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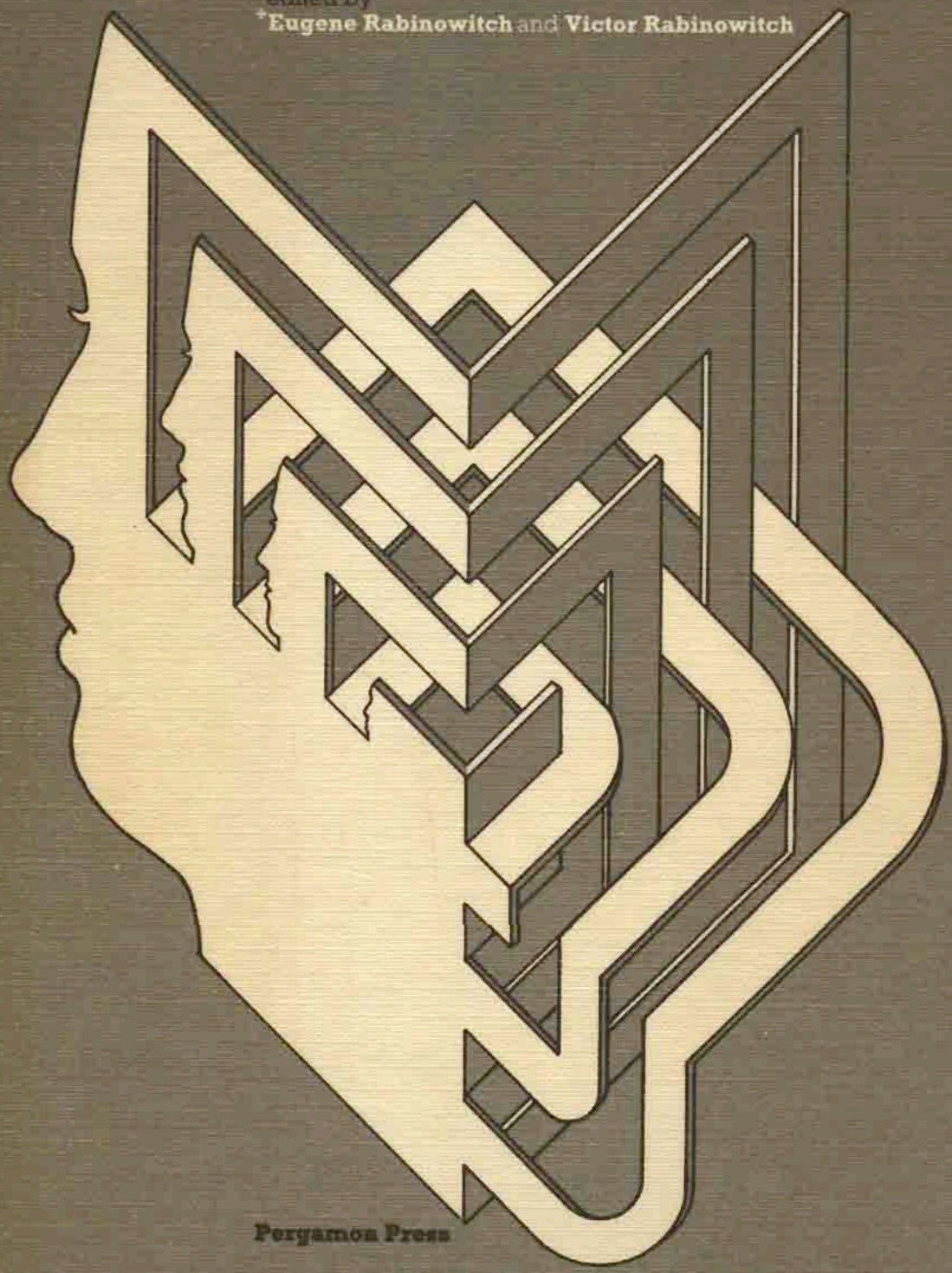

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Contents

*Underdevelopment, Science and Technology: the Point of View of the Underdeveloped Countries**

FRANCISCO R. SAGASTI†

1. Introduction

This paper examines the interrelations between underdevelopment, science and technology. As the subtitle suggests, it attempts to present the point of view of the underdeveloped countries with the aim of outlining the basis for a programme of action.

The central thesis is that science and technology were closely related to the emergence of underdevelopment as it has so far arisen in the twentieth century, and that to a certain extent they are contributing to the maintenance and persistence of underdevelopment. In order to modify this situation, major structural changes are required both in the way scientific and technological activities are organized within the underdeveloped countries, and in the international structure of the world scientific and technological effort. These changes will not come automatically. They need to be pressed by the underdeveloped countries themselves. To avoid the disruption and the social costs that may be involved in reshaping their scientific and technological activities, as well as the structure of the world scientific effort, underdeveloped countries should employ the scientific method itself in planning these changes.

The paper begins by examining the concepts of development and underdevelopment, it then explores their relation to science and technology, and ends with some proposals on the contribution that science and technology can make to the development of the Third World.

2. Underdevelopment and Development

Underdevelopment is a phenomenon in its own right. It cannot be adequately studied and interpreted as a "stage" in a sequential development process, or as an

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interval on a development continuum along which all countries can be placed, and through which all must proceed in order to become "developed". As Furtado[1] and Sunkel and Paz[2] have shown, underdevelopment, particularly in Latin America, is a consequence of the historical process of industrialization in Europe and later in North America. Development and underdevelopment are thus two facets of the same process of expansion of western capitalism beginning in the nineteenth century. This process involved the creation and spread of modern technology and the establishment of an international division of labour with a few more advanced countries producing manufactured goods and a large number of backward countries supplying raw materials and primary commodities. Underdevelopment and development evolved simultaneously; they were and are functionally related and they also interact and condition each other. These two phenomena must, therefore, be understood as interdependent parts of a single system. The key factor differentiating these structures is that the developed, by virtue of its endogenous capacity for growth, became dominant, and the underdeveloped, because of its incapacity for growth, became passive, dependent, and dominated.

These statements summarize the "structural" view of underdevelopment proposed by Latin American economists. They describe accurately the situation in Latin America and many other countries of Africa and Asia, although not all underdeveloped countries can be said to fit this pattern exactly.

Following Perroux[3] and Bravo Bresani[4] it is possible to say that the main characteristics of an underdeveloped country are that it is dominated, disarticulated, and incapable of providing an adequate standard of living for the majority of its population. *Domination* implies that the underdeveloped country does not have a capacity for autonomous decision making, and that it has or exercises little control over its own destiny. External factors, beyond the control of the underdeveloped country, are the main determinants of its economic, social and even political decisions.

Domination is formally defined as a bilateral and asymmetric relationship, irreversible in the short and medium terms, characterized because a change in the dominant unit invariably results in a change in the dominated unit, whereas a similar change in the latter has little or no effect in the former (Bravo Bresani and Sagasti[5]). Domination may thus be considered as an extreme form of dependence. The primary form of domination of underdeveloped countries by developed ones is economic, although it has been shown that economic domination is closely related to cultural

[1] Celso Furtado, *Development and Underdevelopment*. Los Angeles: University of California Press, 1962.

[2] Oswaldo Sunkel and Pedro Paz, *El Subdesarrollo Latinamericano y la Teoria del Desarrollo*. Mexico: Siglo Veintiuno Editores, 1970.

[3] Francois Perroux, *L'Economie du XXème Siècle*. Paris: Presses Universitaires de France, 1961.

[4] Jorge Bravo Bresani, *Desarrollo y Subdesarrollo*. Lima: Moncloa Editores, 1966.

[5] Jorge Bravo Bresani and Francisco Sagasti, Elements for a Development Strategy in the Context of the Global Industrial System. Paper presented at the Research Conference on the Multinational Firm and the Nation State. Philadelphia, Pa.: University of Pennsylvania, May 1971.

and technological domination, with one of them leading to or implying the others (Perroux[6], Thebaud[7]).

Developed countries have been continuously shifting their modes of domination over underdeveloped ones in response to changing conditions and to pressure from them. From the control of raw materials extracted from, and manufactured goods supplied to, the underdeveloped countries, developed countries gained control of a significant share of the industrial production facilities through direct investment, and are now gaining control of the technological know-how required in manufacturing. Such control is acquired through direct investment and through such means as licensing agreements, sale of patents, management contracts, and technical assistance agreements. The primary vehicle through which these various forms of domination are exerted is the international or multinational corporation. The changing nature of domination has been explored fully by Furtado[8] and Dos Santos.[9]

Disarticulation means that the underdeveloped country does not constitute a homogeneous unit from the cultural, economic and social points of view. It is a highly stratified society with little or no interaction among the various strata and with almost no mobility between them. As Delgado has shown for the case of Peru, often some of these strata are more closely related to developed countries, to large cosmopolitan urban centres, and to foreign ways of living, than to other strata within the underdeveloped country. As a result, improvements in socioeconomic conditions generally affect only some segments of the population, leaving the other segments or compartments comparatively unchanged.

The third characteristic, the *incapacity to cover the costs of an adequate standard of living for the majority of the population*, is perhaps the most striking of the three. The majority of the world population, which is concentrated in the underdeveloped countries of the Third World, has a very low and often deteriorating standard of living. Traditional aid and trade measures appear to be insufficient to improve the social conditions of the majority of those living in underdeveloped countries. For example, the Interamerican Development Bank Report on Socioeconomic Progress points out deficiencies in practically all aspects of living conditions for most countries in Latin America. Shortages in housing, high infant mortality, low life expectancy, malnutrition, lack of educational opportunities, and high inequalities in income distribution appear to be "normal" for the majority of Latin Americans. Furthermore, these three characteristics of underdevelopment are being reinforced rather than overcome.

Economic development, from the point of view of an underdeveloped country, can be considered a dynamic process of structural change characterized by three factors:

[6] *Op. cit.*, note 3.

[7] Schiller Thebaud, *L'Analyse des Objectifs de la Politique Scientifique des Etats Occidentaux*. Grenoble: Institut Economique et Juridique de l'Energie, Université de Grenoble, May 1969.

[8] Celso Furtado, *Obstacles to Development in Latin America*. New York: Anchor Books, 1970.

[9] Theotonio Dos Santos, "El nuevo carácter de la dependencia". *La Nueva Dependencia*. Lima: Moncloa Campondónico Editores, 1968.

(1) absolute and sustained economic growth, (2) scientific and technological progress, and (3) social propagation of the effects of (1) and (2) to all sectors of the population (Bravo Bresani and Sagasti).[10]

The first factor, economic growth, traditionally has been considered as synonymous with economic development. Although a necessary condition, it is not sufficient by itself, because economic growth, without technological progress and the propagation of its effects, does not overcome the conditions of domination and disarticulation which characterize underdevelopment.

The second factor, technological progress, refers to the autonomous capacity of a country to generate, disseminate and utilize scientific and technological knowledge in its productive and social processes. However, such progress does not imply rejection of technology imported from abroad. Rather it requires the ability to import, absorb and modify foreign know-how, adapting it to local conditions and even re-exporting it after further development. Only through a process of creating its own scientific and technological capacity can an underdeveloped country be in a position to counteract the effects of technological domination. The third and last factor refers to the distribution of the fruits of economic growth and technological progress to all sectors of the population. This is equivalent to eliminating the disarticulation which characterizes underdeveloped countries, distributing the benefits derived from a development process to the various regions of the country and to all segments and sectors of its society, so as to raise living conditions of all to at least minimally acceptable standards.

3. Some Characteristics of the Relation Between Science, Technology and Underdevelopment

In the past two decades, technology has become increasingly important as a factor in the relations between developed countries, as well as in the relations between developed and underdeveloped countries. Technological progress has been credited with contributing more than any other factor to the economic growth of developed countries, and until very recently resources allocated to research and development in advanced countries have been growing at an exponential rate. In addition, the technological content of manufactured goods has become a major determinant of the patterns of trade between developed countries, and also between developed and underdeveloped countries, as the articles in the book edited by Vernon[11] point out.

Most underdeveloped countries, waging a losing battle with the deterioration of the terms of trade, have seen the technological content of their imports increase steadily. At the same time they have realized that it is becoming more and more difficult to manufacture goods for export competing with firms and countries with

[10] *Op. cit.*, note 5.

[11] Raymond Vernon (ed.), *The Technology Factor in International Trade*. New York: Columbia University Press, 1970.

vastly superior scientific and technological capabilities (Prebisch,[12] Schiavo-Campo and Singer[13]).

Many underdeveloped countries have followed the road of import substitution to begin their industrialization (Latin American countries, for example). In most of these cases each new wave of import substitution generated a demand for increasingly more complex and advanced capital equipment. Such equipment was usually provided from abroad, because their incipient scientific and technological infrastructure had no capacity to provide the know-how needed in productive activities. These conditions have led to an increasing dependence on foreign technology, thereby intensifying technological domination. Herrera,[14] Halty,[15] Sagasti[16] and Sanchez Crespo[17] have studied this phenomenon in detail. Thus in some cases the efforts to begin industrialization have led to increased technological dependence. Furthermore, as Dos Santos[18] emphasizes rapid advances in science and technology in developed countries are making technological domination the major form of domination of underdeveloped countries by developed ones in the second half of the twentieth century.

It has been pointed out, particularly by Thebaud,[19] that a country which does not develop a scientific and technological capacity of its own will necessarily be technologically dependent and dominated by more advanced countries. Given this situation there is a great risk that its enterprises and other productive units, forced to acquire know-how from foreign sources (frequently under unfavourable conditions), may become economically dependent on these sources and dominated by them. Beyond a certain threshold the political and cultural independence of the country may be threatened by these forms of dependence and domination.

Most of the technology available in the world today has been created in the developed countries. It has been estimated by the Sussex Group that fully 98% of the world's expenditures on research and development are made by developed countries. Moreover, the 2% spent by the underdeveloped countries is often misused, allocated to research tasks of little consequence for development, and to research centres with lower productivity than the average in developed countries.

[12] Raul Prebisch, *Transformación y Desarrollo*. Washington D.C.: Interamerican Development Bank 1970.

[13] Salvatore Schiavo-Campo and Hans Singer, *Perspectives of Economic Development*. Boston: Houghton Mifflin Co., 1970.

[14] Amilcar Herrera, *Ciencia y Política en América Latina*. Mexico: Siglo Veintiuno Editores, 1971.

[15] Máximo Halty, *Producción Transferencia y Adaptación de Tecnología*. Washington D.C.: Department of Scientific Affairs, OAS, 1970.

[16] Francisco Sagasti, *Towards a Methodology for Planning Science and Technology in Underdeveloped Countries*. Draft Report presented by The Management and Behavioral Science Center, University of Pennsylvania, to the Department of Scientific Affairs of the OAS. Philadelphia, 1972.

[17] Alberto Sanchez Crespo, *Esbozo del Desarrollo Industrial de America Latina y sus Principales Implicaciones sobre el Sistema Científico y Tecnología*. Washington D.C.: Department of Scientific Affairs, OAS, 1970.

[18] *Op. cit.*, note 9.

[19] *Op. cit.*, note 7.

The research and development activity in developed countries is concentrated in a few large corporations or government-backed organizations, as shown by OECD studies[20] and by Cooper and Chesnais.[21] These conditions have led to the formation of R & D oligopolies in almost every branch of economic activity, and particularly in those with high technological intensity.

This concentrates the power to exert technological domination in a rather limited number of firms in the advanced countries. These firms exert virtual monopolies over the supply of technology, particularly in their relation to underdeveloped countries.[22] Moreover, the absolute level of the R & D effort in developed countries is several orders of magnitude larger than that of the underdeveloped countries,[23] and the existence of a cumulative scientific and technological tradition in the developed countries makes it difficult for an underdeveloped country, or even a group of them, to reach the levels of achievement attained by the developed ones in almost every area of science and technology.

As a consequence, much of the existing stock of scientific and technological knowledge is suited to the needs and conditions prevailing in developed countries, which have little in common with those of the underdeveloped ones (technologies that require large amounts of capital, large-scale production, and highly skilled labour provide one example). Needless to say, these hardly correspond to the situations prevailing in underdeveloped countries.

Furthermore, as the Japanese White Paper on science and technology[24] points out, current trends in scientific and technological research will intensify this divergence. Among the characteristic trends in the development of new technology, it is possible to identify movements toward more automated plant equipment using limited but highly skilled labour and toward increases in the economic scale of productive units. There is also a trend toward the development of new synthetic materials, which has potentially dangerous implications for underdeveloped countries, because they depend largely on the export of raw materials and primary commodities for their foreign exchange.

Underdeveloped countries thus face a lack of suitable technological alternatives. Often they are faced with the dilemma of choosing between increasing industrial output by using modern, generally capital-intensive techniques, or foregoing opportunities for increasing output but maintaining relatively higher levels of employment using archaic or obsolete techniques. The lack of viable and efficient tech-

[20] Organization for Economic Co-operation and Development (OECD), *The Overall Level and Structure of R & D Efforts in OECD Member Countries*. Paris, 1964.

[21] Charles Cooper and Francois Chesnais, "La Ciencia y la Tecnología en la Integración Europea". *Integración Politica y Económica*, O. Sunkel (ed.), Santiago de Chile: Editorial Universitaria, 1970.

[22] Constantine Vaitsos, Transfer of Resources and Preservation of Monopoly Rents. Paper presented at the Harvard Development Advisory Service Conference. Dubrovnik, 1970.

[23] Geoffrey Oldham, Paper presented at the Round Table on Transfer of Technology, Lima, February 1971. Washington D.C.: Department of Scientific Affairs, OAS, 1971.

[24] Japanese Government, *White Paper on Science and Technology*. Spanish translation in *Comercio Exterior* (Feb. 1971).

nological alternatives, together with the underdeveloped countries' low scientific and technological capacities, poses a difficult challenge, particularly in view of the explosive conditions of population growth, unemployment and underemployment. In some cases the lack of viable alternatives and the ignorance of the buyer of technology in underdeveloped countries has led to wastage of scarce resources, particularly capital. Heavy investments have too often been made in plants with capacities vastly exceeding the size of the market. In some cases governments in underdeveloped countries have encouraged the proliferation of oversize plants for the sake of achieving "competition" (in accordance with imported conventional economic wisdom) with the net result of higher costs, inefficiency and dilapidation of resources.

The capacity for creating technology, or even for absorbing imported technology, is not present in most underdeveloped countries. As a result of the passive character of their economic growth, their demands for technology have usually been satisfied from abroad, through the import of equipment and through technical assistance by foreign technicians. Because foreign technology was readily accessible, little pressure was exerted on the local scientific community to provide viable technological alternatives, particularly in the manufacturing industries. Industrialization policies, fostering technological dependence, have often accentuated the cleavage between the local scientific community and the technological needs of the country. In consequence underdeveloped countries find themselves incapable of creating and satisfying their own technological needs and even incapable of selecting and absorbing the least unsuitable imported technology from the limited range available. Furthermore, as the studies carried out by Vaitsos[25] and the Organization of American States[26] show, foreign technologies are more often than not acquired under very unfavourable conditions, which include high implicit and explicit costs, and restrictions on its use.

Because the productive sectors of the economy exert little pressure on the local scientific and technological communities, scientists, professionals, and technicians orient themselves toward the international scientific community, choosing research topics in fashion, seeking to contribute to the advancement of science as an international undertaking, and disregarding the research needs of their countries almost completely. As long as these needs are ignored by the local scientific communities, they can only retain their identity by orienting themselves outwards. Thus we find local scientific communities of many underdeveloped countries alienated from their own environment and zealously defending freedom of research and the values of universal science, to the detriment of their potential contribution to the development of their own countries. The well-known phenomena of "brain-drain" is an extreme manifestation of this alienation.

The international scientific community, erring by omission rather than commission, has contributed to increase this alienation. Not enough attention has been given by

[25] Constantine Vaitsos, *Strategic Choices in the Commercialization of Technology: the Point of View of Developing Countries*. Mimeograph (July 1970).

[26] Organization of American States (OAS), *La Transferencia de Tecnología hacia los Países del Grupo Andino*. Washington D.C., 1972.

scientists to the scientific and technological problems particular to underdeveloped countries. Sachs[27] postulates that the Europocentric character of modern western science has had a retarding effect on the scientific efforts of underdeveloped countries. Estimates by the Sussex Group[28] indicate that less than 1% of the total research effort in developed countries, to which the international scientific community is primarily related, is directly relevant to the problems of underdevelopment, although the amount may be of the same order of magnitude as the expenditures by underdeveloped countries themselves. Prestige is conferred on researchers who work on exotic and sophisticated advanced topics, choice of which is often dictated by scientific fashion or novelty. Most of these have nothing to do with the more pedestrian scientific and technical problems faced by underdeveloped countries.

The insistence on the international and universal character of the scientific enterprise, the rejection of any type of imposition in the selection of research topics and areas, and the emphasis on the objectivity of science and its quest for truth, have all been proposed as characteristics of what Polanyi[29] has called the "Republic of Science". These, advocated as indispensable conditions for doing science, have also had some effect on the behaviour of the scientific community in underdeveloped countries. Any attempt to reorientate the local scientific effort, gearing it to the needs of the country, is arduously fought by scientists, who see it as infringing on their rights, jeopardizing the integrity of their undertaking, and tampering with the freedom of research.

Little attention is paid by the advocates of unrestricted scientific freedom to the implicit guidance of the scientific enterprise in developed countries through the manipulation of resources available for research. The fact that investments in research soared after the Second World War, primarily in defence, atomic energy and space, is not taken into account. Scientists, professionals, and technicians, preoccupied with the freedom to choose their own individual research topics, are not generally aware of the fact that the broad directions of scientific progress have been primarily influenced by political, economic and social considerations.[30]

It must be emphasized that scientists in underdeveloped countries have acted in a "rational" way in the process of becoming alienated. Given the lack of effective demand for their services in their countries and the structure of the international scientific community, they could not help, if they were willing to remain as scientists, but choose research topics sanctioned by the international scientific community, for which resources were often more freely available. This is but another instance of the divorce between individual and collective rationality in underdeveloped countries.

The preceding paragraphs have dwelt on the aspects of the present organization

[27] Ignacy Sachs, *La Découverte du Tiers Monde*. Paris: Flammarion, 1971.

[28] Sussex Group, *Science, Technology and Underdevelopment: the Case for Reform*. Draft introductory statement for the United Nations World Plan of Action on Science and Technology. Brighton: University of Sussex, 1970.

[29] M. Polanyi, "The Republic of Science", *Criteria for Scientific Development, Public Policy and National Goals*, E. Shils (ed.), Cambridge, Mass.: MIT Press, 1969.

[30] Oscar Varsavsky, *Ciencia, Politica y Cientificismo*. Buenos Aires: CEAL Editores, 1970.

of scientific and technological activities which do not appear to contribute to economic development in underdeveloped countries. This was done primarily because the literature on this subject has emphasized the positive contributions of science and technology to development. This optimistic view must be tempered by the realization that the science and technology of developed nations is not, in the main, the kind that is required in underdeveloped countries; the part that is required is not usually available under favourable conditions, and if it is, there is often a lack of competence to use it.

This is not to deny that science and technology can and will contribute to development. Only latter-day Luddites would refuse to recognize their potential contribution. During the Second World War Britain and the allied countries which considered themselves in a state of emergency and enlisted the help of the majority of their scientists, made an unprecedented effort to utilize science and technology. This showed what is possible to achieve in a relatively short period of time if an all-out concerted effort is made. There is no apparent reason why a similar mobilization to tackle the problems of underdevelopment would not produce equally spectacular results.

To summarize, science and technology have the potential to contribute, perhaps more than any other single factor, to overcoming the conditions of underdevelopment. However, the present structures of scientific and technological activities in both developed and underdeveloped countries are such that this potential is not being fully realized. Rather, they appear to reinforce, at least partially, the conditions of underdevelopment.

4. Conditions for Making Effective the Potential Contribution of Science and Technology to Development

From the preceding analysis it follows that, if science and technology are to contribute to the development of the Third World, there must be a major transformation in the structure of the world scientific and technological effort. The necessary changes, which require a firm commitment both by developed and underdeveloped countries, can be grouped into three catgegories:

(1) Modifications in the international division of labour and the orientation of scientific and technological activities at the world level.
(2) Generation of local scientific and technological capabilities in underdeveloped countries.
(3) Full incorporation of science and technology within the scope of development planning efforts.

I shall discuss these in turn.

The first group of changes would include measures to ensure that a larger portion of world expenditures in research and development is allocated to projects relevant

to underdevelopment. The Sussex Group[31] and the United Nations[32] have suggested targets for the percentage of research and development expenditures by developed countries that should be devoted to the problems of underdeveloped countries (figures around 1–2% have been mentioned) and for the percentage of total aid from developed to underdeveloped countries that should be oriented towards the generation of local scientific and technological capabilities.[33]

These proposals involve primarily bilateral forms of "science and technology aid". On their own they are not likely to have a major effect on the nature and distribution of world expenditures on science and technology. At best they would succeed in improving research and development in specific fields for some underdeveloped countries. At worst they would make the development of local scientific and technological capabilities more dependent on specific foreign sources.

Another proposal along this line seeks to establish multilateral "Research and Development Funds" at the world and/or regional levels. These funds would operate with their own independent and stable financial sources, which could be provided by special taxes or duties on activities that are realized at the world level (for example, Sachs[34] has suggested that programmes to control sea pollution be financed with taxes levied on ships operating in international waters). Voluntary contributions made by underdeveloped countries and matched by developed countries could provide additional funds, but not replace an independent and stable source of money. However, the availability of funds *per se* does not constitute a guarantee that the science and technology financed with them will have an impact on the development of the Third World. If these funds were administered by scientists from underdeveloped countries alienated from their own environment, and/or scientists from developed countries who are not aware of the complex interrelations between science, technology and underdevelopment, the distortions found at present in the world scientific and technological effort would probably be reinforced.

Changes at the international level should also include increased co-operation between underdeveloped countries in matters related to science and technology. Eventually, more intensive collaboration may pave the road for effective scientific and technological integration. However, experience has shown that co-operation agreements are relatively easy to reach when issues of a purely scientific nature are involved, but when co-operation or integration programmes involve research activities that may have direct economic application—which could benefit a particular country or even a particular enterprise—agreement is much more difficult to obtain. In consequence, scientific and technological integration among under-

[31] *Op. cit.*, note 28.

[32] United Nations, *Science and Technology for Development*, Summary of the World Plan of Action on Science and Technology for the UN Second Development Decade. New York, 1971.

[33] At present it appears that Canada, through its International Development Research Center, is effectively moving in the direction of making science and technology a significant component of its aid programme.

[34] Personal communication.

developed countries is likely to be achieved only in conjunction with economic and political integration.

There is also a need for establishing a pressure group that would act on the international scientific community, motivating scientists to become involved in projects of potential or direct benefit to underdeveloped countries. In the face of increased East–West dialogue (and maybe even agreement on nuclear matters) this could be a task for the Pugwash movement. A new generation of scientists-activists who would take the banner of science and technology for the development of the Third World could inject a new sense of purpose into Pugwash. Failing this, it would be necessary to organize a new pressure group, perhaps within the framework of institutions such as UNCTAD's Group of 77, to press these issues before the international scientific community.

The list of possible actions at the international level could be expanded to include the introduction of a "technological dimension" in the evaluation of projects financed by international development banks or agencies, the establishment of mechanisms to award prestige to scientists working on problems related to development (a Nobel prize has once been suggested), and the introduction of a "development merit" criterion for evaluating proposed research projects (following Weinberg's approach to scientific choice).[35]

The second group of changes requires action at the country level. In consequence these changes must be tailored to the particularities of a given national situation. Underdeveloped countries are not a homogeneous lot and specific proposals to improve scientific and technological capabilities must take into account differences in size, resources, levels of modernization, cultural patterns and many other factors of similar nature. Nevertheless, it is possible to identify some actions that are necessary for the development of a local capacity for doing science and technology.

First, it is necessary that long-term objectives be clearly formulated, defining the "style" of science and technology that the country is seeking to develop, and its relation to the overall economic and social development strategy.

Second, the interactions between science and technology and the economic, educational, political and cultural environment of the country must be considered. The environment affects both the demand for knowledge generated by scientific and technological activities and the possibilities for producing it locally. In particular, the characteristics of the economic system and of many government economic policies contain an array of implicit science policies—which are perhaps more important than explicit policies—and which frequently run against the objectives of scientific and technological development. For example, the implicit science policy contained in the import-substituting industrialization of many Latin American countries has often reinforced technological dependence. Identifying these contradictions and exposing these conflicts is of primary importance for scientific and technological development. As long as negative implicit policies remain hidden, it will be impossible to remove the obstacles that prevent scientific and technological development.

[35] Alvin Weinberg, "Criteria for scientific choice", *op. cit.*, note 29.

The development of a local institutional infrastructure for science and technology is a third aspect that must be covered. Institutions are the means through which resources are channelled to scientific and technological activities. A wide and well-organized base of institutions constitutes a necessary condition for attaining an acceptable level of scientific and technological development.

Underdeveloped countries cannot expect to excel in all fields of science and technology. Therefore, a fourth aspect to consider is the need for a strategy of specialization to be followed by the generation of a local capacity for science and technology.[36] This implies a choice of domains in which the underdeveloped country would become an advanced centre of knowledge and to which resources would be allocated with priority. In other fields or domains technology could be imported, although it would be necessary to exert control on these imports to avoid the negative effects that often accompany them. However, this strategy does not imply abandoning the support that fundamental science is required to provide; for example a base of scientific activity and qualified manpower for science and technology.[37] A balance must be achieved between the concentration of resources in some domains and the general support that fundamental science must receive.

The last aspect to consider refers to the availability of resources for science and technology. Human, financial and physical resources must be provided beyond the minimum critical mass, particularly in the domains chosen by the underdeveloped country for specialization. The human resources base for science and technology in underdeveloped countries is rather limited, and probably constitutes the main bottleneck for scientific and technological development. To overcome this limitation it is necessary to implement measures that would produce results in the short-term, such as programmes to repatriate qualified personnel working abroad; in the medium term, such as programmes to expose professionals and scientists to advances in modern science and technology; and also in the long term, such as changes in the educational system. Financial and physical resources must also be increased, although there appears to be a greater need for a more rational use of existing funds and facilities for science and technology.

The third group of changes is oriented towards making science and technology an integral part of development planning. The first task consists in making planners and politicians aware of the role that science and technology play in the development process, emphasizing that technological domination reinforces underdevelopment. It is also necessary to show them that development plans and policies often contain negative implicit policies for science and technology, which make development efforts self-defeating in the long run.

The concern for scientific and technological policy-making and planning is of relatively recent origin. As a consequence, there are no proven and accepted methods

[36] Robert Gilpin, "Technological strategies and national purpose", *Science*, **169**, 441–8, 31 July, 1970.

[37] Simon Rottenberg, "The Warrants for basic research", *op. cit.*, note 29.

and criteria that could be recommended and applied with confidence.[38] Therefore, another task of high priority is the development of, and experimentation with, procedures for scientific and technological policy-making and planning. The scientific method itself should be brought to bear in planning the development of science and technology.

The awareness by planners and politicians of the importance of science and technology for development, and the availability of adequate methods for scientific and technological planning, would combine to legitimize the incorporation of science and technology within the scope of overall development planning efforts.

5. Conclusion

This paper has presented a brief review of the interrelations between science, technology and underdevelopment, and of the issues involved in realizing the potential contribution of science and technology to the development of the Third World. Beginning with a definition of underdevelopment and a conceptualization of the development process, it was possible to show the need for major changes in the structure of the world scientific and technological effort. Proposals for action remained at a relatively high level of generality and were offered as an outline to be explored in further detail in a concrete setting.

The three groups of changes described in Section 4 amount to a radical transformation of the world scientific and technological effort. On the basis of past history, it is highly improbable that these changes will come about automatically. If they are realized, they will be the result of purposeful action by those who stand to gain from them. Therefore, this transformation must be pressed and started by the underdeveloped countries themselves.

However, it is rather unlikely that individual country efforts to modify the international division of labour in science and technology, as well as the norms that regulate the behaviour of the international scientific community, will bear fruit in the short and medium terms. In consequence, underdeveloped countries should begin by organizing their own limited efforts, by augmenting their own capacity for doing science and technology, and by joining forces to initiate the transformation. In the last analysis, this is the only way in which the future of underdeveloped countries will be in their own hands.

[38] Reviews of available planning methods for science and technology can be found in: Organization for Economic Co-operation and Development (OECD), *Analytical Methods in Government Science Policy* (Paris, 1970) and Francisco Sagasti, *A Review and Critique of Approaches and Methods Proposed for Scientific and Technological Planning*. Washington D.C.: Department of Scientific Affairs, OAS, 1970.