. The 'trickle down theory' of Reaganomics, the 'flying geese' pattern of shared growth of Japan and the Asian-Pacific countries, or our own vision of 'commanding heights' for the public sector, are broad concepts indicative of the dominant ideologies and their associated visions for economic growth. Notwithstanding the ideological differences, they all envisaged definite roles for science and technology in the overall process, and introduced mechanisms for Governmental encouragement and interventions. Our own once reputed, now much criticised CSIR laboratories, the 'Delphi' exercise undertaken every five years by the Ministry of International Trade and Industries (MITI) of Japan, the 'star-war' programme of the U.S.A., are nothing but vehicles and instances of such Governmental intervention.

The lesson to be drawn from all this is two-fold. First, no science and technology policy would be successful unless