In a bid to expand its area of activity, it is being envisaged to look at the high-school science curriculum and suggest changes wherever deemed necessary. Efforts are also being undertaken to launch a small magazine in physics in the regional language that will cater to the needs of school and college students. This should contain small articles on new and interesting findings in physics, life sketches of eminent physicists, and clear expositions or novel ways of understanding various concepts of physics. OPS is also planning publication of a bulletin on research and review works and innovations in teaching and experimentation undertaken by college and university teachers

In summary, OPS is basically an exercise of soul-search on the part of the physics teachers of Orissa to see that they become useful instruments in not just imparting sound physics teaching to the young minds but also in making them love physics. Odds, needless to say, are heavy. But that only makes the struggle more intense and more worth taking

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COMMENTARY

Industrial research and Indian industry*

S. M. Datta

The development of industry and its infrastructure has been a dominant concern in the planning and implementation of India's economic development programme over the last five decades. Traditionally, India had offered a rich economic heritage based on agrarian and extractive enterprise. However, the aspirations of the large and rapidly increasing population could no longer be adequately fulfilled by the cultivable land resources, which were fast reaching the limits of exploitation. Therefore, manufacturing industry provided the logical choice for improving the domestic product and providing gainful employment.

Prior to the Second World War, the political control of the developing world rested in the hands of a few dominant European powers. The concept of nation-states was mostly academic. The technology of manufacturing industry was proprietary and the risks attendant upon capital deployment were high. The economic development of the British Empire, of which India was an integral part, was focused in the United Kingdom itself, and India, like other far-flung parts of the Empire, found itself starved of capital and technology for manufacturing industry even for meeting the local needs. This supply–demand gap attracted the attention of the flourishing trading community and was mainly responsible for the gradual transformation of the trading class into industrial entrepreneurs. The excellent framework of higher education built around the Indian universities provided trained manpower for managing these early industrial efforts. Thus, local entrepreneurship combined with the able and competent cadre of technological manpower provided a strong bias of self-reliance to India's industrial programme during the years of political awakening.

The objective of industrial development, in India as well as abroad, has always been to provide economic value-addition to the natural resources and their produce through the fulfilment of the consumption needs of the relevant population It was recognized quite early that the efficiency of capital deployment could be leveraged by the combined application of scientific and economic knowledge. Consequently, technology has rapidly developed into a major economic resource. During the second quarter of this century, Germany, the United States, and Japan, recognized the crucial role of science in the entire process of economic development. These countries achieved significantly higher rates of economic growth by focusing the available pool of scientific knowledge on the growing needs of manufacturing technology. The validity of this paradigm is universal and applies equally well to the poorer countries of the world.

The quality and the magnitude of India's scientific and technical manpower abundantly proved itself during the Second World War. It was a logical step forward to harness these resources to the cause of India's economic development and, thus, the Council of Scientific and Industrial Research was born in 1942. Shortly after Independence, as the country launched itself on the path of accelerated development, the role of modern technology in providing solutions to the pressing economic problems came into clear focus and the onus of scientific and industrial research shifted rapidly from the universities to the CSIR-controlled laboratories.

Response from Indian industry

Indian industry has often been criticized by our scientific establishment, with a certain degree of justification, of being apathetic, if not outright averse, to industrial research Yet, the universal lesson of the fundamental importance of science and technology in accelerating the pace of industrial development could not have been missed by the industrial establishment Therefore, it is important to understand the reasons behind this lukewarm response

The first, and probably the most important, reason has been the inability to obtain a complete technological package for any industry within India This disadvantage extended to the supply of expertise needed to maintain and update

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technology. Therefore, it became necessary to rely on technology imports for every conceivable industry and it fell upon the enterprise management to handle the problems associated with technology absorption. As the lion's share of industrial capital formation was appropriated by the state, it was clearly perceived that the government did not have any real intention to honour the oft-repeated statements about the pivotal role of our scientific and technological innovation in the industrial and economic transformation of India.

The second major reason is the emphasis which our planning process has placed on capital formation and investment without creating a balancing stress on the effective utilization of the capital stock so created. Even in the nongovernment sector, the fiscal incentives offered to industry are focused on the quantum of investment alone, almost to the total exclusion of any consideration of productivity. In the government sector, the performance of management has been based on factors other than productivity and efficiency on the pretext of promoting social accountability. In the nongovernmental sector, too, the high debt–equity ratio, the concessional rates of investment financing and, above all, the somewhat irresponsible benevolence of the financial institutions towards the financial performance of the enterprise have, in combination, provided a degree of immunity to the management. Therefore, industry has been under no pressure to utilize industrial research for performance improvement.

The third reason for the lack of interest in technology has been the all-pervasive protection that our manufacturing industry has enjoyed over the last four decades. External competition was blocked out by physical and fiscal restraints on imports. Internal competition was discouraged through the regulations built around manufacturing capacity and growth of output. Various forms of direct and indirect subsidy were evolved to compensate for infrastructural inadequacies. Finally, under the guise of employment protection, the ultimate punishment of poor performance was effectively proscribed. Protected within this cocoon of all-encompassing care and comfort, our manufacturing industry did not feel any need to improve performance or profitability.

The fourth reason has been the relatively unfocused nature of our industrialization. The economy was geared towards import substitution, which provided fertile ground for the proliferation of a large variety of industrial enterprises operating in main through economically unviable production units. The fledgling science and technology initiatives, already suffering from the serious handicaps mentioned earlier, were totally unable to cope with this wide diversity of demand. Seen in this context, it is easy to understand why the CSIR has proliferated into 39 research laboratories with over 100 extension centres and regional stations spread throughout the country.

Changing environment

The economic fall-out of the state of complacent underperformance in our industrial sector was hidden in the early years by the rapid strides made by the agricultural sector under the influence of the package of inputs and practices collectively known as the Green Revolution. These inadequacies were first highlighted under the pressure generated by the crude-oil price increases in 1973 and 1979. The Sixth Five-Year Plan had to take note of the inadequate growth in per capita income until then and as the lessons filtered into the consciousness of the administration, the first cautious moves to reduce the rigours of regulation were made in the early eighties.

The accelerating changes in the world economic scene in the more recent years quickly demonstrated the inadequacy of these hesitant steps and emphasized the need for a faster response from India. It is possible to identify three major forces behind this inexorable pressure for change. These are:

1. The rate of growth in per capita income had been too slow. As a result, the sheer number of politically enfranchized but economically disadvantaged people had grown to over 500 million. The unfulfilled aspirations had spilled over into social movements of enormous magnitude, which are threatening the very fabric of our economy. The need for a rapid improvement in the income levels at the lower end was clearly urgent.

2. As the negotiations of the Uruguay Round progressed through their tortuous path, it became clear that our dependence on external aid must come to an end and that greater emphasis must be placed on external trade and that too in an atmosphere of less protection and greater competitiveness.

3. As the budget deficits mounted, it became quite apparent that the ungainly edifice of socially justified costs and prices maintained by a regime of subsidies could no longer be maintained in its present form. As the growth of subsidies decelerated, the need for improving value-addition in the conversion process has come to the fore.

Faced with this pressure, manufacturing industry is now looking towards technology as the catalytic change-agent for successfully handling the transition from a protected economy to a mildly competitive one. This belated acknowledgement of the potential of technology to contribute to the improvement of productivity, economic development and competitiveness could, however, rapidly degenerate into a whole series of platitudes unless attention is focused on some specific areas where technology can make the largest impact. Some of these areas are:

(i) *Effective utilization of fixed assets and working capital.* The low level of utilization achieved in our industrial enterprises is well known. Systematic application of technology can not only lead to higher degrees of utilization but also identify bottlenecks, on the removal of which the effective capacity can be significantly uprated. Technology can be applied to improving the velocity of the value-addition processes, thereby reducing the need for increasing working capital deployment in direct proportion to production volumes.

(ii) *Creation of an innovation chain to generate tangible product advantages and perceptible performance benefits.* As the market situation shifts from a supply-dominated situation to a demand-driven one, the needs of the customer in terms of quality and cost assume greater importance. This shift in emphasis can be handled only through an efficiently managed process of technological innovation.

(iii) *Imparting flexibility to the manufacturing operations.* Japan has achieved extraordinary success in improving industrial productivity through the development of flexible manufacturing technologies. Such technologies are capable of handling fluctuations of throughput levels, rapid changes in output characteristics and variations in input parameters.

(iv) *Development of environment-friendly manufacturing operations*. The rapid depletion of our environmental resources needs a quick and effective response from the industry, firstly in reducing the environmental impact through associated processes such as effluent treatment, and, thereafter, in evolving process technologies which reduce the environmental impact, such as those used in multicycle power generation.

In short, the principal challenge is to interweave science and technology with the entire sequence of operations in order to create a world-class manufacturing capability out of the somewhat inadequate and unsatisfactory base which we have today. So far as the industrial sector is concerned, this would transform the need for greater competitive ability into an intellectual challenge. Thereby, we shall create a platform where manufacturing and industrial enterprise can meet scientific and technological capability on the basis of mutual communication.

New approach

I am well aware of the fact that the weight of evidence presented so far does not conclusively establish the nexus between industrial research and industrial development. However, they do serve to illustrate the influence that science and technology can exert on the efficiency and the competitiveness of the industrial sector of the economy. The CSIR Review Committee recognized this influence in its report of December 1986, and it would be pertinent to quote one sentence from this report:

> 'The more successful among the late industrializers in Asia, particularly Japan, recognized the fundamental importance of science in the catching-up process of development and sought to draw upon the available reservoir of scientific knowledge and placed increasing emphasis on the interaction between the world of science and the realm of technology in the economic sphere of production.'

The exacting nature of the modern world makes it difficult, if not impossible, to achieve technological innovation through serendipity. Industrial research, therefore, requires an organized approach coupled with deployment of resources. The larger and economically stronger industrial organizations can afford to create their own research capability focused exclusively on the technology needs of the enterprise. Indeed, they should be actively encouraged to create such capabilities. Equally, we must recognize that a large number of our industrial enterprises are unable to afford such initiatives. We have to create a common forum of industrial research and technology innovation for meeting the requirements of the bulk of our industry. As a matter of record, this was the fourth among the seven specific functions assigned to the Council of Scientific and Industrial Research in 1942 through a resolution of the Central Legislative Assembly. It is true that in the intervening 50 years, the CSIR has drifted far from some of these original objectives but there is no doubt that if the need was felt strongly enough, it could be reharnessed to the task at hand. For the present, however, it would be prudent to direct our attention to the definition of this task as viewed from the side of manufacturing industry.

In this context, it would suffice to mention only three major prerequisites to illustrate the nature of focus which must be brought into play when defining the objectives of industrial research. The first and, inevitably, the most important criterion is clarity of objective. The objective of any research programme can be defined only by the client but it is equally important to arrive at a prior agreement on the set of parameters which would be used to determine the progress of the research project. It is also necessary to define at the outset or atleast very early on in the project to set up mutually agreed upon milestones. Science and technology are quite closely related but are not identical. Consequently, they do not use the same language and simple precautions such as those mentioned above can avoid much recrimination. The second important criterion is one of critical mass. However interesting a project might be to the scientific inquiry, it must have enough substance to justify the allocation of resources and generate enough impact on the client's business. In this particular aspect, a multiple-client research organization could combine several subcritical projects into a substantial one, provided, of course, that the costs are allocated on a fair basis and that the confidentiality of the client is protected at all times. Such niceties are often ignored in practice. A third important precondition is the existence of an acceptor mechanism within the client organization. A scientific development requires an established innovation chain to complete successful transition into a product or process technology. Much of this innovation chain must lie within the client organization itself in order to adapt or to modify the scientific development to suit the manufacturing requirements. The project life can be significantly shortened, and the prospects of commercialization correspondingly improved, by ensuring that the client's innovation team begins to interact with the research team from the early stages of the project.

There is also one important prerequisite which any client would reasonably expect from a research organization and that is the principle of exclusivity. Successful innovation requires significant resource allocation and considerable interaction between the client and the research team. It would not be realistic to expect the client to undertake all this trouble unless he is guaranteed the resultant competitive edge through an exclusive contract. The CSIR–NRDC set-up positively emphasizes the non-exclusive nature of the licence and this could be one reason why much business has not come the way of the CSIR laboratories.

Concluding remarks

A relatively self-contained economy like ours can generate sustainable value-addition only through the healthy growth of the primary and the secondary sectors. The rapid growth of the services sector in the recent years indicates an imbalance which cannot be maintained over a length of time. Therefore, we need to devote renewed attention to the development of a vibrant, fast-growing and highly efficient industrial sector which can be globally competitive. This development will need a constant stream of technological innovation which will carry the fruits of scientific research into the manufacturing operations. Past attempts to force the partners into a marriage of convenience through technology import barriers and indigenization subsidies have not succeeded. The

new pressures generated by competition, both domestic and international, are more likely to drive the Indian industry closer to industrial research, and this much desirable outcome deserves to be encouraged by suitable modifications to the regulatory framework, which is still powerful and will remain so for some time to come.

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India's emergence as a global R&D platform: The new challenges and opportunities*

R. A. Mashelkar

I consider it to be a matter of great honour and a special privilege to have been invited to deliver this Lala Karamchand Thapar Memorial Lecture. Lala Karamchand was not only a great industrialist but also a great visionary. He believed in the process of value addition to our natural resources through modern industrial processes. In today's context, India's natural resources (and, indeed, its rich biodiversity) and its manpower are its real assets. In keeping with the basic spirit of Lala Karamchand's vision, I am going to speak about the tremendous potential for value addition through our talented manpower (specifically our S&T manpower) for launching India as a major global player in the field of research and technology.

I am fortunate that the Hon'ble Finance Minister Dr Manmohan Singh has agreed to preside over this lecture today. Dr Manmohan Singh set a new national agenda in July 1991 by announcing the new industrial policy and followed it up with astute fiscal policies. With dynamism and vision he has led India on the path of progress by beginning the process of integrating the Indian economy with the global economy. I strongly believe that the integration of Indian economy with the global economy cannot ever be complete unless the integration of our industrial research and technology with the rest of the world also becomes a part of this grand plan. If this is accomplished with speed and determination, then we can see India emerge as a major global R&D platform. I wish to share this exciting vision with you today.

India has been a part of the international scientific network for many decades now. Internationalization of science is not new. Indeed, scientific cooperation is increasing day by day, thanks to the tremendous developments in communication and information technology Whereas in 1978 only 4% of the research papers had transnational authorship, in 1990 this number had risen to over 10%. India continues to sign several bilateral agreements on scientific collaboration, including exchange of scholars, scientific research data, etc. However, most of these agreements emphasize the generation of knowledge for its own sake. Indeed I remember that not until too long ago, while submitting such proposals, one even certified that the joint collaboration was a purely intellectual pursuit and that no intellectual property of any commercial value was likely to arise from it!

My lecture, however, does not deal with the above type of relationship, which is built in the usual rich tradition of science. My focus today is on *research as a business*. It focuses on creation of partnerships with the rest of the world to generate exploitable knowledge, technologies, new products, processes, etc. In other words, it is about wealth creation in India not only through international trade and business but also through export of knowledge-based products and technologies. It emphasizes a major transformation so that we change our image from 'perennial technology seekers' to 'technology providers'. It has an ambitious agenda of 'reverse transfer of technology' to the developed nations. I realize that in this spirit, export of services like software has already begun; however, much of it is still in the form of bodyshopping. To my mind, India's enormous potential has not been tapped so far. This great potential arises due to India's massive S&T infrastructure and its undisputed intellectual resource base.

Thanks to the foresight of the founding fathers of our nation, India today possesses a massive science and technology infrastructure spread across the country. With over 200 universities, 1500 research institutions and 4000 Ph D's being turned out every year, India is in an enviable position as regards the S&T manpower. Right from the time of independence, science and technology has been considered as an instrument of growth and prosperity. Scientific institutions have been set up and nurtured in many diverse sectors. These have included agriculture, atomic energy, electronics, environment, ocean, space, biotechnology, nonconventional energy sources, defence, health and so on. The chain of national laboratories, which was set up after independence, has built several core competencies in large number of areas. All this gives India a marvellous launching pad, on which it can set up a really ambitious agenda of growth. I believe that by the turn of the century, in a list of competitive advantages of which our nation will be proud of, its R&D strengths could be easily on top if we take some actions, many of which I will specify in my lecture.

International trends in globalizing R&D

Industrial R&D collaboration in the developed world has been increasing exponentially. A strong and synergistic pairing of major players in countries such as USA, Japan as well as Europe dominates the scene. Let me review the worldwide scenario briefly for you, before I take up the issue of positioning India in this league of nations.

Take the case of United States first. The R&D spending abroad by US companies is rising much faster than their

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