THE SCIENTIFIC BASE OF ECONOMIC DEVELOPMENT

P.C. Mahalanobis

Member, Planning Commission of India (1955-1967)

Phases of Economic Development

The essential characteristic of an underdeveloped country is an extremely low level of living, that is, inadequate supply of food, clothes, housing, drugs and other consumer goods, and also lack of facilities for education, care of health, social security, cultural amenities, etc., for the nation as a whole. It is possible to make available small quantities of consumer goods, by direct imports or by production, on a small domestic scale, with the help of imported machinery. In most of the underdeveloped countries it is, however, not possible for lack of necessary foreign exchange to import or to produce, with imported machinery, enough consumer goods for the people as a whole. In India, the first textile mill was established in 1817; and India gradually became second biggest producer of textiles, next only to America. One hundred and fifty years later, India would still remain underdeveloped. The production of textiles or small quantities of other consumer goods for a small part of the nation cannot, by itself lead to industrialisation and economic development.

Economic development can occur only by increasing the per capita production of the nation as a whole, through an increasing use of machinery driven by steam or electricity as a substitute for human and animal labour. In countries with appreciable natural resources, it is necessary to establish the basic engineering and power industries to enable the manufacture of both consumer and capital goods within the country. Establishing a minimum complex of such basic industries would take at least ten or fifteen years, for which planning must start ten or fifteen years in advance.

To increase modern industrial production would call for an increasing supply of engineers, technologists, and technical personnel. The only way to ensure this would be to establish and increase the number of schools, training colleges and universities, and also to train teachers for such institutions. This would take at least fifteen or twenty years; so that, planning for this purpose must start fifteen or twenty years in advance.

The best way of utilising the raw materials and natural resources available within the country, for both domestic consumption and for exports, can be found out only through applied scientific research.[1] Applied research, in its turn, must be

1. Even the most advanced countries are obliged to devote large resources to research for the improvement of products already being manufactured and also to develop new products in order to hold their position in the world export market. It is not possible for the underdeveloped countries to start or expand the export of fully or partly manufactured products by simply borrowing the current technology from advanced countries; it is essential also to develop applied research for a continuing improvement of technological methods.

based on advances in fundamental research. Also, to establish an adequate base for applied research it is necessary to promote the spirit of pure research and supply the stimulus of scientific criticism. This would be possible only when at least a certain minimum number of scientists are engaged in fundamental research and opportunities for pure research are becoming increasingly available. It is therefore, necessary to promote the advancement of both applied and fundamental research. To establish a minimum base for scientific research would take more than a generation of twenty-five or thirty years; this, being the most slowly maturing sector, must be given the highest priority.

The Scientific Base of the Advanced Countries

The scientific base of the modern age can be appreciated by even a brief review of the recent history of the advanced countries. Four hundred years ago the generally accepted view was that the earth was at the centre of the universe; the position of human beings was unique and supreme; and the highest sanction of truth was either divine revelation or abstract logical reasoning in the mind of man. In the sixteenth and seventeenth centuries, there was a complete revolution in the picture of the physical world; the earth was seen as a small planet moving round the sun; and the method of empirical observation and experimentation was gradually established in both physical and life sciences.

Progress was at first slow in the sixteenth century. A few selected names may be recalled to indicate the gradual transformation of ideas. In astronomy, Nicholas Copernicus (1473-1543) supported the view that the planets including the earth itself were revolving in orbits round the sun; Tycho Brahe (1546-1601) supplied astronomical observations of unprecedented accuracy to make the next steps possible; Johann Kepler (1571-1630) formulated the descriptive laws of planetary motion; and Galileo Galilei (1564-1642) made conscious propaganda in favour of the new philosophy of the universe. In anatomy, Andreas Vesalius (1514-1564) published his observations on the human body in 1543; in physics, William Gilbert (1544-1603) gave an account of magnetism based on trustworthy experiments in 1600; in physiology, William Harvey (1578-1657), described the circulation of the blood in 1628; John Napier (1550-1617) supplied a convenient tool for computation by the use of logarithms; and Rene Descartes (1596-1650), a philosopher, contributed the powerful concepts of coordinates for geometrical representation and of mathematical functions. Francis Bacon (1561-1626), firmly stated that the only true method in science was to proceed from particular sense observations to wider generalisations (*Novum Organum,* Book I, xix), and clearly recognised that 'the true and lawful goal of the sciences is ... that human life be endowed with new discoveries and power.'

The concept of an objective world of physical reality gradually took firm shape in the seventeenth century in the hands of gifted astronomers, mathematicians and scientists. A few names may be mentioned from among those who were born in the first half of the century; Pierre Fermat (1601-1665), Christian Huygens (1629-95), Blaise Pascal (1623-1662), Robert Boyle (1627-1691), John Ray (1627-1705), Robert Hooke (1635-1703), Issac Newton (1642-1727), and Gottfried Wilhelm Leibniz (1646-1716). The rate of

advancement of science increased progressively in the eighteenth and the nineteenth centuries, and during the last few decades has opened new frontiers with almost unimaginable possibilities.

The advancement of science prepared the ground for the industrial revolution in Europe in the eighteenth century, first in spinning and weaving, next in the use of iron and steel, and then of electricity in the nineteenth century, which stimulated the growth of the capitalist economies in West Europe and North America. The spread of the scientific outlook also prepared the ground for the Age of Reason and the French Revolution, which occurred at the end of the eighteenth century, and promoted the growth of nationalism in Europe, in its modern sense, in the nineteenth century.

The industrial revolution increasingly replaced human and animal power by steam or electricity to drive machinery for the increasing production of both consumer and capital goods. The development of engineering techniques led to a close linkage between science and technology; and during the last hundred and fifty years, industrial development has been stimulated by scientific discovery and scientific discovery has been stimulated by industrial needs.

For the last five or six thousand years, or more, the average per capita production remained more or less constant or fluctuated within narrow limits. The industrial revolution changed all this, and led to a spectacular increase in the variety and volume of goods produced. As a consequence of such increasing production, the standard of living of the advanced countries of West Europe and North America reached a level far higher than the rest of the world. Also, the advancement of science, technology and industry made it possible for the western countries to become strong military powers; and, because of such military supremacy, the west was able to bring a large part of the world either into direct colonial rule or into conditions of economic-political subjugation.

The first half of the twentieth century saw the rise of the U.S.S.R. as another world power, rapidly growing, through the promotion of science and technology, in economic, industrial and military strength together with a continuing increase in the level of living. The monopoly of scientific and technological knowledge and the unchallengeable military supremacy of the western countries have now gone. The increasing parity between the western and the eastern countries in science, technology, industry, and military power is a most significant fact of the present time. Because of the unprecedented destructive power of atomic and nuclear weapons, it has become absolutely necessary to avoid a nuclear war which would be catastrophic for both sides and the whole world. Co-existence of both the western and the eastern powers has become indispensable.

There is no intention on either side to make a direct attack. The advanced countries pose no special problems because it is not possible to hold such countries indefinitely in subjugation. However, so long as there are underdeveloped areas, both power groups are likely to try to extend their influence over the less advanced countries; and this would remain a continuing source of potential conflicts. The very existence of underdeveloped countries should, therefore, be seen as a threat to peace. Rapid transformation of all the underdeveloped countries into modern viable societies is an essential condition for peaceful coexistence. Such a transformation would promote the enlightened self-interest of

both power groups, and would also create conditions favourable for the advancement of human and cultural values on a worldwide basis.

The Role of Science in the Modernisation of the Less Advanced Countries

Modernisation of the less advanced countries through rapid industrialisation is thus an urgent need for the whole world. Is such modernization possible or can a modern society with a viable economy, with expanding social and political freedom, and cultural amenities, be sustained without establishing a sound scientific base? This is a question of crucial importance for the present age.

In order to answer this question, it is necessary to appreciate the deeper changes in human thinking which were brought about by the emergence of science. In every sphere of organised activity in human society, authority has always been associated, and must always be associated with a system of hierarchical levels. This applies to primitive societies, matriarchal, patriarchal or tribal; successive levels of feudal lords; organised churches and religions; military, police and administrative systems; enterprises, business and commerce; and law. A law court of appeal may reverse the decision of a lower court; but the decision of the court of appeal is itself subject to change by a still higher court. The decision of the highest court, to which a case has been actually referred, has to be accepted not because such a decision is necessarily right, but because it is the decision of a superior authority.[2] Society must accept this authority principle for stability and orderly progress, even in organised revolutionary activities.

This very authority principle must, however, be absolutely and completely rejected in the field of science. Modern science is based on a patient accumulation of facts, on the study of processes and their interrelations or interactions and a stability or uniformity of nature[3] which can be discovered by the human mind. The findings of the most eminent scientists are subject to critical check by their professional colleagues and by the youngest scientific workers, and must be rejected if there is no satisfactory corroboration. Science can advance only through free criticism on a completely democratic basis, with every research worker of competence enjoying equal status. The theoretical or conceptual framework of science must be continually revised to find a proper place

2. It is possible indeed, that this decision itself would have been reversed if there had been a still higher court to which the case could be referred. If a decision of a higher court of appeal is considered to be like the turning up of 'heads' (in tossing an unbiased coin) when the decision upholds the verdict of the lower court, and is considered to be like the turning up of 'tails' when the verdict of the lower court is reversed, then the successive decisions of the higher court would look like the results of the tossing of a coin. This would be the real guarantee that the system of law is functioning properly.

3. The phrase 'uniformity of nature' must be, of course, interpreted to include chance events and random processes. Although games of chance were known and were widely prevalent in ancient times in China, India and other countries, it is important to note that the concept of probability did not arise until the sixteenth and the seventeenth centuries, that is, not until the emergence of modern science. This is easy to understand. Before the emergence of the modern scientific view of an objective world of physical reality, all chance events would have to be necessarily ascribed to the whims of gods, demons or supernatural forces. After the emergence of the scientific view of an objective world of physical reality, it became necessary, both logically and psychologically, for the human mind to accommodate the occurrence of chance events as an integral part of the uniformity of nature. This could be accomplished only on the basis of the theory of probability, or rather, as I prefer to put it, only through a statistical view of the world. It seems to me, therefore, that the concept of probability, or the statistical view of the world, did arise at the same time as the emergence of modern science only because it could not possibly have arisen earlier.

for all known facts. A single new observation may call for a more comprehensive theory. The older accumulated knowledge continues to remain valid; later discoveries must, however, be integrated with the earlier knowledge. The accumulation of scientific knowledge is increasing through the efforts of all the scientific workers of the world. A new fact may be observed or a new theory formulated by any worker, however young, and in any country where research has been established. International collaboration is, therefore, an indispensable condition for the progress of science.

Authority derived from status is irrelevant to science. Science has introduced a new concept of 'scientific', or 'objective validity' which has its foundation in nature itself, and which cannot be upset by any authority based on status or by supernatural powers. The transformation of all the advanced or rapidly advancing countries has been based on accepting, in an increasing measure, a scientific or rational view of life. This is the foundation of the modern age.

It is essential in every country to establish and strengthen the outlook of science, a way of thinking which becomes more and more powerful as it is more widely adopted, and which replaces dogma, superstition, and outdated customs. This scientific outlook cannot be established by force. It must depend on acceptance through proper understanding. In practical affairs, the important point is that a wise policy and programme of action should be increasingly adopted on the basis of rational argument, supported by relevant factual evidence, and should not be rejected because of emotional bias or formal dogmas or conventional rules of procedures. It is, therefore necessary, continually, to encourage and promote the advancement of science in every country, large or small. Because science is indivisible, and also because science must be established in every country, it is also necessary, continually, to promote scientific collaboration between all countries of the world, large and small, and advanced or developing.

It is scarcely necessary to point out that there is no conflict between the scientific and rational view of life on one hand and aims and objectives based on moral or cultural values, on the other hand. On the contrary, moral and cultural values which are truly universal, and are narrowly sectarian or nationalistic in a restricted sense, must have an objective and rational basis.

The advancement of science and the growth of the scientific outlook must be recognised as an essential condition for the modernisation of the less advanced countries. It is necessary for each country to have, as quickly as possible, a sufficient number of men with a scientific outlook to influence the thinking of the nation. How to attract and hold a sufficient number of able persons to science is thus the crucial problem of national and world development. This can be achieved only through a proper and adequate social appreciation of science and scientists. The actual transformation must be brought about from within each country. Scientific aid from the advanced countries can, however, be of great help in this process.

Current Programmes of Technical Aid

The need of technical aid has been recognised for some considerable time. Bilateral or multilateral and international technical aid has often taken the form

of either offering educational and training facilities to young workers from the less advanced countries or sending technical or scientific experts to such countries. Considerable benefit has no doubt accrued through such aid but it is necessary to recognise that such effort has also been wasted.

Scholars from the less advanced countries are usually selected on the basis of results of examinations; success in examinations not being a necessarily reliable indicator of scientific or technical ability, the very process of selection is inefficient. Some of the young scholars have difficulty in adjusting themselves to the pattern of living in the advanced countries. Some of them do not do well in their studies. Some pass the examinations successfully but have no aptitude for scientific work. Some of the more able scholars prefer to live and settle down in the advanced countries, especially in the U.S.A., because of the higher level of living or greater opportunities for scientific work. Some scholars of ability, when they return to their own countries, are unable to find suitable openings for a scientific career; and some of them go back to the country where they were trained. In applied science and technology, and especially in social sciences, many young scholars, who had often studied problems or learnt methods which are appropriate for advanced countries but totally irrelevant to their own native countries, are unable to adapt or develop methods to suit local conditions. Out of the large number of scholars who go to advanced countries for training, only a very small number of really able scientific workers ultimately become available for fruitful work in their own country. The cost of giving scientific or technological training in an advanced country is also very high. Giving training to individual scholars in advanced countries (whether the expenses are provided in the form of foreign aid or met by the scholars themselves or by the country of origin) have been, therefore, extremely wasteful in terms of both men and money.

There have been continuing difficulties in finding suitable individual experts for the less advanced countries. Competent scientific workers are reluctant to accept such assignments partly because of the lack of facilities for their own work in the less advanced countries and partly because their scientific or academic career is likely to be adversely affected through their absence abroad. In consequence, assignments sometimes have to be given to persons who are not fully qualified for the job, with unsatisfactory results. To create suitable conditions for scientific work in the less advanced countries is an indispensable condition for attracting competent scientists to go out to such countries.

Programmed technical aid on a group basis has been more effective. A team of young engineers from a less advanced country can receive most valuable training in an advanced country when such training is oriented to specific technological projects. Teams of experts from advanced countries have also been of very great help in establishing factories or in starting new projects in the less advanced countries. Such technical aid, especially in engineering, technology and applied sciences, should be continued and expanded. Special projects for establishing technological and research centres in the less advanced countries have also been taken up by some of the international agencies. This type of aid can be of great value provided a sufficient number of scientific workers in the less advanced countries

can be trained to work in such centres and also provided necessary conditions are established to enable them to do their work properly.

Science Education and Research

It has been argued in the earlier sections that for modernisation it is necessary to establish a foundation for scientific research and the social appreciation of science in the developing and less advanced countries. Every path-finder in a new field of research must work in the first instance by himself; if he is successful, other persons gradually get interested in the subject. Such path-finders always had, and will always have to overcome much opposition, and even hostility, until the new subject becomes a recognised part of the 'established' field of science. But it is only a few scientists of outstanding ability who can work in isolation. Most research workers require the stimulus of free interchange of views and ideas and of appreciation among professional colleagues.

The community of scientists has a structure of a series of widening circles similar to the structure of scientific subjects or of science as a whole. When a top scientist speaks appreciatively of some work in his special field, other scientists or laymen accept his evaluation and pass on the information to others. The social appreciation of science gradually emerges as a result of the diffusion, in widening circles, of the views of scientists, who are experts in specialised fields of research, to scientists in related and associated fields, then to scientific workers generally, and finally, through persons of position and standing who have contacts with scientists, to the general public. The speed with which such appreciation can spread, increases rapidly with the increase in the number of scientific workers and improvements in the channels of communication. In the advanced countries, the awareness of the importance of science is increasing rapidly which, in its turn, is raising the social status of scientists and is promoting an increasing flow of resources for research.

The whole process is extremely slow in underdeveloped countries. The number of research scientists is very small; and channels of scientific communication are non-existent or meagre. Scientific workers usually receive lower pay and have a lower status than the administrative staff in government or in business concerns; and have to work in a rigid system of hierarchical authorities. Promotion may depend, not so much on the high quality of the scientific work done, but on success in pleasing those who are higher up in the official hierarchy. Even permission to apply for posts elsewhere is subject to the discretion of superior officers. There is a continuing tendency to bring scientists and scientific work under strict control of the administrators, partly, perhaps, from an unconscious fear of rivalry of power. Even if the right of criticism is accepted in principle, it is restricted in practice because scientific workers are often afraid, rightly or wrongly, of giving offence to persons holding higher posts. In consequence, many scientists in underdeveloped countries suffer from a lack of self-confidence, and are afraid to take up original lines of investigation. There is little possibility of a proper evaluation or appreciation of scientific work within the country. This leads to an exaggerated dependence on the opinion of foreign scientists and gives rise to much imitative work. Also, when there is lack of appreciation or criticism from the

advanced countries, there is sometimes a tendency to ascribe the unfavourable view to racial or national prejudices, and there is resistance against collaboration with foreign scientists.

In underdeveloped countries there are very few, sometimes only one or two, individuals of outstanding ability in scientific research or in any other scientific field. As leadership can be supplied only by individuals of high ability, and as such persons are few in number, it is much more difficult in underdeveloped countries to utilise the services of individuals of average ability and qualification. The advanced and advancing countries have a double advantage. They have a large number of persons with qualities of leadership and can, therefore, utilise in a fruitful way larger numbers of persons of average ability. This is why many scientific workers from underdeveloped countries, who are unable to do much useful work in their own native country, can often do very good work in the environment of a higher state of organisation of research in an advanced country.

The aim of scientific aid must be to create in every underdeveloped country, as quickly as possible, a sufficient number of research scientists to form a community of professional workers which would be sufficiently large to facilitate an independent evaluation of scientific work through free criticism and frank exchange of views. It is, therefore, necessary to focus attention on identifying and giving support to persons who have the ability to undertake research work of high quality, and to try to increase their number as quickly as possible, and at the same time to offer opportunities for training to persons of average ability whose services would be equally essential in supplying a wide base for the pyramid of scientific work.

There is urgent need for fostering the spirit of objective scientific criticism through free expression and exchange of views and opinions. One effective way of promoting this would be to make it easy for scientific workers to migrate from one post to another and give an absolute guarantee of such freedom to migrate. Any scientific worker who feels, rightly or wrongly, that he does not have enough opportunities for fruitful work in one institution would be free to migrate to some other institution. Such migrations or the possibility of such migrations would have an indirect but most important selective effect on scientists at all levels.

It is necessary to recognise that the social value of an individual scientist of high ability is far greater in a developing country because of the leadership he may be able to supply. It is only scientists engaged in fundamental research who can function as the eyes and ears of the nation in making the nation appreciate and identify urgent needs of applied research. The emergence of even one or two outstanding research scientists can enhance the prestige of the nation in a most significant way at the international level and promote the growth of self-respect and self-confidence of the nation. This is why it is particularly important in developing countries to identify such individuals, at first very few in number, and give them all possible facilities and encouragement to continue their work in their own country.

In the highly developed countries science advanced both from progress at the highest levels of research, at the top, and from the wide

diffusion of education, at the bottom. The same strategy may be adopted with advantage in the less advanced countries. What is urgently needed is to lay the foundations, with as wide a base as possible, for a countrywide system of school education oriented to science and, at the same time, to develop advanced studies of science and technology and research at the highest level. The school system must fit into the economic life of the general mass of the people and have its grassroots in the villages. It must offer facilities for training technicians and technical personnel for science and technology and also supply candidates of outstanding merit for admission to higher scientific and technological institutions.

Need of Direct Aid for Science

I shall offer, briefly, a few suggestions for giving direct aid for the development of science in the less advanced countries. I have stressed the need for building up a system of school education with a definite orientation to science. It would be, however, a fatal mistake to establish an expensive system of education on the model of the advanced countries which would have little relevance to local needs and would be beyond the means of the national economy. It is necessary to evolve a system, through experimentation and trial and success, which would be within the means of the national economy. The approach must be therefore, to use teaching aids which are easily available or can be made available on a large scale and at a low cost. As most of the pupils will be living in villages, it would be of great advantage if agriculture and some of the rural industries can be adopted as a base for the teaching of science. The programme may consist largely of nature studies, observations, and experiments which can be done with the help of simple articles, specimens, etc., likely to be locally available or which can be constructed with local materials.

There would be still some need of supplying teaching aids and materials from outside which would have to be specially designed to reduce costs. It is essential also to prepare books of instructions and textbooks to suit a fairly wide range of needs. These are difficult tasks which would call for extended study and research by scientists of high calibre with a serious interest in problems of science education. As basic conditions in underdeveloped countries are likely to be similar to a large extent, it may be possible to evolve broad general methods for science education which would be capable of being adapted without much difficulty to suit differing local conditions.

A great deal of pioneering research would be necessary for this purpose for which the help of advanced countries is indispensable. A good deal of experimental studies will have to be undertaken under conditions actually prevailing in underdeveloped regions. In the beginning, the studies would have to be organised on a small scale with the help and support of the local authorities and of such teachers and scientists as may be available to cooperate in the venture in the underdeveloped country itself. The project can be gradually extended, in the light of experience, to cover different subject fields at different educational levels, and also from one underdeveloped country to another. Fortunately, even one or two scientists can start the work in one single country. The important point is to make a beginning at the earliest opportunity.

I may now mention a second type of programme. Certain facilities for scientific research are already available in India and other developing countries. In most of these countries, scientific work is being hampered for lack of small replacement parts, additional accessories and instruments, and supply of essential consumable stores which have to be imported from the advanced countries. It is often difficult to secure import licenses on account of shortage of foreign exchange. This difficulty can be overcome through a simple plan of gifts in kind of replacement parts, instruments and equipment, stores, books and journals and reprints or microfilms of scientific papers etc., to be arranged through non-governmental committees of scientists. Such committees, which can be set up in the advanced countries through or in cooperation with appropriate scientific organisations or societies, would try to secure suitable grants from Government and other sources. In developing countries where scientific research has already started, the counterpart committees of scientists would also be set up, preferably, at a non-governmental level and with a majority of members from universities and non-governmental scientific institutions. All arrangements would be made with the concurrence of the government of the less advanced country concerned, but decisions relating to gifts for scientific work must be made by direct consultations between the scientific committees themselves. A scheme of this type can be usefully started, on an experimental basis, for a few selected countries, at a low cost, with gifts of the total value of perhaps one or two hundred thousand dollars per year. The amount can be increased if the experiment proves successful.

Another important form of scientific aid would be to arrange for competent research scientists from the advanced countries to work for a year or two in existing research units in the less advanced countries or to help in establishing high level research units in such countries. The less advanced countries can offer challenging problems and opportunities for research in many fields of science, which cannot be duplicated in the advanced countries, for example, in geology, meteorology; biology, botany, and zoology; agriculture; medical science and public health; economics of development; linguistics, archaeology; and historical and cultural studies of various kinds. In some of the developing countries there would be also increasing opportunities for active participation in research in mathematics and statistics, and physico-chemical and technological sciences. In establishing research units in underdeveloped countries it would be desirable to keep one broad aim in view, namely, to encourage joint studies by active collaboration between different research units. This would help in developing a community of research cells or units which, in its turn, would foster the growth of the spirit of scientific criticism and appraisal among wider circles of scientific workers.

To attract competent visiting scientists it is necessary to offer them facilities to pursue or start fruitful research in the less advanced countries; sometimes special equipment may have to be provided for this purpose. Secondly, the assignment in a less advanced country would have to be treated as deputation in the same way as participation in scientific expeditions, and which would be recognised as a part of normal duties and also as a possible qualification for promotion. The visiting scientist must receive sufficient

compensation in his home currency to meet his continuing home commitments during his absence abroad. Living and other local expenses should be normally met by the institution or by the government of the country in which he would work. Such sharing of costs would promote effective cooperation by the less advanced country, and would also reduce the total cost appreciably.

An important part of the responsibilities of a visiting scientist would be to give training to the scientific workers of the underdeveloped countries. When necessary, the visiting scientists would be able to select, for further training in an advanced country, the right type of persons who can be depended upon to go back to their own country after the completion of the training abroad. It would be also possible to give aid in the form of equipment and instruments in an effective way on the basis of objective appraisals of needs and possibilities by the visiting scientists.

A fourth programme could be to send from advanced countries young scholars, who have just finished their education in universities or higher educational institutions or have already done some research, to start or continue suitable lines of research for about two years or so in existing institutions or in research units to be established for this purpose in underdeveloped countries. The common participation in research projects of young scholars from the advanced and the underdeveloped countries would be of great help in establishing scientific traditions and an atmosphere of scientific criticism. It would promote self-confidence among the scientific workers of the underdeveloped country, especially if the visiting scholars from advanced countries earn higher degrees from the less advanced countries.

All the above forms of scientific aid can be started, if desired, on a small scale and at low cost, and, if successful, can be expanded in the light of experience. Also, these forms of scientific aid would not in any way overlap or hamper bigger programmes for gifts of expensive equipment or large projects for the setting up of national or regional centres and institutes for scientific research in the less advanced countries. On the contrary, the modest programme described in this note would prepare the ground for bigger projects.

Conclusion

In conclusion I may refer, very briefly, to some recent developments. After the Second World War the movement for terminating colonial rule gained rapidly in strength; and one country after another in Asia and Africa won political independence. It is being increasingly realised, however, that independence is not enough for economic development. The need for economic and technical aid is also being increasingly appreciated. Both the western and the eastern powers have started helping in the economic development of the less advanced countries in Asia, Africa and Latin America, but still without an adequate impact. The time has come to recognise that economic aid is essential but is also not sufficient.

Revolutions to capture political power have been occurring throughout human history and are even now occurring in many of the politically independent countries in Latin America or in most of the newly independent countries in Asia and Africa. Such revolutions do not automatically

promote rapid economic development, because purely political revolutions do not lead to any fundamental transformation of the old society, based on the principle of authority associated with levels of status. It is becoming increasingly clear that rapid economic development cannot be achieved without developing a structure of society in which decisions would tend to be made more and more on grounds of reason, that is, in accordance with the principle of objective validity instead of authority. It is relevant to note that the French Revolution was preceded by the Age of Reason; the American War of Independence had the support of influential leaders inspired by the spirit of science; and the socialist government, which was established after the October Revolution in 1917 in Russia, made great efforts to build up a countrywide system of science-oriented education and to promote scientific research and, in this way, succeeded in modernising the whole society leading to rapid economic development.

One thing is clear. In the absence of rapid economic development, political conditions in the less advanced countries will remain unstable. In many or most countries there would be one revolution after another tending to get the two power groups involved directly or indirectly in the struggle. The world must get out of this vicious circle. There are only two possibilities. One is for a violent type of revolution to occur which would suddenly change the whole structure of society to make it fit for rapid development of science and economic progress. The other alternative is to build up deliberately the foundation of science-oriented education and research to promote the modernisation of society in a peaceful way, and make conditions favourable for economic development.

Aid for scientific and economic development from either the western or the eastern countries, even when given in a spirit of competition, would be cooperative in effect. In any event, competition in constructive tasks of building up scientific foundations in developing countries is less dangerous and is likely to be far more useful than competition in the methodologies of warfare. Also, collaboration in promoting education and research in pure science can be pursued without any threat to national security or national interests, and would be of great help in promoting a rapid advance of the underdeveloped countries and in fostering better understanding among the nations of the world. The advanced countries have a great opportunity for peaceful cooperation in giving aid for science.

This pamphlet was first printed as a pamphlet for private circulation. Certain aspects of these problems were discussed by me in articles and addresses between 1955 and 1959 which were reprinted in *Talks on Planning* (1961), and in other articles such as *A Note on Problems of Scientific Personnel* (1959), *Recent Developments in the Organisation of Science in India* (1959) and a lecture at Sofia University in December 1961. Some of the ideas given in this article were presented by me before a Conference on International Cooperation in Salzburg-Vienna in July 1962.

Professor P. M. S. Blackeet in his presidential address to the British Association for the Advancement of Science in 1957 and in other articles in *Nature* (3 February, 1962; May 1962 etc.) has considered various problems from the point of view of the advanced countries. Professor Stevan Dedijer made a penetrating analysis in an article in *Nature* (6 August 1960) and in another article published recently in Stockholm, TVF, 33, (1962).