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Science and Technology for Development

The Present Situation of Science and Technology in the STPI Countries

STPI Module 4

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Science and Technology
for Development

STPI MODULE 4: THE PRESENT SITUATION OF SCIENCE AND TECHNOLOGY IN THE STPI COUNTRIES

A. Aráoz

CONTENTS

FOREWORD

This module constitutes an integral part of the Main Comparative Report of the Science and Technology Policy Instruments (STPI) project, a large research effort that examines the design and implementation of science and technology policies in 10 developing countries (Appendixes 1 and 2).

The STPI project generated a large number of reports, essays, and monographs covering a great variety of themes in science and technology for development. More than 250 documents were produced by the country teams and the Field Coordinator's Office, and this proliferation posed rather difficult problems during the comparative phase of the project. It was decided that a Main Comparative Report, covering the substantive aspects of the research work of the country teams would be published, and that several monographs treating specific subjects would complement it.

The Main Comparative Report is organized in three parts. The first consists of a short essay covering the main policy and research issues identified through the research, and the second contains the most relevant results of a comparative nature that were obtained in the project. These first two parts have been published by the International Development Research Centre in a single volume in English, Spanish, and French (109e, 109s, and 109f).

The third part of the Main Comparative Report consists of 12 modules containing material selected from the many reports produced during the STPI project. They provide the supporting material for the findings described and the assertions made in the first two parts of the Main Comparative Report.

The modules were prepared by several consultants, and given the diversity of topics covered, the IDRC staff did not consider it desirable nor possible to impose a single format or structure for their preparation. The reader will find a diversity of styles and structures in the modules and will find that the selection of texts reflects the views of the consultant who compiled the module. However, the modules were prepared in close collaboration with the Field Coordinator and were also submitted to a STPI editorial committee who ensured that they provided a representative sample of STPI material. They should be read in conjunction with the first two parts of the Main Comparative Report.

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INTRODUCTION

This module examines the present situation of science and technology in the countries of the STPI project. Most of the reports on which this module is based were prepared by the countries in late 1973 and early 1974, and they mostly use data gathered around 1968-1972. To provide an overview, Table 1 gives figures on the number of universities and research institutes, the expenditures on research and development (R&D), and other relevant indicators. It can be seen that there is a wide disparity among the STPI countries regarding variables such as expenditures on research and development, the stock of scientists and engineers, and the number of researchers in the country.

It may be useful to compare briefly some figures for the developed countries with those in Table 1 for the STPI countries. For example, India had around 80,000 researchers in 1970, which is the largest figure for the STPI countries. This compares with more than 100,000 for the Federal Republic of Germany in 1971, about 1 million for the Soviet Union in the same year, and nearly 530,000 for the United States in 1973. Even smaller industrialized countries have a larger number of researchers than most STPI countries, particularly when figures are compared with the total population. For example, the Netherlands, with a population of about 12 million, has more than 22,000 researchers, whereas Korea, with a population of more than 30 million, has around 14,500 researchers.

The differences become more marked when figures on financial resources are examined. The largest scientific and technological countries in the world, the United States and the Soviet Union, each spend more than $30,000 million per year on scientific and technological (S&T) activities. Brazil, the STPI country that is spending most on S&T activities, was planning to reach $900 million in 1977.

In examining the data on each of the STPI countries, it should be kept in mind that no full diagnosis of the science and technology system was intended as part of the STPI research project. Therefore, this module highlights the main features of the science and technology system in each country, emphasizing the capacity to generate and supply the elements of knowledge related to industry. All of the STPI teams avoided getting involved in extensive and time-consuming efforts to survey the entire field of science and technology institutions, human resources, financial allocations, etc. Instead, they chose to rely on existing data gathered by government agencies and to complement this information with selected samples and case studies. For example, in Mexico, in addition to the inventory of the scientific and technological potential carried out by the National Council for Science and Technology (CONACYT), the Mexican team interviewed personnel in 12 key research institutes. In Argentina, in addition to the inventory prepared by the Secretariat for Science and Technology at the Ministry of Education, the STPI team carried out in-depth case studies of two research centres of the National Industrial Technology Institute (INTI). In Peru, the STPI team carried out a survey on a selected sample of 78 research institutes, drawn from the universe identified earlier by the National Research Council in the inventory of the scientific and technological potential. In Korea, the STPI team relied on information gathered periodically by the Ministry of Science and Technology, which is published in annual reports on the state of science and technology.

ARGENTINA(1)

The Research and Development Infrastructure

The 1969 survey carried out by the Secretariat for Science and Technology, which covered 961 institutions, has been the only exhaustive census of research institutes in Argentina.

In that year there were 31,569 persons employed in these institutes, of which 10,827 were scientists involved in research activities. However, a rather small percentage of these scientists (36%) were devoted exclusively to research tasks, and it was estimated that the total number of effective man-years devoted to research in Argentina in 1969 was around 4,450.

The majority of scientists were concentrated in two fields - medical sciences, and natural and exact sciences - each of which comprised more than 30% of the available scientific manpower, whereas agricultural sciences, engineering sciences, and social sciences each accounted for about 10%. Considering the categories of researchers, the majority were the "independent (senior) researcher" category (35%), while the "associate researcher" and "junior researcher" categories accounted for 25.5% and 19.3% respectively. Finally, the "research assistant" category comprised only 17.9% of the scientific personnel involved in research. This indicates that there was a sort of "inverted pyramid" pattern of distribution of researchers by category and that there may be problems in the future growth of research personnel and in ensuring the replacement of more senior researchers through internal promotion.

The bulk of scientific personnel was located at universities and other higher-learning establishments: 64.7% of the total number of researchers were associated with the university system, while the public sector accounted for about 36% of researchers, divided equally among centralized and decentralized institutions. Private nonprofit organizations had 4.8% of the total number of researchers, while state and mixed enterprises accounted for only 1.8%.

A striking characteristic of Argentinian research institutes is their limited size: the average had only 11.3 researchers per institute, which would correspond to 4.6 man-years of equivalent full-time dedication. About 30% of the institutes in universities and private organizations had less than five researchers, and only 2.7% of all research institutes had more than 50 researchers. The average yearly expenditure per researcher was around $7,400, well below what most industrialized countries allocate per researcher.

There are two qualitative aspects of the Argentinian S&T effort that merit special attention. The first concerns the potential usefulness and applicability of research results, while the second relates to the quality of the research. In the 1969 survey each of the projects that were identified was assigned an area of probable application. Only 6% of the projects were considered as having potential application to industry and 20% to agriculture. This lack of applicability is confirmed by the rather low level of experimental development carried out in Argentina with the aim of putting research results within the reach of the industrial sector; by the very small percentage of research contracts with the productive sector (less than 1% of total contracts held by the research institutes); and by the limited amount of funds spent by industrial research institutes on extension activities (about 7% of their total expenditure).

The quality of research is a rather difficult thing to evaluate, but an indication may be obtained from the quality of research proposals. Evaluations of 995 research programs and projects presented to the Secretariat for Science and Technology for approval, each carried out by two independent evaluators, led to the following results: less than 25% received approval by the two evaluators, 13% were the subject of contrary opinions, and 11% were rejected by the two evaluators. The remainder of the projects fell into a "grey area" of insufficient information, errors in the formulation of the project, observations made by the evaluators that were not answered, etc. The relatively small number of projects that obtained approval by the two independent evaluators indicates that researchers and institutes have not attained the level of consistently preparing research proposals that could be approved on the basis of their scientific merit and relevance to the Argentinian situation.

An analysis of the types of interrelations among the various research institutes showed that there is little communication among them and that most of them work in isolation. This was further confirmed by their low level of utilization of support services, primarily documentation and information.

Furthermore, with the exception of the National Industrial Technology Institute (INTI), which will be examined below in further detail, there is no tradition of contractual practices in the performance of research and development by Argentinian institutes. The 1969 survey found that only 6% of the current expenditure of the largest 103 institutes came from contract work; private enterprises accounted for a negligible proportion of research contracts, the state being the principal client.

The relations between the scientific and technological system and the higher-education system also merit attention. The personnel engaged in scientific and technological activities represent a small percentage of the total stock of qualified scientists and engineers in Argentina. In this regard the STPI Argentinian report (2) mentions the following:

(1) The scientific universe incorporates only 3.3% of higher-education graduates.

(2) The total number of researchers in 1969 was smaller than the number of annual graduates from the universities. This shows that there is an abundance of human resources that could be incorporated into the science and technology system in the short term.

(3) There are few formal graduate courses, although some research institutes - mainly at the universities - have their own in-house training programs. Most aspiring researchers try for fellowships for graduate studies abroad.

To complete this overview of the main characteristics of the Argentinian scientific and technological system, a few words are in order regarding its links with the world scientific community. On the basis of an analysis of financial resources, exchange of personnel, interinstitutional agreements, and exchange of information, the Argentinian report concluded that the direct impact of the international scientific community on the orientation of Argentinian research is of little importance. Nevertheless, the report goes on to explain:

"the generally accepted view of the existence of a strong scientific dependence on the world centres of knowledge has its explanation in factors of a different nature, such as the lack of local demand for national science and technology, the lack of a science policy, the particular interest of researchers and research units for advanced or leading research themes" (3).

On the positive side, it is important that Argentinian science and technology have reached high levels of development in several fields. Latin America's only two Nobel Prize winners in the sciences are both Argentinians; the Atomic Energy Commission has attained a level of technical excellence that does not compare unfavourably with that of the few industrialized countries that control atomic energy know-how; and there are several branches of applied science, such as chemical engineering and metallurgy, in which the Argentinian science and technology system is well developed. Thus, the quality of Argentinian science and technology is rather uneven and wide generalizations tend to mask the achievements in particular areas.

Organization of Science and Technology Activities

Research institutes in Argentina exist in three sectors: the public sector, the higher-education sector, and the private sector.

The public sector comprises both military and civilian research organizations. In 1969 the military research institutions were grouped under the Military System for Research and Development (Sistema Militar de Investigación y Desarrollo), which was entrusted with the function of establishing, coordinating, executing, and controlling research and development programs oriented toward the requirements of Argentina's military services. It is important that until the early 1950s more than two-thirds of the largest research centres in the public sector belonged to the military, and that in the first half of the 20th century several branches of Argentinian industry developed in close connection with military requirements.

Among the civilian institutes in the public sector, there are a few that deserve to be mentioned. Chronologically, the first of these is the Laboratory for Materials Testing and Technological Research of Buenos Aires Province (LEMIT), which was founded in 1942 and has been responsible for carrying out significant work in the fields of civil engineering and construction, natural resources, and quality control of industrial products. It is a rather large organization with more than 40 sections, organized according to disciplines. Another provincial institution worth mentioning is the Commission for Scientific Research of Buenos Aires Province (CIC), which is an autonomous body involved in the promotion and execution of research in a wide variety of fields, ranging from radioastronomy to microbiology.

The main civilian research organizations in the Argentinian public sector are the federal institutions, including the National Atomic Energy Commission (CNEA), the National Institute of Agricultural Technology (INTA), the National Industrial Technology Institute (INTI), the National Council for Scientific and Technological Research (CONICET), and the National Commission for Geoheliophysical Studies (CNEGH). Each will be discussed briefly in turn, although the National Industrial Technology Institute (INTI) will be discussed in further detail at the end of this section.

The National Atomic Energy Commission (CNEA) was created in 1950. It was directly attached to the Presidency of the Republic and has full autonomy in scientific, technical, commercial, administrative, and financial matters. Even though it was not initially assigned policymaking functions in the field of atomic energy, as the Commission grew in importance and influence it became in reality the government policymaking body in nuclear matters. From the beginning it paid attention to the creation of a human resource base and to the provision of an adequate infrastructure for scientific research, not only in nuclear matters proper, but also in areas such as metallurgy that were considered essential for attaining a certain level of decision autonomy in the nuclear energy field.

At present the Commission has more than 100 laboratories distributed in four locations, two chemical-processing plants, and several other supporting installations. As an example of the level of development reached, fuel elements for atomic reactors have been manufactured in the Commission's laboratories, using the most advanced techniques and involving the active participation of industrial enterprises. To help industry to achieve the levels of technical excellence required to manufacture the components that go into the construction of a nuclear plant, the Atomic Energy Commission created a special service called Technical Assistance to Industry (SATI). The combined effect of the measures taken to develop the Commission's own scientific and technical capabilities and to improve the technical level of industry is reflected in the fact that about 40% of the first atomic power plants (measured in terms of project cost) were of Argentinian origin, a proportion that has been significantly raised in the second plant now under construction.

The National Institute of Agricultural Technology (INTA) was created in 1956 as an autonomous organization within the jurisdiction of the Ministry of Agriculture. It is financed by a 1.5% ad valorem tax on the export of agricultural and cattle products and by-products. INTA was created with the purpose of promoting, coordinating, and executing research in the field of agriculture and cattle raising, but - as happened with the Atomic Energy Commission - it soon went into policymaking for agricultural research and development. INTA has created a vast network of research centres and agricultural stations, spread all over the Argentinian territory, as well as a few central laboratories dealing with problem areas such as natural resources and veterinary medicine.

INTA has a variety of links with productive units and government agencies, and in 1973 it had more than 150 agreements with provincial governments, private institutions, universities, international agencies, and foreign governments. It has also established a special fund to promote agricultural research by other agencies, private enterprises, and research units. However, although INTA's operating budget doubled during its first 4 years of operation, it remained static in real terms during the 1960s and early 1970s, which has limited the operating capacity of the Institute.

The National Council for Scientific and Technological Research (CONICET) was created in 1958 as an autonomous organization depending on the Presidency of the Republic, with the aim of promoting, coordinating, and orienting research in the pure and applied sciences. However, this institution has not performed the function of setting priorities according to the research needs of the country, and has acted primarily as an agency to foster scientific (more than technological) activities through the creation of the "scientific researcher" career structure, the granting and administration of fellowships, and the provision of subsidies to researchers and research programs. In 1972 CONICET absorbed about 12.5% of the government funds allocated to science and technology.

CONICET now has 48 affiliated research institutes, about half of which were created in 1973-1974. Of these, 12 are fully dependent on CONICET and the rest involve mostly university participation. The expansion of the Council's activities has taken place without an explicit frame of reference and little attention has been given to the directives of the national science policy body, the Secretariat for Science and Technology.

The National Commission for Geoheliophysical Studies (CNEGH) was created in 1969. It has become a promotion and coordination agency in its own field, at the same time carrying out research through its four associated laboratories. Rather than staying exclusively in its own field, the Commission has branched out into other areas of a more applied nature, particularly electronics.

With regard to the research institutions in the higher-education sector, about two-thirds of Argentina's research personnel are located in university research centres, although universities receive only one-third of the financial resources for research and development, which has affected the nature and quality of the research activities carried out in the universities.

In 1969 university research centres accounted for about 60% of the research projects that were under way, centred mostly around the fields of medicine and natural and exact sciences. The concentration of human resources in the university system is confirmed by the high proportion of the total scientific manpower located at the university: 62.9% of researchers in natural and exact sciences, 55.8% of those in engineering and architecture, 71.9% of those in medical sciences, 47.7% of those in agricultural sciences, 67.6% of those in social sciences, and 94.0% of researchers in the humanistic fields. However, as could be expected from the relatively low level of financial resources allocated to the universities for research, these high proportions are reduced notably when full-time equivalents are considered, for most of the scientific personnel at the universities are involved in tasks other than research.

With regard to the third sector, private research institutions can be classified into nonprofit research centres and those that are part of private enterprises. Argentina has about 50 nonprofit research centres, although they are quite heterogeneous with regard to their size, productivity, quality of the research, and so on. Of these only two had the size and conditions to be properly considered as research centres that could make significant contributions to knowledge. According to the 1969 census, nonprofit research centres represented about 5% of the total number of institutions and employed around 500 researchers. Their weight is not too significant within the Argentinian science and technology system.

The research activities of private industries were not covered in detail by the 1969 survey of the Secretariat for Science and Technology. There are other sources of information that give an indication of the magnitude of research activities of private industry, although they are of a partial nature and may be misleading. One of these sources is the information gathered from enterprises that requested tax rebates on the amount they spent on R&D activities, in accordance with two articles of Law 18527 (which has since been revoked). During the period that these two articles were operational, 281 enterprises submitted applications to obtain tax rebates, indicating the amounts spent and submitting descriptions of the scientific and technological activities carried out. These included scientific research, technological development, design of prototypes, development of new processes, product engineering, operation of pilot plants, etc. The total amount declared as S&T expenditure by the enterprises exceeded $23 million in 1973, although this figure covered activities considered as R&D by the entrepreneurs themselves, rather than those activities deemed acceptable for tax exemption by the committee in charge of evaluating the applications.

Most of the enterprises applying for tax exemption were located in the pharmaceutical, machinery and equipment, and electrical machinery branches, whereas the branches of chemical products, transport equipment, and electrical machinery accounted for the larger shares of funds declared as being spent on R&D.

These enterprises were also asked, as part of their application, to indicate their payments for royalties. Although significant inconsistencies were found when the declared figures were compared with the data from the National Registry of Technology Transfer, they give an indication of the extent to which the Argentinian private sector was dependent on foreign technologies and of the amounts paid for technology transfer. The 281 enterprises under study declared paying about $11 million for royalties, although none of the enterprises in the transport branch - in which the majority of royalty payments are concentrated - declared the amounts they paid. Data obtained from the registry of licencing agreements and a careful evaluation of the applications for tax rebates lead to the conclusion that instead of having a ratio of two to one between R&D expenditures and royalty payments, this ratio would actually be one to five.

Other sources of information (4) point out that the largest private firms in Argentina are involved in a variety of "minor" scientific and technological activities oriented toward improving productivity and mastering the technology incorporated into their productive activities. Thus, it could be said that private sector enterprises, as well as state enterprises, are actively involved in the performance of scientific and technological activities, and that this constitutes a rather important component of the Argentinian science and technology effort.

The National Industrial Technology Institute

The Argentinian STPI team prepared a case study report on the National Industrial Technology Institute (INTI) and its impact on technological development (5). Being the largest Argentinian organization in the field of industrial technology and having more than 20 specialized research centres, INTI has had a significant impact on the technological level of Argentinian industry in the last decade.

The objectives of the report on the case study of INTI were to examine the way in which the Institute, the system of research centres it operates, and the performance of two specific centres, affected the technological development of Argentinian industry. An implicit objective was to examine what happens when the state - associated or not with the private sector - decides to intervene in certain branches of industry through the performance of research, development, and service activities. The idea was to identify the conditions under which it is able to link up with the productive sector, examining the significance of the successes and failures in terms of alternative strategies for action.

INTI was created in 1957, on the basis of the Technological Institute that had been part of the Ministry of Industry for more than 12 years. The representatives of private industry on INTI's Board suggested that it be financed with a levy of 0.25% on all loans granted by the Industrial Bank and the National Bank to industrial enterprises, which was sanctioned by law, and in 1958 the government granted INTI full administrative and financial autonomy. The legal framework of laws, decrees, and regulations that governed the operations of INTI was rather vague and encompassed the whole range of functions from carrying out and promoting research to maintaining relations and establishing links with industry. This lack of specificity in the functions of INTI was both an asset and a liability. While on the one hand it allowed a wide range of options to be exercised in the development of the Institute, on the other hand any attempt at giving an operational content to these functions required a complete reappraisal of the universe of possible actions, forcing long discussions at the level of the Board and delaying effective action.

The normative ambiguity of INTI, and the range of conflicts arising out of the different positions of those who were in charge of steering its activities, were largely a reflection of the eclecticism that every state organization confronts, for it must try to make the "national interest," which the agency is supposed to serve, compatible with the "private interests" of the clients that demand the organization's services. The subsequent evolution of INTI was largely conditioned by the balance that it had to establish between these two orientations (6).

The compromise that was reached in this regard is reflected in the two types of activities defined for INTI:

"a) Activities for which it is possible to find persons or institutions, either public or private, that would be disposed to provide resources to support them. In general, there are industrial groups which need - or at least are conscious of - the usefulness that a promotional action of this type could bring to them. This would be channeled through the technological centres.

"b) Activities of fundamental importance for the country, which nobody in the private sector would be prepared to finance, either because they do not provide an immediate benefit, or because part of our industry is in foreign hands which are not interested in promoting local competition....This group of activities has centered around INTI's own laboratories, which tackle problems of national interest not necessarily coincident with the immediate interest of enterprises" (7).

Although this differentiation appears to divide sharply the functions of INTI's centres and laboratories, there is in fact a great deal of interaction among them, with the laboratories providing services to the centres. To a large extent the activities of the latter depend on the support of the former.

By 1976 INTI had more than 1,000 persons working at the centres, the laboratories, and the central administration. Of these 610 were professionals and technicians, with about half of them in the highest professional category. The total number of research centres in 1973 was 22, which is the same number as in 1965, although eight of them had replaced a similar number of centres that were closed during the intervening period.

The peculiar characteristic of INTI is the way in which the system's technological centres have been able to act as a bridge between INTI and Argentinian industry. This is due to how the centres were conceived, the manner in which their juridical nature was established, and the way in which they have operated. The Board of INTI is allowed to "promote among the entrepreneurs the formation of research centres for the study of concrete problems and for the development of special activities, with the collaboration and consent of those who contribute to their formation." The main conditions that INTI established for the creation of such centres were the following (7):

(1) The centres are defined as temporary or permanent entities, whose objectives are to undertake studies and to carry out research in a particular scientific or technological field of interest to industry.

(2) The centres must be created upon the request of an interested party (enterprises, societies, university institutes, government departments at the local, provincial, or federal level), which assumes the role of promoting nucleus.

(3) The promoters must guarantee financial support to maintain the centres' functioning during a reasonable period to attain the desired objectives. INTI contributes with general, administrative, and technical services, although it may also make special contributions of variable nature and importance.

(4) The director of each centre is designated jointly by the promoters and INTI.

(5) Administrative jurisdiction over the centres' operation is a prerogative and responsibility of INTI.

(6) The centres should evolve toward greater functional autonomy, even to the point of becoming totally independent organizations without direct ties to INTI.

Thus the system of technological centres allows INTI to operate with great flexibility and to involve industry directly in the setting up and operation of the centres.

BRAZIL (9)

The National Science and Technology System

The growing importance of science and technology within Brazilian economic policy may be inferred from its recent elevation to the status of a "sector," with a system of its own for planning and execution and with a Basic Plan for Scientific and Technological Development (PBDCT). The system was formally defined by a 1972 decree, which constituted the "national science and technology system" with the purpose of formulating and executing a policy within this area. This task is entrusted to two organizations, the National Research Council (Conselhi Nacional de Pesquisas, CNPq), with an advisory role on S&T matters, and the Ministry of Planning and General Coordination, which is to advise on the financial and economic aspects, keeping in mind the relations between S&T development and the general strategy of national development.

The activities in the area of science and technology should, according to this decree, be organized in the form of a system, to be made up of all organizational units of any degree that utilize government resources to carry out activities of planning, supervision, coordination, promotion, execution, or control of S&T research. Sectoral subsystems are to be in charge of coordinating the component units, formulating sectoral research policy, preparing research programs, and controlling their execution. The Planning Ministry and the National Planning Council are to examine the organizational projects of the sectoral systems and harmonize them before seeking approval from the federal government. In addition, the national system originally organized within the area of the federal administration would progressively be articulated within the state systems. On the other hand, the Brazilian Academy of Sciences was given an advisory role, particularly regarding the coordination and sponsoring of previously existing programs and projects.

The expansion of scientific and technical activity in Brazil has been fostered by two successive S&T development plans. In 1971 the total federal resources for science and technology were about Cr$250 million; in 1973 they reached about Cr$2,000 million, and almost Cr$2,500 million in 1974, at current prices. The second PBDCT allocated Cr$22,000 million for 1975-1979. This meant a very large increase in the resources for science and technology. It was planned also that 95.2% of the funds would come from internal sources and 4.8% from external sources. The distribution of funds was planned to be as follows: planning and studies, 2.9%; new technology, 16.4%; infrastructure technology, 10%; industrial technology, 28%; agricultural technology, 11%; technology applied to social development, 4.7%; and basic research and postgraduate studies, 22%. The expenditure for science and technology in 1972 was estimated to be approximately $78 million.

The Foundation for Technical and Scientific Development (FUNTEC), which is in the National Development Bank and has become a very important channel for the funding of research, distributed its funds in 1973 in the following manner: universities, 67.2%; military bodies, 20.9%; education and culture (Ministry), 11.9%. It should be noted that the private and state enterprises have practically not asked for any resources from this fund. Since the Bank keeps good contacts with industry, this phenomenon cannot be attributed to a lack of communication; it probably reflects the preference these enterprises have for importing technology, as well as the decision to carry out research, when they do, with other sources of funding. Other explanations may possibly be that the enterprises do not want to spend time preparing detailed proposals for their projects, that they want to keep their information to themselves, or that they do not want to run the risk of the Bank controlling their activities.

The sources of funding contemplated in the Plan are, on the one hand, those of international technical and financial cooperation (international and foreign banks, bilateral cooperation, technical assistance agreements with international organizations, etc.), and on the other, internal sources that are to be mobilized through the following channels:

(1) The National Research Council (CNPq), which transfers resources to the institutes under it and in addition finances programs and projects for research and training.

(2) CAPES, an organization in the Education and Culture Ministry, which is principally dedicated to funding postgraduate fellowships in the country and overseas.

(3) The National Fund for Scientific and Technical Development (FNDCT), which is managed by FINEP (Financiadora de Estudos e Projetos), a state enterprise linked to the Planning Ministry.

(4) FUNTEC, the technical and scientific development fund, created in the National Development Bank in 1974, which has been the principal financial support of the programs of basic research and postgraduate training in the last few years and will now be increasingly directed to the financing of programs and projects of applied research and experimental development.

The Brazilian STPI team has concluded that the main direct instruments of scientific and technological policy in Brazil have been financial instruments. The Basic Plan for Scientific and Technological Development is fundamentally an aggregation of projects that have been suggested by the interested institutions within the federal orbit. Financial support is mainly oriented toward improving conditions for the supply of knowledge. Demand for those resources has not been sufficient to give them full utilization, possibly on account of organizational difficulties and lack of human resources in educational and research institutions, and little interest on the part of the enterprises that prefer to import technology. On account of these difficulties, a great concentration of the applications in a few institutions can be noted. This aggravates the relative imbalance among institutions, although on the other hand such concentration allows the creation of a "critical mass" in the recipient institutions. The trade-off between these two effects is difficult to evaluate.

Research and Development in the Industrial Sector

A survey was conducted of 454 of the 500 largest industrial firms in 1967-1969. Because industrial research is concentrated in the largest manufacturing enterprises in the country, the measure of the volume of research carried out by such enterprises is therefore a reasonable approximation of the industrial research carried out by the whole productive system.

The survey employed the following classification of industrial research:

(1) Creation in its own right, i.e., research that leads to the production of a new process or product.

(2) Creation, i.e., research that introduces substantial changes in products or processes that already exist but that are of such a nature that the result may be considered as a new product or process.

(3) Adaptation, i.e., research that introduces noncomplex changes in already-existing products or processes.

(4) Experimentation on a pilot scale, construction and production of prototypes (materials and products) and pilot plants (processes) for test purposes.

Apart from these four categories of research, it was considered that a series of activities done by research institutes falls into the category of routine activities of industrial technology (e.g., routine tests and engineering).

Of the 454 industrial firms surveyed, 64% carried out research in 1967-1969, as against 36% that only did routine activities. Among the former, the distribution by the type of research was as follows:

Creation in its own right	:	0%
Creation	:	16%
Adaptation	:	67%
Pilot plants, experimentation	:	17%

Among the 36% that did not do any research themselves, totaling 162 firms, 62% subcontracted research projects. The proportion of firms that subcontracted research was higher in foreign firms (84%) than in national firms (51%).

Research was distributed unevenly among the different industrial branches: one-third of the research was carried out in textiles, nonmetallic minerals, and food processing; and two-thirds in electrical equipment and components, transport equipment, chemicals, pharmaceuticals, and metallurgy.

There was also a notable difference among firms that carried out research according to whether they were foreign owned or nationally owned. Seventy-five percent of the foreign firms surveyed declared that they carried out some sort of research, whereas the proportion was only 61% for national firms. A more detailed screening of the answers showed that the foreign firms engaged in adaptation and pilot-scale experimentation, whereas national firms tended to concentrate on creation research.

The predominance of adaptation clearly shows the importance that the transfer of technology from abroad has for Brazilian industry: enterprises limit themselves to reelaborate, with more or less depth, the existing know-how. This is particularly so in the foreign subsidiaries, as is shown by the lower proportion of creation R&D they undertake. These enterprises depend to a very large extent on their parent companies for the supply of new technical knowledge. But also the national firms, particularly the more dynamic ones, are relying predominantly on foreign technology to speed up the pace of technical change.

One might suggest that the importation of technology in Brazil is, before anything else, an indication of the technological dynamism of the enterprises that undertake it.

The survey also revealed an interesting relationship between a firm's installed research capacity and its import of technology from abroad through technology contracts. Only 42% of the firms had entered into technology contracts registered in Brazil, but the proportion fell to 30% in firms that did not carry out research.

Research Institutions

A number of surveys were carried out regarding the activities of research institutions in the 1967-1970 period. The Brazilian STPI team used the results to prepare a report on these institutions, which is summarized next.

One of the studies identified 132 research institutions, of which 60 were carrying out technological activities and 46 industrial research activities. The size of these and the volume of their work were very uneven; among the 46 industrial research institutions, seven carried out about two-thirds of the total volume of activity.

The 46 institutions had 5,205 persons of a medium or higher level on their staff, of which about half were dedicated to technological activities. The distribution of these persons by institution was less concentrated than that of the activities, and it was also found that the more active an institution the higher the percentage of its personnel dedicated to research. It may also be estimated that slightly over 1% of the country's available stock of high-level personnel was employed in institutions of industrial research.

Most of these institutions were in the government sphere, 63% in the federal government and 20% in the state government. Among the former, educational institutions predominated.

Regarding the activities of the institutions, the seven more active ones carried out three-quarters of the research activity. They also performed a wide range of other activities such as bibliographical work for industry, studies of specifications and technical standards (collaborating with the Brazilian Association of Technical Standards), training of personnel for themselves and for industry, practical training for university engineering students, and various routine activities such as tests, analyses, and certification of products. Although the latter activities can give origin to technical research, this had not happened in the majority of cases.

The survey showed that research institutions were engaged principally in non-research work of the type mentioned above, which amounted to about 55% of the total activities surveyed (the figure would be higher if other simple activities, the number of which is large, were to be considered). Regarding research and development, data for the seven most dynamic institutions showed that they were practically the only ones to carry out research resulting in new products or processes. A different survey of five institutions shows that the majority of the most complex assignments carried out by them were of a basic research nature, which would reflect their poor links with the productive sector.

The type of work carried out by the research institutions, with a concentration on routine activities (principally tests and quality control of little complexity) on the one hand and activities of basic research on the other, results from the peculiar interaction between the institutions and the productive sector. In the survey of 46 institutions that carried out industrial technological activities, only 11 had an active relation with industry and a deliberate and aggressive policy in this regard. Among the other institutions, there was a passive behaviour, their only linkage activity being to disseminate the results of their work through technical publications or by facilitating information to enterprises that demanded it. Only about one-third of the assignments were motivated by requests from third parties, the rest being carried out on the institutions' own initiative. In fact, about three-fourths of the assignments carried out by request were undertaken by the seven more active institutions. The activities requested were mainly of a routine character (70%); of those carried out on the institutions' initiative, about 54% were research projects.

Such results seem to suggest that the industrial sector has not played a dynamic role vis-à-vis the national technological institutions, to the point that its demands have not even been able to use fully their limited research capacity. The analysis further concludes:

(1) More complex requests are made principally when local inputs are very important for the productive process and it is difficult or very expensive to import technology.

(2) Government ins itutions are the principal clients for complex services, not because of a deliberate policy but because they are acting in productive branches where the technological and economic characteristics of the productive processes make it difficult or impossible to import technology.

(3) The research institutions constitute a secondary source of technology for the enterprises, which prefer to import their technology or to develop it in their own installations.

(4) It is the small and medium-sized firms and the government institutions that request most services from the research institutions; large enterprises tend to import technology and to use their own laboratories. This phenomenon is stronger in the case of services of a higher complexity, and therefore large enterprises are not an important factor in the growth of the institutions.

(5) There are difficulties in communications and relations between the research institutions and the enterprises on account of differences in motivation, patterns of behaviour, and language.

(6) The research institutions are deficient in human resources, as well as in materials and equipment, so that sometimes they cannot properly attend to requests for complex services.

The surveys show that specialization of institutions by branch happens only when the institution is specifically created in this way, and that most tend to deal with many branches and activities. To take care of this diversified work, the most necessary technical and scientific fields are those that represent the point of convergence of the needs of diverse branches; for instance, chemical engineering and materials science. The principal institutions are not too specialized and they cover a wide range of technical fields, which however are related among themselves.

Thus the research institutions have not become an engine of technical progress in Brazil; however, their role of support to industry should not be underestimated, particularly for that part of the industrial spectrum made up by medium-sized national enterprises.

Brazilian industry demands foreign technology: this is a consequence of the dependent pattern of industrialization followed by the country, and of the characteristics of national enterprises. However, some internal characteristics of the institutes aggravate the situation. Among them should be mentioned the lack of financial, human, and material resources and the difficulties that stem from static and inflexible administrative structures. This is reflected in the passivity already mentioned.

To improve the effectiveness of research institutions, by solving the internal problems on the one hand and by establishing links between them and the enterprises on the other, several possibilities may be mentioned. On the financial side, improvements should be made in the budgetary practices and in the behaviour of federal and state financial agencies. Administrative structures would need to be improved to endow these institutions with a higher stability and to improve their flexibility. On the question of relations with the productive sector, the relevant studies made on this question should be disseminated and a number of seminars should be organized, for instance on the administration of research.

COLOMBIA[10]

Background

The analysis of the role of science and technology in economic and social development poses a problem about the science and technology development policy that Colombia should follow. To impel the development of the country in this field, the government created in 1968 the Fondo Colombiano de Investigaciones Científicas y Proyectos Especiales "Francisco José de Caldas," better known as COLCIENCIAS. Beyond its funding mission, COLCIENCIAS is in charge of formulating a development policy in the field of science and technology and of advising the government on the implementation of this policy. In addition, in the field of regulation and orientation of technology imports, an institutional complex has appeared that is made up by the Royalties Committee (Comite de Regalias), the Global Licences Committee of INCOMEX, the organization in charge of foreign trade, the Exchange Office of the Bank of the Republic, and the Division of Private Investments of the National Department of Planning. At the level of execution of scientific and technological activities, the government has created and consolidated an infrastructure of research and technical assistance centres in the principal productive sectors, among which should be highlighted the Instituto de Investigaciones Tecnológicas (IIT) and the Instituto Colombiano Agropecuario (ICA).

As consciousness has grown about the many aspects of science and technology development, the need has emerged to analyze in more detail its relations with many aspects of the country's development. Within the sphere of social and economic development, science planning and implementation have been oriented toward four principal objectives; first, to identify the science and technology needs of the country as they derive from the social and economic problems; second, to strengthen the capacity of national enterprises to evaluate, incorporate, and absorb technology; third, to regulate and orient technology importation; and fourth, to strengthen selectively the national infrastructure and the existing activities in science and technology.

To formulate concrete programs of action in relation to these four objectives, a number of basic studies have been made to diagnose the situation of science and technology in Colombia and the principal obstacles for its development (11). From these studies the following can clearly be seen:

(1) Technological decisions that guide the country's development in this field are basically taken at two levels:

(a) Technological decisions taken by the enterprise, public or private, about the type of goods and services it will produce, the technology and capital goods it will buy, the source of information or technical services it employs, and the technological activities it carries out as part of the production process (maintenance, trouble shooting, repair and reconstruction of machinery, etc.).

(b) Technological decisions taken in the large state investment projects that incorporate decisions similar to those mentioned above. As a consequence the need comes out to identify the mechanisms and instruments through which it is possible to influence such decisions to orient them toward the objectives of development.

(2) Technological decisions taken in the enterprises or in state investment projects are intimately linked to other major decisions regarding investment, production expansion, the introduction of new products in the market, etc., and therefore it is possible to exert an important influence through a number of policies that are more in the area of economic development (for instance, industrial, foreign trade, taxation, trading and price policies) than through the policy of scientific and technological development itself. Therefore an examination must be carried out of the technological aspects and the technological implications of such economic policies.

(3) By analyzing the technological situation in certain branches of the productive sector, it has been possible to detect the growth of a certain technological capability related to the management, mastery, and assimilation of the technology being utilized. This is reflected, among other things, in the activities of maintenance, engineering, machinery reconstruction, fabrication of parts of the equipment, and adaptive technological innovation, which are carried out by enterprises in the branch or by technological institutions connected with the branch. This is notable in textiles and ceramics. It is important to identify the factors in such activities and how they may be affected favourably by policy.

Resources and Activities of the Science and Technology System

A survey was made of the 1971 financial, human, and institutional resources that had to do with scientific activities in Colombia. The first conclusion is that the teaching and support activities are those that absorb the largest part of the system's human and financial resources. The activities of research and diffusion occupy a secondary place.

Taking into consideration only the research activity, the principal resources of the science and technology system may be summarized in the following figures:

(a) Total research expenditure: $12,356,240
(b) Total number of researchers (professionals whose principal activity is research): 1,140
(c) Total number of research projects being executed: 991

Colombia is investing less than 0.2% of the gross national product (GNP) in research activities. This proportion is low in comparison with that of other countries. From the point of view of the number of researchers in the country, the situation is similar. The 1,140 professionals who undertake research in Colombia make up about 0.5 researchers for each 10,000 inhabitants, a rather low ratio compared with other countries.

By analyzing the distribution of financial and human resources, and of research projects, in terms of sectors of application and areas of science, it is possible to get a general picture of who carries out research in Colombia and what the orientation of this activity is.

The government spends 47.9% of the research expenditure and employs 51.2% of the researchers in the country. If the part of the university sector that is funded by the state is included, the preponderance of the public sector is even higher and reaches 65.6% of all financial resources devoted to research in the country.

When the distribution by scientific discipline is analyzed, the importance of agrarian research comes up clearly. Agrarian sciences absorb 32.7% of the research expenditure as well as 30.5% of the researchers. Health sciences come in the second place. On the other hand, the research effort devoted to engineering is very low, with only 13.5% of the human resources and 2.5% of the financial resources.

Institutions of the Science and Technology System

The main institutions engaged in research in Colombia are the decentralized institutes in the jurisdiction of different ministries. Among them the following may be mentioned:

(a) Ministerio de Obras P licas: Centro Interamericano de Fotointerpretación; Colpuertos; Instituto Nacional del Transporte.

(b) Ministerio del Trabajo: Servicio Nacional de Aprendizaje; Instituto Colombiano de Seguros Sociales.

(c) Ministerio de Minas y Energía: Instituto de Asuntos Nucleares; Instituto Nacional de Investigaciones Geólogico-Mineras; Instituto Colombiano de Energía Eléctrica.

(d) Ministerio de Salud Pública: Instituto Nacional de Cancerología; Instituto Nacional de Programas Especiales de Salud; Instituto Colombiano de Bienestar Familiar.

(e) Ministerio de Agricultura: Instituto Colombiano Agropecuario; Instituto Colombiano de la Reforma Agraria; Instituto Nacional de Recuros Naturales.

(f) Ministerio de Desarrollo Económico: Instituto de Fomento Industrial; Instituto de Investigaciones Tecnológicas; Fondo de Promoción de Exportaciones; Instituto Colombiano de Comercio Exterior.

(g) Ministerio de Educación Nacional: Instituto Colombiano de Pedagogía; Instituto Lingüístico "Caro Cuervo"; Colcultura (Instituto Nacional de Antropología); Instituto Colombiano para el Fomento de la Educación Superior.

(h) Ministerio de Hacienda y Crédito Público: Instituto Geografico "Agustín Codazzi."

(i) Ministerio de Gobierno: Fondo de Desarrollo Comunal.

(j) Ministerio de Comunicaciones: Empresa Nacional de Telecomunicaciones.

(k) Ministerio de Defensa: Hospital Militar Central; Industria Militar.

(l) Oficina de Presupuesto de Inversiones: Fondo Nacional de Proyectos Especiales de Desarrollo.

On account of the importance of the government sector in research activities, it is interesting that until recently there was no central mechanism to coordinate the allocation of funds to research and other scientific activities within the sector. However, a unified national budget for science and technology activities was recently adopted and it is hoped that through this instrument it will be possible to direct the science and technology efforts of this sector toward common objectives in favour of economic development.

Of the 110 institutions covered in the survey, 23 were in the government sector, 41 in the education sector, 43 in the productive sector, and three in the nonprofit private sector. However, only 10 were engaged principally in research; most of the institutions devoted themselves mainly to S&T support activities, and in nine, diffusion was the principal activity.

The productive sector is principally devoted to support activities and only one of the institutions in this sector was engaged principally in scientific research. In the government sector the situation is similar, the majority of the institutions being engaged principally in support activities, and only four mainly in research programs. In the education sector most of the institutions were principally engaged in education, and only two in research.

Human Resources of the Science and Technology System

The survey showed that 10,866 persons were dedicated to scientific activities. Of these almost 69% were in the education sector, 15.7% in the government sector, and 14.9% in the productive sector. On analyzing the relations between the staff dedicated to scientific activities and the total personnel of the institutions covered within each sector, the results show clearly that it is the education sector that dedicates a higher proportion of its personnel to scientific activities. Even so, in this sector the percentage of scientific personnel to total personnel is very low, only 32.5%, even though this figure includes personnel engaged in teaching.

On classifying human resources according to the scientific activity undertaken by each person (research, education, diffusion, support activities), it was found that the most important activity was education, to which 67.1% of the personnel were principally dedicated. Only about 10.5% (1,140 persons) declared that their principal activity was research, and 470 professionals said that it was diffusion.

The highest proportion was working in the area of the social sciences, with 3,612 persons (33.2%), followed by basic sciences, 2,492 (22.9%), health sciences, 1,926 (17.7%), engineering sciences, 1,702 (15.7%), and finally agricultural sciences, 1,134 (10.5%). On analyzing the distribution among the various sectors, it can be seen that there is a high concentration of scientific personnel in the education sector in three areas of science: health sciences, basic sciences, and social sciences. In agricultural sciences there is an even distribution of personnel among the three principal sectors, government, education, and production. It is also worth mentioning that the productive sector is an important source of employment for scientific personnel in agricultural and engineering sciences.

About two-thirds of the scientific personnel in the country work full-time. The highest proportion of part-time personnel, about 40%, is found in the activity of education, whereas in diffusion and support activities he majority of the personnel work full-time.

With regard to the personnel specifically dedicated to research and development, which amounts to 1,140 (about 10.5% of the 10,866 total in scientific activities), this personnel is highly concentrated in two sectors, government and education, which between them contain 76.2% of the personnel primarily engaged in research and 82.2% of the personnel engaged in carrying out research projects.

These two sectors, on the other hand, carry out about 77% of all research projects in the country and represent nearly 80% of the financial resources allocated to all projects. The contributions of the productive and nonprofit sectors are rather low.

The largest proportion of persons whose principal activity is research is found in the government sector with 51.2%. However, the highest proportion of individuals who carry out research projects is in the education sector with 56.3%, a discrepancy due to the fact that in this last sector there are persons who take part in research even though their principal activity is education.

The education sector carries out the highest number of research projects in the country, almost 60% of the total. However, such projects are generally of a smaller scope than those in the government sector. As a consequence the government sector concentrates the highest amount of resources devoted to research, about 47.1%. However, one must take into account that a high proportion of the research carried out in the education sector is financed by the government because it takes place in state universities.

When classified by scientific discipline, the agricultural sciences show the highest number of personnel, with 348, about 30.5% of all researchers, followed by the social sciences (323 researchers, 28.3%), basic sciences (188, 16.5%), engineering sciences (154, 13.5%), and health sciences (127, 11.2%).

Almost 87% of the researchers are full-time, and of this group, more than half are in government, 20% in education, and 20% in the productive sector.

Financial Resources of the Science and Technology System

It has already been noted that in 1971 Colombia spent $12,356,240 on research and development activities, which corresponds to 0.16% of the GNP. This amount was distributed as follows:

Government sector	-	47.9%
Education sector	-	22.9%
Productive sector	-	19.9%
Nonprofit sector	-	9.3%

In the government sector the highest amount of funds went to the Instituto Colombiano Agropecuario, in charge of projects related to the agrarian sector, the Instituto de Recursos Naturales Renovables (INDERENA), which undertakes research on the flora and fauna of the country, the Instituto Nacional para Programas Especiales de Salud (INPES), the Instituto de Asuntos Nucleares, etc.

The education sector spent slightly over $2.8 million on research and development, with some $2.2 million by state universities and almost $0.65 million by private universities.

In the productive sector the amount spent on research and development was almost $2.5 million, $1.4 million of which was in private, $733,000 in public, and $315,000 in mixed enterprises.

In the nonprofit sector the expenditure was $1.15 million; the institution with the highest research budget was the Centro Interamericano de Agricultura Tropical (CIAT) with $918,000.

Research Projects Being Undertaken

Research is performed in less than three-quarters of the 110 institutions covered in the survey (43 public, 21 private, and three mixed).

A total of 1,030 research projects was carried out, but information is on hand for only 991, which occupied 1,024 researchers. This personnel makes up the bulk of the Colombian scientific community and constitutes the most important human resource in the difficult task of producing science and utilizing technology.

The education sector performed slightly over half of the total projects, and 25 of the 36 universities covered by the survey undertook research projects. The government sector had slightly over 20% of the projects, the productive sector 13.7%, and the nonprofit sector 6.6%.

When classified by scientific discipline, 32% of the projects were in the basic sciences, 31.1% in health sciences, 22.7% in human and social sciences, 9.7% in agricultural sciences, and 3.6% in engineering sciences.

When classified by possible field of application, most projects were concentrated in five principal fields: agriculture (295 projects), health (329 projects), regional development, education, and economic and social development.

Diagnosis of the National Situation in Science and Technology

In general the scientific and technological activities of Colombia are characterized by their weakness, disarticulation, marginality, and dependence.

The country's potential in research and development, compared with that of other more developed countries, is very low. Colombia has about 0.5 researchers per 10,000 inhabitants, less than Argentina, Canada, Yugoslavia, and Rumania, which have similar populations to Colombia, and naturally much less than developed countries in general. A similar observation may be made regarding financial resources allocated to research and development activities, for which the country only spent 0.2% of its gross national product.

These indicators only give a relative idea of the weakness of Colombia's research potential. It is necessary to look at both the quantity and the quality of the human resources engaged in research. Here one may say that there is little utilization of the resources dedicated to R&D. In general, research activities have been carried out only as a complement to other activities such as teaching and administration. This may be seen from the fact that out of the 10,866 persons only 1,140 declared research as their principal activity. The country in general has few high-level scientists, which diminishes the efficiency of research work; of the 10,866 persons engaged in scientific and technical activities, only 908 declared they had a graduate degree.

In general, it may be said that the country does not stimulate persons to cultivate scientific activities, nor does it give sufficient incentives to create an interest on the part of young people. Scientific associations are scarce, and they lack means; researchers have not found the stimuli or the means to carry out wide-ranging and profound scientific work.

On the other hand, there is not much money devoted to research; in the universities, for instance, only 6% of the budget goes to research, and in the specialized institutes, where it is understood that research is the principal activity, the funds for this only reach 26%.

In general, research projects have few financial resources; the average per project is slightly below $400,000 pesos (about $10,500). In some university institutions, as well as in the majority of private enterprises, there is no scientific research, or if it exists it is rudimentary and it is carried out only sporadically by some interested researchers and ceases when they leave. Twenty-five of the 40 universities included in the survey did not carry out any research project.

Finally, there is an inadequate utilization of physical resources, and in some cases the equipment is out of order or obsolete.

The second characteristic of S&T activities is disarticulation, or rather, the weakness of the interrelations among the different scientific activities. Research is still largely an individual activity and has not fully become an institutional activity, as can be perceived from the weak integration of groups. Of the 2,149 interdisciplinary groups that were detected, almost 72% had less than six persons and 45% had less than three persons. There have been few points of contact between research carried out in universities, government centres, and industries. Research results tend to remain at the experimental stage, because of lack of funds or even lack of interest to carry out activities toward application of the results. Researchers concentrate on two or three scientific areas to the detriment of other areas: agrarian sciences have 30.5% of the personnel and social sciences 28%; engineering has only 13.5%. There is a lack of knowledge of the human potential for science and technology. The universities prepare professionals without knowing the future demand; the training of scientific and technical personnel in general does not correspond to the needs of the national science and technology system, there being a concentration of students in some areas and a high dispersion of professional careers, many of which do not correspond to needs. There is a lack of medium-level technicians. As a structural characteristic, there is a migration of highly qualified professionals; annual emigration is about 400. The majority of Colombian universities do not offer graduate studies and hence there is a lack of opportunity for improving the training of professionals already in activity. There are structural or legal obstacles to scientific exchange, and the participation of Colombians in seminars, symposia, short courses, etc., is thereby made difficult. Colombia lacks a good system for the diffusion of knowledge, there being only libraries, some which are good but with limited access.

There is a lack of coordination between the entities in charge of research and the information centres, and between the latter and the users of information.

Research results are not properly disseminated and get to be known by very restricted groups. Finally, the activities are principally carried out in three regions of the country, Bogota, Cali, and Medellin, which together have more than 70% of the scientific and technical personnel.

The third characteristic of the scientific and technical activities is their marginality, or little relation to the economic and social development. There is a "vertical" marginality in the sense that the higher government spheres that make decisions are not aware of the importance of science and technology as a factor of development. There is also a "horizontal" marginality, which means that there is little contact between the few scientific and technical activities in the country and the goals of social and economic development. For instance, research on engineering is not giving any importance to studies on materials or on industrial development; in the agricultural sciences, activities do not always take into account the problems of industrialization, export, or regional development; the social sciences have not yet made the first truly national study on the problems that affect the Colombian resident today. Universities and research institutes are the principal promoters of research, whereas the productive sector finds it easier and more economical to buy the necessary technology overseas. Industry depends to a large extent on foreign technology, toward which it is oriented, or on universal knowledge, often found in out-of-date patents, and it does not go to the universities in search of help, nor does it sponsor research. The universities are not attuned to the concrete and specific needs of industry, and industry does not appreciate the occasional services it gets from the universities. The industrial sector carries out tasks of technical improvement and adaptation of technologies, which sometimes are significant for national development. As regards technical assistance to industry, there are some firms that give assistance to large enterprises, and these activities are growing. But there is little help for medium and small industries, and this is a field where action should be taken. On the other hand, there is a resistance to ask for such services on the part of the potential users.

A fourth characteristic of the scientific and technological activities is their dependence. Because there are few technical researchers in Colombia, most of the technological development comes from outside. Implicit in the present system of technology transfer are excessive costs and various restrictions. The imported technique frequently is not adapted to the local production factors, and only seldom is the possibility studied of replacing obsolete technologies with other alternatives. This slows down technical change. Subsidiaries of foreign firms receive from their headquarters the technical knowledge needed for their activities and do not have much use for the national scientific and technical capacity. In general, Colombian enterprises do not carry out research but buy technology outside through mechanisms that are not the most adequate and with a low negotiation capacity. Technical knowledge and capital goods are bought from a very small number of countries and there are few efforts to diversify the sources. The mechanisms used by enterprises to transfer technical knowledge, the attitude toward that knowledge, and the presence of restrictions tied up with financing, are factors that militate against the mastery of that knowledge, which moreover remains in only one enterprise without being diffused. The country does not offer enough facilities or incentives for the publication of research papers, so researchers are forced to publish them overseas.

Finally, there is a tendency for scientists trained in foreign countries to migrate, because they feel it is very difficult for them to carry out significant scientific activities in Colombia.

EGYPT[12]

Historical Background

Egypt's contribution in the field of science and technology in the ancient world is well known. The technical and engineering competence of the period up to 671 B.C. is witnessed in the construction of pyramids. The Alexandria University and library were established in the Ptolemic period (332-30 B.C.). The scientific and cultural life was greatly affected by the Roman invasion. Scientific activities again flourished during the period of Islamic civilization. Science in the modern sense took root in Egypt in the 19th century during the reign of Mohammed Ali (1805-1883) when an ambitious educational system was organized under European teachers. Egyptian students were sent abroad, especially to France. By the end of the century a Western-educated class was emerging.

Looking at the development of the S&T system, one can see that during the first half of this century a limited number of scientific organizations were set up for encouraging scientific learning and research in areas like agriculture, zoology, botany, chemistry, meteorology, geology, and medical sciences. The Egyptian Agricultural Organization, the Geological Research and Survey Organization, the Chemistry Department, the Meteorologist Administration, and others, opened up.

The first secular educational university - Cairo University - was founded privately in 1908 and became a state university in 1928. The activity in scientific research and education continued to occupy a place in the national social development goals: new universities and research laboratories were established and the creation of scientific services and societies was encouraged. Since 1952 the Egyptian government has attached a great deal of importance to the development of educational facilities. This resulted in the setting up of a number of primary, general, and technical preparatory and secondary schools and centres for higher education.

It was estimated that in 1975 there were nearly 200,000 students in higher education. There were 10 state universities, most of which included faculties for agriculture, science, medicine, dental surgery, pharmacy, engineering, commerce, law, and arts; 15 higher-education institutes for agriculture, industry, and commerce; and one private university (the American University founded in 1919). More than 200,000 students received their bachelor degree between 1965 and 1973, half of them in the humanities and social sciences, and the rest distributed evenly among the natural sciences, engineering, medicine and health, and agriculture.

In addition, there are various graduate courses, and some 600 students are sent abroad every year for further graduate work. As well, some 200 postdoctoral trainees go abroad every year for periods of 6 to 12 months.

The future plan for higher education includes the setting up of 18 new universities to ensure that higher-education facilities are available in every governorate in Egypt.

The first government-sponsored body for the growth of scientific research activities was established in 1948. At the initiative of this body, the National Research Centre, a multipurpose research institute, started functioning in 1956.

It is clear that the economic development of the productive sector has a profound influence on the growth of the S&T system in a country, due to the demand pulls generated by this sector on the S&T system. The growth of Egypt's manufacturing industry may be said to have begun with World War I. Isolation and increased demand then gave rise to a number of small-scale industries, but many of these had to close down in the face of foreign competition during the 1920s. The adoption of a protective tariff and the establishment of Bank Misr and the group of companies it supported in the 1930s coincided with a rising tide of Egyptian nationalism; a number of manufacturing activities mainly catering to domestic consumption were established. On the eve of World War II local industry satisfied a substantial part of the domestic demand for textiles, cement, sugar, edible oils, soap, etc. The war greatly stimulated the Egyptian industry and a wide variety of goods came to be produced, e.g., textiles, chemicals, building materials, processed food, and so on.

Also, entirely new industries sprang up, including rubber and pharmaceutical manufacturing. By the end of the 1940s industrial production had reached about 140% of its level in the 1930s.

Throughout the 1950s industrial production continued its growth at an average rate of 7% per annum, helped by the chronic deficit in the balance of payments. A drive toward self-sufficiency after the 1956 War resulted in an intensive industrialization program, which began tentatively in 1957 and was later incorporated in the first five-year socioeconomic development plan from 1960 to 1965. During this period the gross value added by industry and mining rose, at constant prices, at an average rate of 9.5% per annum. In the late 1960s the industrialization process was affected by the lack of foreign exchange and shortages in spare parts and raw materials, but recovery has been rapid and with further developments in production, including mining and electricity. As part of the industrialization process, a variety of heavy industries have been established, such as iron and steel, aluminium, automobiles, and fertilizers.

In 1955 industry and petroleum jointly accounted for 24% of the GNP against 28% for agriculture. That share has now gone up to almost 30%, meaning that Egypt has ceased to be a predominantly agricultural country.

Industrial activities since the late 1950s were predominantly carried out by government-owned enterprises and subjected to central control. Since the early 1970s more encouragement has been given to the private sector and to private foreign investment.

The financing of the industrialization process depended largely on foreign loans, as a supplement to local resources. Also, the development of industry was mainly based on the transfer of foreign technology (turn-key factories). It can be said that about 80% of the equipment and installations as well as the rights of industrial ownership (licences, patents, trade unions, know-how, etc.) are from abroad: from the early stages up to the end of the 1950s from the Western countries, and thereafter the larger part from the U.S.S.R. and Eastern socialist countries.

Some Issues for Science Policy

The relationship between the industrialization process and scientific activities in Egypt has been weak. It is embodied in consultation, the provision of trained manpower, and sometimes the participation of top management of industrial organizations and enterprises.

An examination of the present state of Egyptian industry and the mechanisms of acquisition and application of new domestic and foreign technologies discloses the existence of major constraints and deficiencies.

There is in Egypt a wide network of institutions responsible for or interested in promoting scientific and technological research, but links among them are generally lacking. There is a need for existing institutions to be brought into closer relations to avoid the adverse effects and strain on resources resulting from duplication of work.

There is a need for setting up a well-defined strategy that will lay down the pattern of technological development and devise ways and means to arrive at the optimal solution that helps in realizing economic and social development.

Furthermore, there is no coherent policy for the establishment of institutions and centres for the development of industries, nor is there any harmonized pattern of control on the activities of such institutions and centres to guarantee their orientation toward local problems. Links between research and development institutions, on the one hand, and individual productive units, on the other hand, are not strong enough to ensure day-to-day contacts.

Perhaps more serious are the modest human and financial resources allocated to research and experimental development centres.

One cannot disregard the weakness of a comprehensive database to provide, periodically and systematically, scientific and technical information and statistics needed to guide technological development.

There is a strong tendency in Egypt toward the use of established foreign skills. This tendency will greatly impede the development of indigenous expertise. Keeping pace with international technological developments, through inflow of technology and know-how, should not hamper the simultaneous development of indigenous research and development facilities. There should be a policy aimed at encouraging the growth of consulting services and restricting foreign consulting services to fields where domestic expertise is inadequate or not available.

The pay for Egyptian experts working in research and development or scientific and technological services is not attractive enough. This has led to the outflow of scientists, engineers, technologists, and other skilled personnel to developed countries. This brain drain is harmful to the national economy because it means a great loss of human capital and a significant decrease in the country's scientific and technological capabilities. No systematic study has been undertaken to estimate the economic effects of this phenomenon.

Science Policy Bodies

The first governmental decision-making body for science and technology, the Supreme Science Council, was established in 1956. This Council succeeded in mobilizing a great number of institutions and members of the scientific community in elaborating the first national Scientific Research Plan for the years 1960-1965. This Plan was to be implemented in different research institutes, including universities, the National Research Centre, and the research units belonging to technical ministries. But for different reasons the Council was replaced by the Ministry of Scientific Research in 1961. Later in 1965, another body was created and entrusted with the organization of scientific research and was named the Supreme Council for Promotion of Scientific Research. It continued its work until 1968, when it was once again replaced by the Ministry of Scientific Research. But this Ministry survived only until 1971, when the Academy of Science and Technology was set up as an autonomous body affiliated to the Prime Minister. The Academy was affiliated to the Minister of Higher Education and Scientific Research in 1974 and to the Minister of Scientific Research and Atomic Energy in 1975.

The mandate of the Academy is to support R&D activities and technology development at the national level, i.e., formulating S&T research policies and development plans, financing and coordinating the research projects of national priority, building up research facilities and human resources, disseminating S&T information, developing bilateral regional and international scientific relations, and popularizing science.

The history and analysis of the above-mentioned institutions makes it clear that one of the major difficulties that the country has encountered in building up its own national science policy and structures is the lack of stability of institutions responsible for science policy.

The building up of a national science policy, which plays an essential role in the development of the country, depends mainly on the efforts done at the ministerial level, which includes, on the one hand, the Academy of Scientific Research and Technology and, on the other hand, the operating ministeries, many of which have R&D functions guided by Research Planning Boards. These government organizations act together with the Ministers of Planning and Finance under the overall coordination of the Cabinet.

R&D Institutions

There are about 77 research centres, institutes, and stations under the central government. In addition there are about 150 scientific departments affiliated to the state universities that are engaged in research activities. Research institutions exist under several jurisdictions:

(1) The Academy carries out research through eight major institutions: the National Research Centre, the Atomic Energy Establishment, and six specialized research institutes (Petroleum Research Institute, Institute of Metallurgical R&D, Theodore Bilharrze Institute for Indigenous Diseases, Oceanography Institute, National Institute of Standards, Observatory Institute).

(2) The universities have some 150 scientific departments where research is conducted, particularly by MSc and PhD candidates.

(3) The technical ministries also carry out research (Agriculture: the Agricultural Research Centre, made up of 10 specialized research institutes and about 30 research stations; Irrigation: five newly established research centres; Industry: eight research centres and institutes for engineering, electronics, metallurgy, ceramics and building materials, food and textile industries, and in addition some 30 research units in large public enterprises; Public Health: 10 research institutes working in different areas of medical and pharmaceutical research; Planning: a national planning institute and an institute of administrative sciences; Social Affairs: a national centre for social and criminological research, and a demography institute).

In addition, there are two scientific services centres in the Academy's jurisdiction: the National Scientific Information and Documentation Centre, and the Scientific Instrumentation Centre.

Human Resources

A census of scientific and technical manpower was carried out by the Academy showing the following figures for 1972:

	PhD	MSc	Total
Engineering	804	483	1282
Medicine	1558	213	1871
Agriculture	1170	1279	2449
Basic Sciences	1440	1221	2661
Social Sciences	2027	897	2924

Estimates by the Academy for 1975 put the total number of Egyptians holding doctoral and masters degree in science at around 18,000. There is a shortage of applied research workers, technicians, and specialists in scientific services, which are essential for technological development. In addition to the lack of trained manpower, other reasons, like the lack of stability, of good support for research, and of a healthy atmosphere, have caused a migration of scientific and engineering manpower to other Arab states and to Western countries.

Financial Resources

As regards the funds for research activities, definite figures are not available, and it is estimated that the overall research expenditure may be 0.2% to 0.5% of the GNP. Funds are totally supplied by the government, with a small proportion of technical aid, bilateral and multilateral.

Final Remarks

Egypt has made an effort over the last 25 years to build up a scientific and technological community through the establishment of a number of universities and research institutes. But this community has remained on the periphery of the development process. This is due to the lack of interaction between science planning and policy, technology planning, and economic planning, as these activities are controlled by different departments. The ongoing policy of technology imports and the absence of a national policy for developing or building indigenous technology has adversely affected the growth of the S&T system. The situation is further aggravated by the shortage of funds for R&D, the lack of any funding mechanism, and poor R&D management in existing institutes.

The problem is how to utilize the Egyptian S&T community to the fullest extent possible to achieve the type and degree of R&D and technological innovation required. This will depend on national efforts and coordinated action on a broad front.

INDIA[13]

Historical Background

India's contribution to science during the earlier part of its history is well known. However, because of various historical factors, there was a break in scientific activities. It was only in the 18th century that as a result of scientific interest the Ariatic Society of Bengal was established (1784). During the 19th century, a number of scientific organizations were set up in various disciplines, such as geology, botany, physics, chemistry, meteorology, and medical science. In the early 20th century a number of institutes were established relating to agriculture, medicine, forestry, etc.

The development of modern science was not merely an organic extension of the earlier tradition. The major events in the postindependence period (1947) were the creation of an extensive institutional network, a chain of research laboratories, and the expansion of university and technical education. To give an idea of their development, the Council of Scientific and Industrial Research was established in 1942, the Atomic Energy Commission in 1948, the Universities Grant Commission in 1956, the Defence Research and Development Organization in 1958, the National Commission on Agriculture in 1970, and the Electronic Commission in 1971. In addition to these various central ministries, the national government set up research institutes concerning various disciplines. The government's faith in science and technology was reflected in the passing of the Science Policy Resolution in 1958, which aimed to "secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge." Since the enunciation of the Resolution, scientific activity has quickened in pace and broadened in scope. As a result a substantial infrastructure of institutions and capabilities in a variety of scientific and technological fields has occurred.

The rapid development of scientific activity in India is reflected in the substantial increase since 1958 in the resources devoted to R&D and the number of people engaged in R&D. The total expenditure in both private and public sectors increased from $36 million in 1958 to about $270 million by 1972 (in terms of GNP, from 0.23% to 0.54%). The number of persons engaged in research increased from about 21,000 to about 100,000 during the same period.

Science Policy Bodies

From 1947 to 1955 decisions on the setting up of scientific institutions and their funding were arrived at through a relatively unstructured policy process. Later, with the expansion of the Planning Commission in the preparatory phase of the Second Plan, the responsibility for integrating science into development fell to the Member for Perspective Planning and the Scientific Research Division of the Commission. The responsibility of the Planning Commission in the area of scientific research was spelled out in 1959 as "the setting up of such independent committees, panels, etc. of scientists, as need arises, and taking their views and recommendations into consideration in connection with Five Year or Annual Plans for economic development and the attainment of national aims...."

But during the Second and Third Plans, only one such panel was set up for formulating schemes for the research activities of the Council of Scientific and Industrial Research and the scientific organizations associated with the Ministry of Education. None of the other scientific agencies of government were brought in for coordination within what was meant to be the framework of a national plan for science.

With a view to designing a mechanism for obtaining scientific advice at the highest level, the government set up the Scientific Advisory Committee to the Cabinet (SACC) in 1956, with explicit and wide-ranging terms of reference. This Committee had, however, no mandate for the preparation of a national science plan. But the SACC did set up ad hoc working groups on specific scientific issues, involving some scientists and technologists.

The SACC was replaced by the Committee on Science and Technology (COST) in 1968, with the Member for Science of the Planning Commission as chairman and comprising agency heads and a few individual scientists, an economist, and a technologist as members. The terms of reference of this Committee were a little wider, but did not include the preparation of a science and technology plan. COST did, however, set up a number of standing committees, working groups, and ad hoc committees, involving a number of working scientists, technologists, and industrial interests for many of the scientific and technical areas it examined.

In November 1971 the government appointed a ten-man National Committee on Science and Technology (NCST) as an apex body to advise the Central Cabinet on all matters pertaining to science and technology. One of the major mandates of the NCST was the preparation of the S&T Plan. Its functions were as indicated below:

(1) Preparation and continuous updating of national scientific and technological plans, both as Five-Year Plans and as Perspective Plans. This would have to be carried out in close association with the Planning Commission, and be intimately related in terms of relative priorities of allocation and resources to the national socioeconomic development plans.

(2) Arranging for a periodical discussion of the draft plan and other major issues of science policy by a fairly large representative section of scientists, educationists, industrialists, and policymakers.

(3) The pattern of development of scientific and technological research, including intersectoral resource allocation and measures needed for correcting imbalances that may arise.

(4) The pattern of development for further utilization of the nation's scientific and technological resources; in particular, measures for striking a balance between domestic capabilities and foreign assistance.

(5) Cooperation and communication between government, semigovernment, and nongovernment scientific and technological institutions and professional bodies in the country.

(6) International scientific and technological matters.

The composition of the NCST reflects the interesting fact that working scientists covering different disciplines were nominated. The objective in specifically excluding the heads of the major scientific organizations was to involve working scientists in decision-making and also to prevent institutional loyalties from being projected onto the national scene.

The NCST is headed by a chairman who is directly answerable to the Prime Minister. In addition to the NCST, there is a standing group of ministries, i.e., the Cabinet Committee on Science and Technology presided over by the Prime Minister, which reflects the government's faith in science and technology. For execution and implementation of the government's policies, the Department of Science and Technology was created in 1972, headed by the Minister for Science and Technology.

In short, the process of the formulation of the S&T Plan that was adopted has been both democratic and interactive. About 200 scientists, technologists, economists, and administrators were drawn from various research institutes, administrative ministries, the Planning Commission, and the universities. Once the Plan had been submitted to the Cabinet and accepted by it, it was left to the ministries to implement the Five-Year Plan by asking for allocations for the concerned programs in their annual budget.

After the expiry of the term of the members of the NCST, its membership was increased to 23 members, including heads of all the major research organizations, with a view to smoothing the implementation and execution process.

Organization of Scientific and Technical Research

Scientific research in India is carried out mainly by a number of organizations operating with financial assistance from the government: the Council of Scientific and Industrial Research (CSIR); the Department of Atomic Energy; the Indian Council of Agricultural Research (ICAR); the Indian Council of Medical Research (ICMR); and the Research and Development Organization of the Ministry of Defence. In addition, there are a number of institutes attached to the various ministries for carrying out research programs of practical application in their respective fields of activities, such as irrigation, power, railways, telecommunications, broadcasting, and civil aviation. The public sector agencies in the fields of electronics, machine tools, steel, fertilizers, etc., also carry out research in their respective fields.

Research programs of laboratories and research institutions are approved by their executive councils. The overall guidelines are, however, laid down by the governing bodies of the various councils which, though autonomous, draw their finances from their respective ministries. The programs carried out by the institutions under the government departments are approved by their respective ministries. The total activities of the various organizations in the field of scientific and industrial research form an integral part of the national planning process.

The Council of Scientific and Industrial Research (CSIR) is an autonomous body responsible to the Department of Scientific and Industrial Research of the Cabinet Secretariat and administers the Industrial Research Fund, to which contributions are made annually by the government.

The Council's laboratories are distributed all over the country. In locating the laboratories many requirements had to be considered and met; such matters as the existence of industries that benefit directly from the laboratory concerned, the proximity of academic and research institutions, and sometimes the availability of existing buildings have been taken into account.

There are at present 30 research institutions functioning under the CSIR, including four regional research laboratories besides the Publications and Information Directorate, the Indian National Scientific Documentation Centre, the Birla Industrial and Technological Museum, and the Visvesvaraya Industrial and Technological Museum. In addition, there are 62 experimental stations, survey stations, and field centres attached to the various laboratories. Some of the laboratories dealing with physics and chemistry are engaged in research and development activities that are basic to industrial development generally. Some are concerned with problems of interest to specific industries such as electronics, glass and ceramics, leather, minerals and metals, marine chemicals, drugs, and scientific instruments. Some deal with the nation's general needs with regard to food, fuel, building, and roads. There are establishments concerned with research in mechanical engineering, aeronautical engineering, public health engineering, electrochemistry, geophysics, oceanography, experimental medicine, and toxicology. The regional research laboratories are concerned with problems of industrial development in their respective areas. During the last 25 years the Council has developed in its laboratories more than 400 processes for industrial application, published nearly 10,000 research papers, and taken out about 1,200 patents.

All the laboratories are equipped for applied and development research. They do a substantial amount of basic research, particularly oriented basic research. Pilot plant facilities are provided fairly liberally for developing research results and establishing technical and economic feasibility for industrial production. In addition, they maintain a close liaison with industries and provide them with the technical services of testing and certification of products. The work of the laboratories relating to investigations on the utilization of indigenous materials, the development of substitutes for imported products, the adaptation of known technologies to suit local needs, and the development of expertise have laid the foundation for the establishment of several industries in the country.

New branches of science and technology such as geophysics, petroleum technology, oceanography, and aeronautics, which had previously received little attention in India, have been developed in newly established CSIR laboratories.

The CSIR has been providing, ever since its inception, grants-in-aid to stimulate research at a large number of centres, to expand research facilities, and to cover the cost of training research personnel.

During 1969 there were 627 research schemes in progress in the various university departments and research institutions other than CSIR laboratories, and 2,294 research fellowships were awarded for working in various institutions. The CSIR has taken an important step in promoting the establishment of cooperative research laboratories for industry, particularly since most industrial concerns in India are too small to maintain research departments on their own. There are at present nine cooperative research laboratories associated with the textile, cement, plywood, and tea industries. They undertake, on behalf of the member firms, not only basic and applied research germane to the problems of industry, but they also carry out market surveys, consumer trials, and quality control operational research. Practically half of their expenditure, recurring and capital, is met by CSIR grants.

The Indian Council of Agricultural Research has 23 research institutes and nine soil conservation centres under its administrative control. The central research institutes have 98 research stations/subcentres in various parts of the country. While the central institutes are engaged in projects of importance to the whole of India, the state governments have well-developed agricultural research stations functioning under their control to deal with problems of particular importance to them. In six states, Punjab, Haryana, Mysore, Andhra Pradesh, Madhya Pradesh, and Maharashtra, all the research stations are working as research centres of the respective agricultural universities. In other states, research work is being gradually transferred to the agricultural universities.

The Indian Council of Medical Research is an autonomous body, responsible to the Union Ministry of Health, to promote research by making full use of the facilities available in its existing institutions and supplementing these by the provision of additional resources of men and money. Besides giving short-term grants to research workers for specific investigations in both fundamental and applied research, the ICMR has established research units in medical colleges, research institutes, and hospitals. These units are formed around persons who have done active work in the relevant field.

The Defence Research and Development Organization was created in 1962 to provide some measure of internal autonomy for scientific research within the defence setup. It has a two-tier organizational pattern: (1) the headquarters, responsible for policy direction, control, and coordination as well as liaison with the armed services; and (2) a large field setup consisting of 31 research and development establishments/laboratories, two functional directorates, and one documentation centre.

The needs of the defence services call for the application of science and technology to problems of equipment as well as questions relating to the selection of personnel, their food and clothing, and overall organizational and operational problems. The scope of scientific research, design, and development activity of the Defence R&D Organization extends over a wide field, embracing armaments, electronics, aeronautics, oceanography, instrumentation, engineering, metallurgy, applied mathematics, physics, chemistry, biology, physiology, psychology, and, in fact, every discipline that has application to defence.

Practically all the R&D effort is related to specific objectives, only a small fraction being devoted to basic research. The emphasis in development work is on the utilization of indigenous materials and products designed to function efficiently in the climatic conditions existing in different regions and at different altitudes. The Atomic Energy Commission has the following objectives:

(1) To survey the country for atomic minerals and to work and develop such minerals on an industrial scale.

(2) To do research on scientific and technical problems connected with the development of atomic energy for peaceful purposes.

(3) To train and develop the necessary scientific and technical personnel for this work.

(4) To foster fundamental research in nuclear physics in its own laboratories and in the universities and research institutes in India.

The Department of Atomic Energy (DAE) functions directly under the Prime Minister. The Chairman of the Atomic Energy Commission is the Secretary to the Department of Atomic Energy. The Department is responsible for a number of research centres, among them the Bhabha Atomic Research Centre (with research groups in physics, electronics, engineering, metallurgy, and biomedicine), the Indian Space Research Organization, the Space Science and Technology Centre, and the Reliability Evaluation Laboratory, in addition to other units and productive undertakings.

The government, in addition to giving financial assistance to the Council of Scientific and Industrial Research, the Indian Council of Agricultural Research, the Indian Council of Medical Research, the Defence Research and Development Organization, and the Atomic Energy Commission, maintains a number of research institutions that are attached to the various ministries, for carrying out research programs of practical application in their respective fields of activities. Some of them, like the surveys, the Meteorological Department, and the Forest Research Institute, function directly under the ministries concerned, whereas the others, like the rubber, coffee, and silk research institutes and the Indian Standards Institution, are autonomous organizations functioning under the overall supervision of the concerned ministries.

The state governments generally have research establishments in the fields of agriculture, animal husbandry, fisheries, medicine, public health, and public works. A few states also have research institutions in forestry and sericulture. Agricultural and animal husbandry experimental stations account for the largest number of state government research establishments. Since the concept of fullest integration of research, extension, and education has been accepted, the state governments are taking steps to transfer research stations to their agricultural universities. In the fields of medicine and public health, the state departments usually have a vaccine institute (Pasteur Institute in a few states) and an analysis laboratory. The state public works departments have some engineering institutions for carrying out testing and developmental work, and the home departments have forensic laboratories.

Research is carried out by a number of private research institutions, such as the Indian Association for the Cultivation of Science, Calcutta, the Raman Research Institute, Bangalore, and the Bose Research Institute, Calcutta. The government provides grants to some of the private scientific and research institutions, associations, and societies for the maintenance and advancement of their work, for expanding and enlarging their research activities, for publishing scientific journals, and for holding conferences and symposia. Some of these research institutes were endowed privately by scientists and philanthropists. The most notable are the Indian Association for the Cultivation of Science (Calcutta), the Indian Institute of Science (Bangalore), the Bose Research Institute (Calcutta), the Indian Statistical Institute (Calcutta), the Physical Research Laboratory (Ahmedabad), the Tata Institute of Fundamental Research (Bombay), the Institute of Paleobotany (Lucknow), the Raman Research Institute (Bangalore), and the Tata Memorial Centre (Bombay).

Regarding research in industry, a large number of industries are collaborating with the national laboratories on technical and scientific matters. Often the laboratories act as technical consultants to the industry and take up specific research projects of interest to it.

A number of design and consulting organizations, in both public and private sectors, have appeared in the fields of iron and steel, mining, and fertilizers.

A survey of 500 industrial firms conducted in 1965 by the Research Survey and Planning Division of the CSIR revealed that many of them have laboratories for doing routine work, but only about 50 organizations had facilities for research. The total investment in research by the industries was therefore extremely limited. According to the survey, private industry spent Rs11.7 million on scientific research in 1963-1964 and employed 390 scientists.

A preliminary survey of R&D in the drugs and pharmaceuticals industry in India for 1967 showed that the pharmaceuticals industry spent in 1967 Rs25 million on research, which came to 1.1% of the total sales and employed 771 R&D personnel.

A preliminary survey on the status of research and development in the chemical industry was made by the Indian Chemical Manufacturers Association in 1969. Replies were received from 77 companies. The survey revealed that the R&D budget as a percentage of the annual turnover in a large number of cases came to well below 1% and even less than 0.5%.

The Industrial Credit and Investment Corporation of India Ltd. made a sample study in 1970 among 100 companies engaged in the manufacture of electricals, electronics, engineering items, chemicals, paper, and cement to collect information on their experience in developing R&D facilities in their units. About 55 companies furnished the requisite data. According to the survey all the units have routine R&D cells, and more than two-thirds have R&D departments staffed with qualified scientists and engineers. Some of the units are also equipped with engineering and economic evaluation divisions for translating research into pilot scale, and then into commercially viable products. In general, the objectives of R&D among these units can be broadly classified as follows: improvements in existing product lines in postsubstitution, diversification, and the creation of a strong patent position. These units spent some Rs40 million annually in 1969-1970.

Financing of Scientific and Technical Research

Scientific and technical research is supported by the central government, the state governments, universities, and industry. India spent Rs57 million on research in 1950-1951. In 1969-1970 the total expenditure was about Rs1,460 million. Out of this the central sector contributed Rs1,232 million. Indian expenditure on R&D has increased from 0.23% to 0.44% of the GNP during the last decade. This is expected to rise about 0.5% by the end of the Fourth Plan. In terms of the central budget, the R&D expenditure has increased from 2.0% to 2.8% during the last decade.

During 1969-1970 the rough distribution of the central sector's total research expenditure among the various organizations was as follows: Council of Scientific and Industrial Research, 16.3%; Department of Atomic Energy, 21.77%; Defence R&D Organization, 11.6%; Indian Council of Agricultural Research, 13.0%; Indian Council of Medical Research, 1.4%; and the ministries of the central government, 36%.

Expenditure on scientific research by the state governments increased from Rs10 million in 1958-1959 to Rs122 million in 1969-1970. The state governments spent mainly on the agricultural, veterinary, and medical sciences. In institutions of higher education of the central government, expenditure rose from Rs14.56 million in 1958-1959 to Rs48.35 million in 1968-1969. This expenditure in 1968-1969 comes to 4.6% of the total public expenditure on scientific and technical research.

The expenditure on scientific research by industry in the private sector rose from Rs1.5 million in 1958-1959 to Rs106 million in 1969-1970, some 7.3% of the total expenditure on scientific and technical research. Taking a total production of about Rs25,000 million in the private sector, industry in India is spending only about 0.6% on R&D.

Scientific Workers and Research Technicians

In 1947 the Ministry of Education made a quick survey of the scientific manpower position and established a National Register of Scientific and Technical Personnel under the Council of Scientific and Industrial Research (CSIR). Since then the Division of Scientific and Technical Personnel of CSIR has made continuous assessments of the manpower position in the country with the help of its Register and other facilities.

During the last 2 decades education and training facilities have been greatly increased. The annual output from the universities, colleges, and polytechnics increased seven times since 1950, reaching 127,000 persons in 1970. The total number of personnel with recognized degrees and diplomas who can be classified in scientific and technical categories has been estimated at 1,187,500 in 1970. Scientific and technical personnel between 1950 and 1970 increased by a factor of six. Some 13% of the total stock in 1970 were postgraduates, 35% were science graduates, and 36% were engineering graduates and diploma-holders.

In aggregate terms the growth of scientific and technical personnel in India in the last 2 decades has been impressive. The scientific and technical manpower employed in R&D work increased from 21,000 in 1958-1959 to 80,000 in 1969-1970. Although there has been a considerable increase in the number of scientific and technical personnel during the last 2 decades, the number actually engaged in R&D work is only about one per 10,000 population.

A number of scientists, engineers, and doctors receive their education and do research abroad. About 1,000 of them return every year after completion of their education, training, research, or other assignment. The government instituted a scheme for a "scientists' pool" in 1958 to help the scientists and technologists returning from abroad to get temporary placement. The scheme is also open to persons possessing high qualifications from Indian universities. A special Recruitment Board, in consultation with the Union Public Service Commission, selects suitable persons for the pool. The National Register of Scientific and Technical Personnel in the Council of Scientific and Industrial

Research provides the particulars on the majority of candidates. The pool scheme serves a specific but limited objective. It provides temporary employment for 1 or 2 years, by which time the pool scientists are expected to find regular jobs. Selected candidates are attached as pool officers to appropriate organizations, where they can work in their field of specialization. Their salaries in the pool are paid by the Council of Scientific and Industrial Research. About 7,000 persons have so far been selected for the pool.

The number of scientists who have migrated mainly to the United Kingdom, the United States, Canada, and West Germany from India is estimated at about 30,000 of the total stock. Steps are being taken to provide adequate facilities and job opportunities for scientists to avoid this brain drain.

The scientific and technical manpower in India is doubling every 7 to 8 years. The government has been employing about two-thirds of the scientific and technical personnel, and private industries and organizations take the remaining one-third. Of the MSc's and PhD's in science, nearly 30% are engaged in research. Among the graduates in engineering and medicine about 8.5% are engaged in research.

In spite of the shortage of technical manpower, the problem of unemployment among them also persists. Geologists and geophysicists recorded the highest proportion of unemployment, 10.7%. The extent of unemployment among the higher-degree holders in science in other fields was: biological scientists, 9.4%; agricultural scientists, 4.7%; statisticians, 7.7%; mathematicians, 7.2%; chemists, 5.7%; physicists, 4.8%. Among the general science graduates the unemployment percentage was found to be 16% and among agricultural graduates about 4%. This indicates a high proportion of wastage among graduates who have had 3 to 4 years of college education in general science.

Problems and Prospects

In its 1973 report, "An approach to the science and technology plan," the NCST identified some major deficiencies in the country's science policy. A first deficiency is the absence of rational policies for science or guiding principles for decision-making on the magnitude and distribution of funds for scientific research. The report pointed out that there has been in the past no explicit policy on the level and allocation of funds for scientific and technological activity, well over 80% of which was funded from the central exchequer. Each agency has submitted its proposals to the Planning Commission; the Commission has appraised them from primarily a financial point of view, endorsed the plans largely unmodified, and recommended their funding to the government. The government, in turn, has accepted these recommendations and taken them to Parliament, which, in large measure, has been generous and has voted for the funds requested. In sum, the overall funding of scientific research has been decided more by the absorptive capacity of the agencies and institutions concerned than by considerations of the economic or social importance of the fields.

The absorptive capacity of the different agencies and institutions has varied very widely. Part of the reason for this variation is the complexity of the technology handled by the different agencies. But it has, in no mean measure, been also due to a range of factors external to the complexity of the technology and to whether or not the scientists were capable of doing good science. These reasons have often had to do with such things as the organizational flexibility within agencies and departments, the standing of the heads of agencies, and other factors quite unrelated to the requirements of the national economy. The result of this essentially laissez faire attitude to the allocation of funds has been a growing mismatch between the distribution of funds for scientific activity and the economic and social importance of the areas of funding.

Thus in 1970-1971, although agriculture contributed to roughly half of the gross domestic product, the central and state R&D allocation for this sector was only about 21% of the total. Whereas the atomic energy and space programs alone accounted for 20% of the total expenditure on R&D in the central sector, medical research, health, and family planning absorbed only about 5%. Whereas the share of research and development on defence was 12%, irrigation and power accounted for less than 2%, and natural resources surveys (excluding oil) together accounted for less than 8% of the total expenditure on scientific acitivity in the central sector.

A second deficiency lies in the area of matching the demand for science - such as has been perceived - with the supply of science - such as has been performed. The communication gap between industry and the industrial research laboratory remains large. When scientific institutions have had to interact with government departments, the latter have been totally unable to appreciate the imperatives of science and the requirements of scientists. Emphasis on financial trivia and a lack of appreciation of the cost of lost time are the chief characteristics of the existing situation.

A third deficiency is in the set of policies relating to the performance of scientific institutions, principally the continued neglect of badly needed organizational and administrative reform, including personnel policies. Where reforms have been recommended, they have not been fully implemented. The values and methods of decision-making in the majority of Indian scientific institutions continue to be either feudal in character or they tend to subordinate the role of the scientist to that of the bureaucrat.

A fourth deficiency is in the country's policies toward the import of technology. It has not been sufficiently recognized that it is very necessary to gear the indigenous scientific effort in such a way that it complements and, in time, displaces the imported technology. Also, there has not been a determined effort to utilize the capabilities already developed in the country. This lack of effort has, to a considerable degree, been due to the absence of an active agency to promote indigenous technology.

The Plan document adds that inadequate interaction between the scientific and technological system and the productive structure of India's economy has harmed both. The past few years have seen the large-scale introduction of equipment and machinery, intermediate materials, spares, and components, along with a great deal of process know-how bought with export earnings and foreign equity, credit, and aid. The near absence of local science and technology efforts even toward adapting imported technology and equipment to indigenous resources and needs has perpetuated this dependence. The benefits accrued largely to the metropolitan centres to the neglect and sometimes at the expense of the rural areas. It would be unwise to rely on solutions that heavily depend on scarce materials or are prevalent in industrially advanced countries. Perhaps no other single set of government policies has such a profound influence on the demand for and utilization of domestic technology as policies toward foreign investments in the manufacturing and mining industries and the import of technology in, besides industry, sectors such as transport and communications. The document also points out:

"Considerable R&D inputs have gone into practically every segment of the economy in the course of the last two decades. Under their impact and with reference to historical factors such as technology imported in the past, availability of technical skills and the like, the state of technological competence in different sectors covers a wide spectrum - from the very efficient to the fairly inefficient, from the modern and forward looking to the traditional....the central aim of the schemes and projects that constitute the S&T Plan is to make the assets - whether already existing or proposed to be created - yield more than in the past. This is the primary criterion which has been applied in determining how much R&D and what kind of R&D should be undertaken in any given sector during the next five years....Much of the effort in the past has been directed towards process/product technology; the relevance and importance of such effort will no doubt continue in our future plans. But emphasis on engineering design and fabrication has probably received less than adequate attention in the past. The goal of achieving a sustained self-reliant economic growth manifests itself in an equal emphasis on the formation of skills related to the combination of process/product technology and engineering design and fabrication....Research, Development and Design would have to form a three component system....The distinctly utilization-oriented approach that underlines the present S&T Plan is the concern for securing close links organizationally and operationally between the producer of research and its potential user."

This S&T planning exercise has been the first attempt of its kind in India. The formulation of the S&T Plan was, however, only the first step in the effective utilization of S&T for development. Although it creates a blueprint and a map for the future, it is only in its effective implementation that its success will lie. And it is this difficult road that lies ahead.

KOREA (14)

Historical Background

Throughout its long history Korea has made some indigenous scientific and technological developments in areas such as printing, astronomy, weaving, and handicrafts. Industrialization in Korea today, however, is almost completely dependent on technology imported from developed countries.

The introduction of Western culture and technology to Korea began around 1880, toward the end of the Yi dynasty. Until 1910 the introduction of modern technology was dominated by Japan and the Western powers, which competed for control of resources and commercial and political rights in Korea. Some technologies in small arms, explosives, agriculture, paper, mining, printing, leather goods, communications, and railroads were introduced from Japan, the U.S., Germany, and Russia. Electricity was introduced from the U.S. in 1898. The first scientific institution was the Industrial Research Institute, founded in 1883.

Under Japanese rule, between 1910 and 1945, the Japanese introduced Western technology to Korea on a large scale. During this period hydroelectric power, fertilizers, cement, textiles, and steel industries developed along with a general consumer goods industry. But the development of industry was determined by the Japanese strategy for controlling the Far East and preparing for World War II. As a result the main emphasis was placed on mining and transportation.

Steady progress was made at this time in the education system. In 1924, during Japanese rule, the first modern university was established, and the first college of engineering was set up in 1938. Opportunities for Koreans were, however, severely restricted by a quota system that maintained a strict ratio of Korean and Japanese students. All in all, by 1945, only 800 Koreans had graduated, of which 300 were from the Medical School and about 40 from the School of Science and Engineering. After independence, the building of the education system, including technical and higher education, was sharply accelerated.

Industrial development during the Japanese period was concentrated in northern Korea, where hydroelectric power and mineral resources were available. The southern part, with a milder climate and flat lands, concentrated on agriculture. Thus, when Korea was divided into North and South after World War II, there was almost no heavy industry in South Korea, and in particular no electric power generating capacity. The American and United Nations assistance between 1945 and 1951 supported mainly the import of consumer goods, and there was no significant technological development. The Korean War of 1950-1953 devastated both North and South, and even small-scale industries were totally destroyed.

For the following decade Korea depended heavily on grant-aid from the United States and the United Nations. This made little contribution to technological modernization, but it did support the training of technical personnel in foreign countries and the provision of teaching facilities at engineering colleges and technical schools within Korea.

There was thus at this time some development in scientific and technical manpower, but little institutional development. The first serious attempt at promoting research was the establishment of the Atomic Energy Research Institute in 1959. Despite a limited output in terms of research findings, this Institute provided valuable lessons for the development of Korea's science and technology, in particular demonstrating the long-term nature of research investment and the importance of research institute autonomy.

With the shift in national policy in the 1960s to a strong emphasis on dynamic and progressive economic growth came the formulation and implementation of the First and Second Science and Technology Development Plans, in parallel with the corresponding Economic Development Plans. The Economic and Scientific Advisory Council and the Ministry of Science and Technology were established within the government structure, followed by the foundation of the Korea Institute of Science and Technology in 1966, and later (1971) the Korea Advanced Institute of Science, the Korea Development Institute, and the Agency for Defence Development, which, together with the earlier-founded Korea Scientific and Technological Information Centre, constituted the Science Park, officially named the Seoul Research and Development Complex.

The main contributions of the First and Second Science and Technology Development Plans were the formulation of plans for manpower supply and the expansion of research facilities. Although a comprehensive science policy was not elaborated, it is significant that science and technology were dealt with as a specific entity within national planning. Scientists and engineers were perhaps less closely involved in science planning than economists in economic planning, but this was understandable given the comparative weakness of the research tradition and an inadequate recognition of the importance of linking research with the productive sectors through experimental development and engineering. In general, interactions between scientists, engineers, industrialists, and government personnel seem to have been inadequate.

During the 1960s Korean industrial development was largely dependent on U.S. grant-aid, long-term foreign loans, the construction and operation of industrial plants imported on a turn-key basis, the development of domestic markets under strong tariff protection, and exports of labour-intensive products based on cheap labour. The technical needs of industry were limited. But in the future, industrialization will have to be carried out under less favourable circumstances, and Korean industry will need to develop the capability of manufacturing export products on the basis of indigenous technological development and innovation. This will entail a switch from the importation of plants on a turn-key basis to the importation of proprietary and other technical know-how, moving from packaged technology to unpackaged technology and adaptation, and then to indigenous innovation. In turn, this will require a much broader base of trained technical manpower, covering a wide range of skills at many different levels.

Policymaking for Korean S&T Planning, Coordination, and Promotion Bodies

The major science and technology policies in Korea are approved by the office of the President. The government's faith in science and technology is reflected in the establishment of the Ministry of S&T (MOST), the Korean Institute of Science and Technology, and the Korean Advanced Institute of Science. The President's office monitors the progress of new S&T projects.

It is the responsibility of the Minister of S&T to initiate, review, and lay policy guidelines for science and technology. He is also responsible for preparing detailed actions, plans, and justifications for the presidential policies.

Although the President assumes the final responsibility for all administrative activities of the Republic, the National Assembly has the right to deliberate laws and regulations. More importantly, it has the power to approve or revise the budget plans submitted by the President. At the National Assembly the Committee on Economy and Science handles matters concerned with science and technology.

The Economic and Scientific Advisory Council is a high-ranking advisory committee to the President, designed as a means of bringing scientific and academic opinion into national policymaking. The formation of the Ministry of S&T in 1967 and more recently the National Council for S&T has overshadowed the Economic and Scientific Advisory Council in matters concerning science and technology.

The National Council for S&T is headed by the Prime Minister, and its members are the Ministers of the Economic Planning Board, Home Affairs, Finance, Defence, Education, Agriculture, Fisheries, Commerce and Industry, Construction, Health, S&T, Transportation, etc. The Prime Minister also nominates certain members to this Council, which was recently established under the newly revised S&T Promotion Law. The rationale behind the Council is that science and technology should be effectively and efficiently developed as an integrated national effort, and that it cannot be developed through the efforts of a single ministry or by scientists and engineers through sporadic segmented approaches. The National Council for S&T is charged with the task of laying policy guidelines for planning, coordinating, executing, and monitoring national R&D projects as well as policy matters concerning science and technology. The task of implementing and executing the policies approved by the National Council is the responsibility of the Ministry of S&T.

In fact, the Ministry of S&T plays the coordinating role and its functions are discharged through its two offices and three bureaus as the main administrative bodies. The Ministry of S&T has some degree of negative budgetary control but very little ability to supply funds to initiate projects.

During the First and Second Science and Technology Development Plans, efforts were focused on consolidating the basic foundation for S&T development. As an accomplishment of this effort five institutes were established in Seoul as the Seoul Science Park: the Korea Advanced Institute of Science, the Korean Institute of S&T (KIST), the Agency for Defence Development, the S&T Information Centre, and the Korea Development Institute.

Although KIST has been functioning as the centre of industrial technology research and development, the need for more strategic technologies will increase with the expansion of the economy, and a single comprehensive research institute will not be able to meet these increasing needs. Realizing this, the Korean government launched an ambitious plan to establish 10 new research centres in the late 1970s. It is also hoped that industrial firms will participate actively in the expansion of R&D facilities.

Scientific and Technical Manpower

In the present state of affairs there seems to be considerable uncertainty about the supply and demand position of scientific and technical manpower. It appears that there will be a considerable oversupply of natural scientists and of most types of engineers, but there will be a serious deficiency of technicians and craftspersons if sufficient training facilities are not created. In general, Koreans show a reluctance to become scientists and technologists because of the lack of social status and recognition and the low salaries.

Statistically, Korean scientific and technical manpower was around 0.55 million in 1972, of which qualified scientists and engineers accounted for only about 5% (27,400). Within the total there were about 15,000 researchers, of whom 2,600 were in universities. Thus Korea has five researchers per 10,000 population, as against about 15 in Japan.

R&D Expenditure

R&D in Korea is largely financed and carried out by government institutions - ministerial or quasi-public like KIST. Private industry and the universities make a much smaller contribution. The overall expenditure on S&T amounted to 0.38% of the GNP in 1973; within this the expenditure on R&D represented 0.31% of the GNP, about $24 million in absolute terms. These percentage figures have fallen slightly in recent years, but it is planned to increase the expenditure on S&T to about 1.5% of the GNP by 1981, of which 87% will be spent on R&D, equivalent to 1.3% of the GNP.

R&D Institutions

There were 86 government research institutes in 1973. Many of them are small and make a very limited contribution; a survey showed that project targets are usually not clear, 40% of the units have a research staff of less than 10, only two have more than 100 researchers, the institutes often overlap (e.g., eight are engaged in food research), outstanding research workers are rare, and there is little or no interaction with the universities.

Significant work is done only at a few of these units: the Seoul Science Park, particularly KIST (which in 1972 undertook some 90 research projects), the Atomic Energy Research Institute, the units at the Office of Rural Development, the National Industrial Standard Research Institute, and the National Geographical and Mineral Research Institute.

The main functions of the R&D institutes, with some notable exceptions, have been testing for government or industry, survey work, training and enlightening the public, and advising the government on technical matters. The R&D activities have been restricted to the minimum necessary to support their principal functions or to the work of a few exceptional self-motivated scientists. Because of disparities in pay structures, good research workers tend not to stay long in the government service.

Research activities by university faculty staff are conducted with very limited funds, averaging about $1,000 per researcher per year. Partly because of meagre resources and partly for reasons of prestige, the projects are usually concerned with some aspect of basic research.

Private industry contributes about one-third of the total research investment. Of some 250 enterprises with more than 500 employees, 118 had research departments, with an average staff of eight, mostly working on testing and quality control. The government is now offering financial support and other incentives for private R&D expenditure.

It is hoped that government R&D will be concerned primarily with strategic technology development, whereas private industry research activities will deal with adaptation and improvement of imported technology through institutions such as KIST. Private industry will be encouraged to carry out its own research or to place R&D projects with reliable institutes such as KIST, with supporting government funds. The technical diagnosis and counseling programs for export industries carried out by KIST are to be extended to cover small industries and designated companies.

MOST has a relatively small R&D fund allocated to specific fields on a predetermined basis: heavy and chemical industries, 67%; basic science, 15%; agriculture, forestry, and fisheries, 7%; resources survey, 4%; technology survey, 4%; and social overhead capital, 4%. An R&D committee composed of authorities from the academic and industrial communities has been established to select projects and assign qualified research workers. Appraisal criteria include relevance to the government's long-term planning, the R&D facilities required, the marketability of the product or process, and profitability when commercialized, but problems have been encountered in the relative weighting of these criteria, because of insufficient information and forecasting data and inadequate project planning. As already observed, university research is very limited and is hampered by inadequate facilities and funds and outdated curricula. MOST has therefore proposed the setting up of a National Science Foundation to improve funding particularly in this area.

Demand for R&D

So far development of industry had depended very largely on foreign technology. The importation of technology is only a part of much larger arrangements involving investment of foreign capital. Although the importation of technology is governed by the Foreign Capital Inducement Law, the effectiveness of this Law is questionable in so far as the importation of technology is concerned. This Law defines imported technologies as only those involving patents and licences for which royalties are to be paid. Therefore, the technology embodied in the manufacturing facilities and intermediate goods is not included. For these reasons the actual cost and scope of technology imports is difficult to determine.

Mechanisms for technology transfer may include direct foreign investment, through wholly owned subsidiaries or joint ventures, licence agreements, turn-key contracts, etc. In practice proprietary technology is often tied with nonproprietary, and the transfer process is frequently dominated by direct investment. The 1973 amendment to the Foreign Capital Inducement Law brought in the policy to encourage joint ventures rather than foreign ownership. By 1972 the equity investments totaled $372 million, 80% of the projects being in joint ventures and the rest being wholly foreign owned. There has recently been a very rapid increase in foreign investment, with a sharp increase in remittances of profits.

It is clear that this results in very little demand pull on the indigenous R&D. The other reason for the lack of demand pull has been the noninteraction between research institutes, universities, and industry. For these reasons the government-funded R&D institutes carry out work of little relevance to the needs of the productive sector or the economic development of the country.

MEXICO[15]

Historical Background

The formation of Mexico's scientific and technological system was greatly influenced by the economic relations established by the Spanish Metropoli. Spain's interest in preventing the colonies from developing their own industries was notorious, thus maintaining a captive market for its products, with the exception of the sectors of special importance to the mercantilist policy. The incorporation of technical knowledge into production was not permitted, except in those fields in which the Metropoli was interested.

At the time of the Mexican Revolution, in 1910, there was only one university in all of Mexico, technical education was anemic, and there were enormous deficiencies in the primary and secondary levels. In 1916 a decree was issued for the creation of a vocational school for mechanical and electrical engineers. In 1917 primary education was made compulsory. The technical school for builders and a number of institutes and schools for science, industry, and agriculture came into being during the 1920s. From 1940 on, the process of institutionalized scientific research in the country was strengthened. It cannot be determined whether the creation of these centres responded to a demand inherent in the evolution of productive sectors or whether it was simply the result of advances in higher learning, although there is good support for the latter hypothesis.

In general, science was kept sheltered within the institutions of higher learning; this characteristic was preserved throughout the subsequent evolution of the scientific system. Higher-education institutions limited themselves to the diffusion of knowledge generated in foreign countries. The fact that the academic and scientific societies multiplied in number does not mean that the research being done in the country was comparable to that of Europe. A look at the publications during that period reveals that a great majority dealt with somewhat detailed descriptions of vegetables, animals, and minerals existing in the country, meteorological phenomena, etc., and that the subordinate nature of the work carried out in these institutions was not greatly modified.

Until 1971 Mexico did not have an institution responsible for science policy, and this caused many distortions in the development of the science and technology system. It is true that institutions in charge of coordinating and promoting R&D activities existed since 1935, but their functions were limited to granting a few scholarships and funding some research projects.

The Commission for the Promotion and Coordination of Scientific Research in 1940 and later the National Institute for Scientific Research (1950) showed their concern for the formulation of a national science policy to remove the obstacles that obstructed the nation's progress.

Between 1969 and 1970 a study of the process of scientific and technological development was undertaken in Mexico and its main conclusion was that a body was needed to be in charge of elaborating a science policy and implementing it. This led in 1971 to the creation of the National Council for Science and Technology (CONACYT), with the purpose of coordinating the scientific and technological efforts and acting as an adviser to the government in these fields. The creation of CONACYT started a new phase in the evolution of scientific and technological research. After an initial period the institution set out to establish better organic links between R&D and the requirements of the productive apparatus, and it formulated the Indicative Plan of Science and Technology, which was published in 1976.

The science and technology system in Mexico closely resembles a pluralistic model in which decisions related to science and technology are taken in an isolated manner and the different R&D institutions are relatively autonomous decision centres. It might be thought that since the public sector is responsible for over 80% of the financing, there are no obstacles for the orientation of R&D; but the situation is more complex on account of vested interests, ministerial control of some R&D centres, the important issue of the universities' autonomy, etc. Unfortunately, CONACYT was created with a serious shortage of policy implementation mechanisms. Moreover, the lack of experience that Mexico had on the subject, as well as the rapid growth of CONACYT during the first few years, limited the role of this new institution.

The Scientific and Technological System in 1973(16)

During the last few years there has been a considerable increase in the number of researchers and research institutions, as an effect of the promotion of scientific and technical activities. The national expenditure on research and development grew by 90.6% between 1969 and 1973, from 770 to 1,400 million pesos. The number of institutions went up by 32%, from 364 in 1969 to 482 in 1973. The equivalent full-time personnel grew by 51%, from 3,659 in 1969 to 5,517 in 1974.

This significant growth of the national scientific and technical system is still insufficient if Mexico's effort is compared with the efforts of countries with a level of development similar to Mexico's, and particularly if the situation in the more developed countries is observed. Whereas the expenditure on research and development in Mexico in 1973 was about 0.22% of the gross national product, Argentina spent some 0.3% in 1971, and India 0.5% in 1970. Naturally the difference is much larger with regard to the developed countries. However, when looking at the expenditure per researcher, the position of Mexico is not so bad; in 1974 it was about $17,000, which was higher than Argentina ($7,000) and India ($2,434), and almost the same as the Soviet Union ($16,400 in 1972).

The relation between research personnel and population was relatively low in 1974, reaching only 1.6 per 10,000 inhabitants, whereas the 1971/1972 relation was 2.8 in Argentina, 1.8 in India, and 25.9 in the United States.

Research institutions directly depending on the federal government made up almost 30% of the total number of institutions in the country and spent some 60% of the total R&D expenditure in 1973. The corresponding figures for university institutions in the public sector were 35% and 22% respectively; institutions that financially depended on the federal government (64% of the total number of institutions) spent 82% of all resources. One-half of all equivalent full-time researchers worked in federal government institutions, and about one-third in the official university centres.

The private sector used few resources for R&D; of the total national R&D expenditure, 7.2% corresponded to enterprises and 2.4% to private universities, the rest being accounted for by nonprofit institutions and by institutions that depended on state governments or the foreign sector.

About two-thirds of R&D resources went for wages and salaries, 13.5% for the purchase of material and scientific equipment, and 19% for the rental and purchase of buildings and installations, maintenance, and other items.

Another important characteristic of research in Mexico is its geographical and institutional concentration. In 1973 research institutions in the Federal District and the State of Mexico had almost 82% of the national expenditure and gave employment to 81% of the equivalent personnel.

For many years the economic situation of universities and other institutions in the provinces was rather precarious. More recently an improvement has taken place, allowing them to expand and carry out some new and important activities. However, this expansion was more quantitative than qualitative, as a response to the very high demands of the growing student population. Provincial universities still have many problems such as lack of adequate teachers, obsolete academic curricula, deficient laboratories and workshops, inadequate teaching methods, and low salaries. There is also a system made up of 42 regional technological institutes, some of them with magnificent laboratories and workshops; however, these are not utilized in general for research because the working conditions and salaries are not sufficiently attractive to good research teams.

Mexico, as other developing countries, has a large number of small institutions and a few large ones. The 10 largest institutions, each ranging from 85 to 461 equivalent full-time researchers, together accounted for 1,630 researchers, about 30% of the total in the country. On the other hand, 68.4% of the institutions had only five researchers or less; only 3.5% of all institutions had more than 20 researchers. The scarcity of personnel has an even greater impact because of the dispersion of researchers in a great variety of working topics. In some of the most important disciplines, such as physics, mathematics, and biology, the projects undertaken were extremely diverse if the limited number of researchers in each of these disciplines is taken into account. Another important objective to be achieved in a good number of branches of science and technology is the constitution of reasonably sized research teams; in 1974 there was less than one equivalent full-time researcher per project on the average.

Another element contributing to the slow development of science and technology in Mexico is the insufficient academic training of the personnel that carry out these activities. In 1974, 56.1% of the R&D personnel had a level of studies equivalent to a bachelor's degree or less, and only 33.3% had carried out master's or doctoral studies (19.5% masters and 13.7% doctors). About 10.6% had carried out specialization studies.

About 80% of the research personnel had been trained in Mexico, and of the remaining 20% that had studied in foreign countries, 44% had achieved a doctor's degree. The concentration of foreign-trained people was higher in basic research.

Regarding the type of activity, the national R&D effort was principally concentrated in applied research and development; in 1973, 85% of the expenditure and 76% of the equivalent R&D personnel were undertaking those activities in the agrarian, industrial, medical, and other sectors. The remaining human and financial resources were applied in basic research. Each person dedicated to applied research and experimental development had at his or her disposal almost twice the financial resources of a person devoted to basic research.

Basic research was principally carried out in universities (62% of the equivalent personnel) and to a much lower degree in state institutions (27.8%). The latter concentrated most of the applied research and experimental development in agriculture, fishing, extractive industries, energy, social welfare, and renewable resources, whereas the private sector concentrated on organizations oriented toward industry.

The social sciences received in 1973 a higher share of financial resources for basic research (6.7% of the national R&D expenditure) than that channeled toward the exact sciences (4.8%) and the natural sciences (2.7%).

R&D oriented to specific areas of utilization was concentrated in those sectors where the economic participation of the state had been particularly important, or in areas where technology had to be adapted to national conditions: oil and energy (18.2% of the national R&D expenditure), agriculture (15.4%), medicine and health (9.6%), and the intermediate goods industry (6.8%). These four subsectors represented about half of the national R&D expenditure. However, the relative position among them varies if they are ranked according to the equivalent personnel in R&D: medicine and health, 12.4%; agriculture, 1.3%; intermediate goods industry, 9.7%; and oil and energy, 8.8%.

However, this concentration does not mean that the applied research and development directed at those sectors is adequate for their need for scientific and technological knowledge. In oil and energy, for example, slightly over 60% of the resources were dedicated to the solution of problems in the production of oil and its derivatives, and 31.5% to nuclear energy research. Other energy sources received scarce attention. In the intermediate goods industry, efforts have concentrated on petrochemistry, with little attention to the rest of the industry. In agriculture, research is principally directed at satisfying the needs of commercial agricultural exploitation, with little attention to other areas where technology is little developed at the world level, such as tropical agriculture. In health and medicine, a good part of the research is concentrated in a limited number of areas, principally those related to curative medicine, with little emphasis on preventive medicine.

Research on other areas of importance to Mexico continues to be low. In 1973 research on the technical problems of industry received very low financial support (about 4.7%), and the situation was similar regarding research on cattle, forestry, mining, transportation, communications, and other areas. This panorama reflects a profound technological dependence of the largest part of the national economic system.

The present structure of applied research and development tends toward separating scientific and technological research from the dynamic, technically complex economic activities. The exception perhaps is in the area of oil and petrochemicals, where the state is carrying out an important effort.

Finally, it should be added that the support services needed by R&D activities are still deficient (for instance, the information system, which is disjointed, the scientific reviews, which are of poor technical quality, the geological and soil utilization charts as well as the inventory of natural resources of the country, which are still in their initial stages).

Characteristics of the S&T System

In general, it can be stated that an integrated system of generation, diffusion and utilization of scientific and technological knowledge does not yet exist in Mexico. With the exception of a few productive sectors like the petroleum industry, agriculture, and the generation of electricity, which are state controlled, there is no integration between the scientific and the productive sectors. Because the productive sector is based on imported know-how, firms emphasize the links with their principals rather than with the local S&T system. There is no real demand pull from the productive sectors. For this reason the research institutes do not have programs of activities directed toward the problems of development, and a high percentage of R&D units take up academic problems. Moreover, they centre around problems defined by R&D centres located in highly industrialized countries. Estimates of the percentage of expenditure on R&D that is devoted to basic research range from 44% to 55%, a very high figure since in developed countries it does not go beyond 10% to 20% of the total.

Therefore, the planning of activities in R&D centres takes into account mainly the internal objectives of the institution, and links with productive activities are limited to technical services, testing minor adaptations of processes, etc. This may be interpreted as the embryonic stage of what could be more complete at the level of research. Most of the units demanding technical services from R&D centres are large enterprises, some of them foreign owned, which have the capacity to make an explicit demand for technical services; such services are demanded basically for the solution of very specific technical problems.

The influence of the scientific world on Mexican science is very profound. It has been said that many of the problems studied by scientific research in Mexico are an integral part of programs drafted overseas and carried out to a great extent in other countries. Another foreign influence is through the training of researchers overseas, who on returning to their native country have a set of ideas more in agreement with world science than with local problems.

Such influences are reflected in the low volume of efforts devoted to important areas. For instance, in 1969 only 1.6% of the researchers carried out R&D activities in the field of measure sciences (Mexico has 10,000 km of coastline), and only 2.3% worked on technological applications for industrial development; very few research centres take up the problems of arid regions.

On the other hand, work by multidisciplinary teams, the importance of which has increasingly been recognized, is very rare. A survey in 1970 showed that of a total of 1,309 research projects carried out, 798 (61%) were in the charge of a single full-time researcher.

R&D Links with Production

The links between activities of the research centres and the productive apparatus are in general in the process of being established; there has been a traditional separation between R&D and production.

It is widely recognized that small farmers and "ejidatanos" have received very few benefits from agricultural R&D, possibly because of the type of research carried out in the agricultural sector and of the very low ratio between the extension agents and the farming families, which is approximately 1:10,000 (as against 1:600 in the U.S. and Japan).

In the industrial sector, engineering in Mexico, which has had varying degrees of development, can be analyzed. In some fields such as civil engineering there has been a good development, whereas in the engineering of industrial projects the development of a local capability is in its initial stages.

The present complexity and rhythm of technical progress demand a new type of enterprise and organization, the engineering firm, which brings together engineers and technicians from different fields to carry out the conception and realization of industrial projects of great complexity. Engineering firms represent a natural link between R&D activities, licencing, and the design and manufacture of equipment. It is therefore very important to generate a local engineering capability that will carry out these tasks.

At present there are in Mexico some 10 to 12 firms able to provide consulting services, detail engineering and, to a lesser extent, basic engineering. Of these firms, three or four are totally national. In the public sector an interesting case is that of the Mexican Petroleum Institute, whose organization includes research, training, and also the equivalent of an engineering firm. The Institute has been indispensable to Petroleos Mexicanos because of an increase of the latter's scientific and technical requirements and to preserve a certain degree of independence vis-à-vis foreign engineering firms and process licensors.

It was estimated that between 1971 and 1976 Mexico would need engineering services for more than 3,000 million pesos, and it was also estimated that the present capacity of the existing engineering firms would permit the generation of projects for more than 8,000 million pesos a year; local capabilities therefore can meet local needs but only as far as detail engineering work is concerned. As before, basic engineering will have to be acquired abroad in the majority of cases. On the other hand, the supply of engineering services is highly concentrated (the largest national private firm presently controls two-thirds of the market). Foreign firms are now attracted to the Mexican market and are associating with national firms. Nevertheless, in the industrial engineering field, the processes and basic engineering still come mainly from abroad.

In general, there is little connection between engineering firms and the scientific and technological system of the country, and there is no indication that national engineering firms have served as a link between production and the realization of industrial projects on the one hand, and R&D activities on the other.

Importance of the Public Sector

An outstanding characteristic of the Mexican science and technology system is the overwhelming participation of the public sector. The greater part of R&D funds comes from the public sector, which includes the government subsector as well as all state-owned enterprises and decentralized institutions. The part corresponding to the public sector in 1970 was estimated at 95%. In terms of human resources, 42.7% were in the public sector, 52% in the higher-education sector, and only 4.1% in the private sector.

The 1970 survey showed that there were no researchers in the private sector in some important fields such as mathematics, agriculture, cattle breeding, forestry, marine sciences, earth sciences, engineering sciences, and communication sciences. This is a consequence of the important role played by the state and of the way productive forces developed in the country, with an overwhelming reliance on foreign technology.

The very large share of researchers in the public sector has brought about certain unfavourable effects. First, it is possible that there may have been inefficiencies in the administration of scientific research, because of the lack of internal assessment mechanisms in the institutes in charge of research. There are sufficient isolated data to support the conclusion that irrationality in the purchase of equipment has not been exceptional; in some of the centres that were visited, the existence of idle equipment was identified, up to 95% in one case and 70% in another. On the other hand, many of these R&D centres have carried out deficient planning, resulting in the purchase of equipment without a precise definition of what it could be used for. This is the case with an expensive electronic microscope, purchased with the help of a foreign credit even though there was no personnel to handle it. In contrast with this, several centres have bureaucratic problems that make it difficult to import the equipment needed for some research programs.

Furthermore, the techniques for budget administration are inadequate in view of the particular requirements of R&D projects. It is rare to find a research institute that uses pluriannual budget programing techniques. In R&D centres within ministries, the global budget is approved annually and this hinders the execution of long-term projects and reduced flexibility, in addition to the bureaucratic red tape that delays the approval of the budget.

The Relation Between the S&T and the Education System

An important part of the scientific and technological system is institutionally related to the higher-learning system; 143 of the 313 institutions identified by CONACYT were found to be directly dependent on higher-education institutions. However, there is little relation between higher learning and the R&D effort, and the contribution of R&D to higher education is probably marginal.

Academic research is relatively small and is carried out only in the last few years of the higher-learning cycle. There are no defined programs for this research, but it is important, nevertheless, that there are some isolated cases in which an attempt has been made to link the student to the specific scientific problem of industrial research and adaptation of technology.

On the other hand, study programs in higher-learning institutions do not seem to guide the student toward active research or to encourage a critical approach. Besides, higher education in Mexico faces problems such as the constantly increasing student population and the need to improve academic standards beyond their present level, since there are numerous indications that the academic level in general has suffered a drop in the last few years.

There is a need to revise and update academic programs, which today do not orient the students toward research, but rather produce professionals and technicians for the economic system.

The defects of the higher-education system are the results of many factors, but without a mechanism that will allow for educational planning, it is impossible to prevent distortions such as the great concentration of students in a few institutions or in certain traditionally privileged disciplines to the detriment of others that are necessary for the industrial scientific and technological development of the country.

Technology Imports

Imports of technical knowledge carried out by the productive apparatus are not filtered by the national scientific and technological system. The vast majority of it comes from external sources, for reasons that are common to many other developing countries. Although a certain degree of control exists in relation to some of the phases of technology transfer, there are no mechanisms to orient the inflow of imported technology and therefore the transfer of technology is carried out in an indiscriminate and nonselective manner. R&D centres carry out very few tasks related to the adaptation of foreign technology to local conditions. When adaptations do take place, it is very probable that they are mostly minor adaptations, for instance to pressure, temperature, and humidity conditions or to characteristics of raw materials; it is also probable that only very few major adaptations are carried out, either to market scale, factor proportions, or resource endowments.

The productive sector has a weak demand for technology originating in local sources for a variety of reasons, the most important one being the attitude of Mexican businesspersons. The scarce technological capabilities in national industry are revealed both in its aversion to risks, and therefore to carrying out R&D activities, and in its technological link with external sources. The S&T system does not normally intervene in the selection of foreign technologies, and in general the process has been irrational, which is basically reflected in the costs those imports have represented for the country. Imports of technology are normally carried out without any macroeconomic or even ecological criteria. As a result the costs of technology transfer have greatly increased in recent years.

In 1972 the National Registry for the Transfer of Technology was created to regulate the process of technology transfer in its diverse aspects. Up to December 1973 it had received more than 6,000 contracts, which demonstrates that imports of technology and trademarks are much more numerous than was previously supposed. Of these, about 5,000 were negotiated before the law went into effect. During the first years that the law was in effect, some 700 contracts were approved of the 900 presented for the registration. Finally, it should be noted that the Registry works in coordination with CONACYT.

Final Remarks

In general, it can be stated that in Mexico an integrated system of generation, diffusion, and utilization of scientific and technological knowledge does not exist. With the exception of some sectors, it can also be concluded that scientific research in Mexico is not linked with the productive apparatus and with the problems of development.

Basic scientific research predominates among the activities of the scientific system. Nevertheless, this research is not focused on the definition of new paradigms. In general, it is centered on certain problems defined by R&D centres located in highly industrialized countries.

The linkage elements between R&D and the productive apparatus are still in the stage of being formed. Also, the support services of the S&T system, with the exception of some isolated efforts, are very deficient.

The public sector has played an outstanding role in the promotion and coordination of scientific activities. It is possible that the importance of the public sector may have some effects that are not beneficial in terms of the administrative efficiency of research centres.

There are many research centres that institutionally depend upon the higher-education system, but the relations between research and higher learning are very weak. Also, the problems that higher learning in Mexico has to face represent an obstacle for the training of the human resources that the S&T system needs.

Until 1971 Mexico did not have an institution responsible for the formulation and implementation of a science and technology policy. The creation of the National Council for Science and Technology (CONACYT), in spite of the problems inherent in its tasks, represents a very important advance over the pre-1971 situation.

The imports of technical knowledge carried out by the productive apparatus are not filtered by the scientific and technological system. The creation of the National Registry for the Transfer of Technology is the first step toward a policy on technology imports.

PERU(17)

Historical Background

From the end of the 19th century until the beginning of the 1930s Peru was in a stage of growth based on the insertion of its economy in the international market; it exported raw materials and imported finished goods. Such a situation does not exert pressures for the introduction of technical innovations, even in the export activities; the latter incorporated the necessary technology directly from overseas through capital goods and the technicians needed to use them. Higher-education activities started to develop within a limited university structure that concentrated on medicine and law. Academies were founded, such as that of medicine in 1854, with the principal function of nucleating those interested in the advance of science. There appeared therefore an embryonic stage of scientific activities and a recognition of their individual and social importance.

The following period goes from the Great Depression to the end of the 1950s. Once the effects of the Depression were overcome, the situation was similar to that in the previous stage, growth being fundamentally based on exports. However, a significant reaction took place after a growing process of import substitution was started and this greatly influenced economic policy. But the large increase in the needs for intermediate goods and equipment caused new restrictions, this time on imports, which once again increased substitutions to the point where the industrial activities that supply the internal market were reduced to a subsistence level. This industrial crisis showed the limits of development possibilities through import substitution and led to a different form of dependence, more complex than in the former period.

The saturation of foreign markets for agricultural products, and of internal markets for industrial products, demonstrated the need to improve production and start scientific and technical activities in the industrial and agrarian sectors. The state took up the main role in this regard, helping the development of existing institutions and creating new ones - the Institute of Industrial Technology in 1950 and the National Commission of Nuclear Energy in 1955. In this way a certain research capacity was built up, but the activities were concentrated on basic research and on subjects not connected to the economic problems of industrial development. There was a beginning also in a number of scientific and technical services, principally standards and quality control related to export products.

Universities started to develop significantly in this second period. Their number grew from seven in 1955 to 33 in 1970. The student population grew rapidly, from 31,000 in 1960 to 96,000 in 1969. This rapid expansion, aggravated by the lack of the necessary human, economic, and physical resources, affected the quality and the efficiency of education.

In the third stage of national development, starting at the end of the 1950s, Peru took measures in the international arena to counteract the weakening of the import substitution process, which had already run its course in most consumer goods, including some durables. To this was added the difficulty of increasing productivity and output in the agricultural sector to allow more traditional exports, which on the other hand were affected by low international prices. The Latin American Free Trade Area and the Andean Group were created with the purpose of deepening the substitution process by entering into the production of capital goods and certain durable consumer goods, like automobiles, and improving the conditions of production of enterprises that could now look for regional and subregional markets, with the corresponding increase in scale and in the utilization of installed capacity.

During this stage much foreign capital and technical knowledge came into the country, particularly from the United States, through direct foreign investment in manufacturing, which profited from the government's promotional policies. Such measures allowed the indiscriminate importation of technology and were not favourable to the development of the incipient science and technology system.

Similar situations existed in all countries of the Andean Pact, which collectively adopted policies to help autonomous development (Decisions 24, 84, and 85 on the control of imported technology, the localization of foreign capital in the Andean countries, and the regulation of patents and trademarks).

Peru took several measures to counteract the lack of internal demand for scientific and technical activities that this situation caused. In 1960 it created the National Centre of Action for the Growth of Productivity (CENIP) and the Institute of Agricultural Technology. In 1970 it created the Institute of Industrial and Technological Research and Technical Standards (ITINTEC), and it was decreed that industrial enterprises should employ 2% of their net income as a fund for technical and scientific research. This research may be carried out by the enterprises or it may be contracted out. However, there are still problems of critical mass and of orientation of specific requirements; foreign suppliers keep on being the principal source of technological alternatives and of many S&T services.

In the higher-education sector a law for the reorganization of universities did not modify the tendency to concentrate enrollment in humanities and education, with a disregard for scientific and technical branches. Of the 31,000 students in 1960, 38% were in humanities, 21% in education, 20% in engineering and architecture, 12% in medicine, and only 9% in sciences. In 1969 the humanities were even more important, with 47% of the student population, followed by education with 24%, whereas engineering and architecture had gone down to 17%, as well as medicine and sciences with 7% and 5% respectively.

In any case some changes took place in the university activities, incorporating research as an important task and one complementary to the training of professionals. However, research meant mainly basic research.

The government also took other measures during the last decade that show that it has recognized the importance of developing the science and technology infrastructure. On the one hand, research was fostered in the Ministries of Agriculture and Public Health, and on the other, a number of institutions were created to carry out a wide range of activities: in exact and natural sciences (Instituto Geofísico del Perú, Instituto del Mar, Oficina de Evaluación de Recursos Naturales), in technology and agrarian sciences (Instituto de Investigaciones Agro-Industriales), and in fields directly relevant to industrial development (Centro Nacional de Acción para el Incremento de la Productividad, Instituto de Investigación Tecnológica Industrial, Instituto Científico y Tecnológico Minero, and Research Divisions in some Ministries).

Finally, in 1968 a National Research Council within the Presidency of the Republic was created with the mission of promoting, coordinating, and supporting scientific and technological activities in the country. This implies once again a recognition of the social importance of science and technology.

The Scientific and Technological System in 1970

A survey was carried out by the National Research Council on the situation of the Peruvian science and technology system in 1970. The survey covered all institutions engaged in research and development in the following sectors: public enterprises, public higher education, private higher education, government, and others. In addition, manufacturing firms were surveyed in the city of Lima.

The survey showed that the scientific and technical personnel engaged in research and development activities numbered 1,925, the national expenditure on these activities reached almost S/250 million, and the number of research projects being carried out was 1,124. Table 2 summarizes the information for each sector.

It can be noticed that the highest concentration of institutions, personnel, and projects occurred in the public education sector, whereas current R&D expenditure, which includes salaries and operating expenses, was highest in the government sector. In the higher-education sector there was an emphasis on basic and applied research.

Within the public education sector the highest concentration took place in the agricultural and the exact and natural sciences, with respectively S/31 and S/26 million, 345 and 397 scientists and technicians, and 256 and 205 ongoing projects. The expendit e per project was about S/120,000, which is slightly less than $2,500 per project; this is a very small amount, showing that there is an atomization in research and development activities, with a low probability of producing results that will have an impact on development. In the government sector the emphasis was also placed on the same subgroups, although resources were more abundant, about S/313 and S/846 thousand respectively; in the exact and natural sciences subsector this came to almost $17,000 per project.

An interesting result of the survey concerns the dates of foundation of the institutions. The most intensive development of the system started in the late 1950s. Between 1956 and 1970, 148 institutions were created, representing about 76.6% of all those surveyed; 116 of them belonged to the education sector, public and private. But there was a scarcity of institutions principally devoted to engineering and technology, which only numbered 16.

Regarding their size, about 56% of the institutions had less than 100 researchers, 76 had between 11 and 40, and only nine had more than 40. Of the latter, seven were in the public education sector and concentrated principally on agriculture and on the exact and natural sciences. Only one had more than 40 researchers in engineering and technology, which was in the university sector.

Many institutions devoted a small part of their expenditure to research and development. Of the 193 that gave information, only 45 allocated more than 50% of their expenditure to R&D. The proportion was higher in university institutes, half of which devoted more than 50% of their expenditure to R&D. Of the 193 institutions, 115 declared they were carrying out basic research, 171 applied research, and 108 experimental development.

With regard to the occupational structure of the institutions, the survey showed they employed 5,534 persons, of which 1,925 were scientists and technicians, and 1,089 auxiliary technicians. About 45% of the personnel of the institutes did not carry out scientific activities; 35% worked in scientific activities including R&D, and the remaining 20% in non-R&D scientific activities. On the other hand, 42% of the scientific personnel spent more than 50% of their time on R&D activities. About 21% of the scientists and technicians worked part-time. The higher-education and government sectors contained 93% of the scientific and technical personnel, particularly in agriculture, exact and natural sciences, and medical sciences. The public sector had 1,490 researchers (77%) and the private sector 435 (23%). It is noteworthy that the subsectors of engineering and technology and of industrial manufacturers had a minimum participation.

Regarding the financial resources of the R&D institutes, about 80% came from the funds assigned by the institution on which they depended. Grants represented about 11%, and they were concentrated principally in the agricultural subsector. Revenues from research contracts scarcely reached 6% and only occurred in the subsectors of agriculture and of exact and natural sciences. Revenues from other services were only about 4%.

Some 83% of all funds were allocated to the government and public higher-education sectors. In the first sector there was no participation of manufacturing industries and engineering; in the second sector 72% of funds were concentrated in agriculture and sciences.

Information on the expenditure by activity was obtained for 130 institutions, showing that some 44% of current expenditures were allocated to R&D, principally in agriculture, followed by biology and earth sciences.

The number of projects has recently experienced an important increase, reaching a total of 1,124 in 1970. Almost half were in agriculture, with 542; this was followed by exact and natural sciences (257) and medical sciences (200). These three subsectors accounted for 89% of all projects. Information on the area of application of the projects shows that the system is not oriented to producing results for industry, the principal consumer of technology.

Conclusions from the 1970 Survey

The resources of the scientific and technical system are insufficient to assure that the activities are efficient. The emphasis is on the higher-education system, where there is the highest concentration of institutes, personnel, projects, and financial resources, and on the government sector, principally the agricultural subsector, with a higher availability of funds for current expenses; this leads to a predominance of basic and applied research over experimental development. Public and private enterprises have a notorious scarcity of resources, which reflects on the weakness of activities in engineering and technology and in manufacturing industries.

It is clearly a question of too little mass to carry out an efficient R&D activity. The system is still being formed. R&D activities are spread over a large number of small projects. More than 50% of the institutions have less than 11 researchers, who in general are not fully dedicated to their work, since they use an important part of their time in other activities, perhaps because there is a lack of support and auxiliary personnel (0.8 technicians per researcher). The weakness of the national S&T potential is also demonstrated in the insufficient development of diffusion and associated S&T activities. More than 70% of the institutions devote less than half of their internal expenditure to R&D; almost 70% are also engaged in university teaching.

This low level of resources is clearly seen in international comparisons. The 1,925 scientists and technicians engaged in R&D become 1,238 equivalent full-time scientists, which represents 0.9 researchers for each 10,000 inhabitants. This proportion is much below that of the industrial countries, which reaches values of 25 to 30 researchers, and it is also lower than smaller countries like Austria, Ireland, and Yugoslavia, which have from 3 to 8 researchers for each 10,000 population. On the other hand, the global resources of the system in research and development reach about S/250 million, equivalent to about $5 million, which represents 0.13% of the gross national product and $0.3 per inhabitant, a very low proportion indeed.

Another deficiency resides in the education system, which has too many students in the humanities and too few in the technical subjects that are demanded by industry. However, 5% of the GNP - some $132 million - was allocated to this outdated, traditional system in 1967.

There are few relations among the S&T activities, resulting in a system that is not integrated as such. Certain research areas are much more developed than others, responding not to national priorities but rather to the availability of funds, and they do not contribute substantially to solving national problems, even though the majority of these activities are carried out by the public sector. This comes out clearly from a comparison between the priorities of the 1971-1975 development plan and the current pattern of S&T activity in the country. The R&D effort that the country carries out in each sector, as measured by the expenditure, should be directed principally to the higher-priority sectors - the manufacturing industries first and agriculture second. Technology inputs should also be in harmony with such priorities. But much less importance is given to R&D related to manufacturing industries, whereas most R&D concentrates on agriculture. From the disciplinary point of view, the emphasis on agronomy, biology, earth sciences, zootechnics, etc., demonstrates that technological solutions are being researched in the agricultural and exact and natural sciences subsectors, and not in manufacturing industry.

The scientific and technical system is internally imbalanced in its structure and principally oriented toward scientific development, showing a small amount of R&D effort, an insufficiency in the diffusion activities, and an institutional disarticulation between production, diffusion, and utilization of knowledge in productive activities. This makes up a typical picture of underdevelopment, with a small demand for domestic science and technology, a clear orientation toward outside technology sources, and a small technical capacity, all of which weakens the internal supply of knowledge. The S&T system is neither able to satisfy demands nor to select efficiently, and adapt, technology coming from outside.

The 1975 Survey

In 1975 the National Planning Commission made a survey of 73 institutions, of which 11 were in the government sphere, 32 were public universities, 6 private universities, 32 private enterprises, and 2 public enterprises.

The results confirmed in general the findings of the previous survey of 1970, but a few additional points were made in the report:

(1) There was a concentration of basic research in public universities, particularly in the exact and natural sciences; within public enterprises it was possible to observe the importance of adaptive research. Activities in standards, metrology, and quality control were also important.

(2) Looking at the way the institutions operate, it was found that in the majority of them, decisions about personnel, finances, equipment, scientific orientation, information, etc., were taken through two or three steps, save in manufacturing industries, in which most decisions were made through only one step.

(3) The 73 institutions had a total of 1,189 persons devoted to research, 16.2 per institution. However, 40% of these researchers dedicated less than 20 hours a week to research, the rest of their time going to teaching (in universities) or to other technical activities (in industry). This would imply that scientific and technical research in a large proportion of the institutions is carried out at very low levels with respect to the time spent on them, and the effects have a repercussion throughout all the scientific and technical systems.

(4) Regarding the demand for S&T activities, more than two-thirds of the activities originated inside the institution (in some cases the proportion was 100%). Outside demand came mainly from nationally owned institutions in the agricultural sector and from consumer goods firms in the industrial sector. However, most of the institutions surveyed that belonged to the education sector had attended to requests from industry,

although the frequency was low in the case of engineering and technology. This is a positive factor showing that there is an interest in the services that universities can give to industry.

(5) About 30% of the projects were carried out in collaboration with other institutions. Of these, one-fourth had the collaboration of foreign institutions.

(6) Regarding possible areas of application of projects, the most important one was manufacturing, with 106 projects, one-third of the total, followed by the study of the environment and natural resources with 39 projects (12.5%).

The information obtained in the survey was of course limited and insufficient, but a number of elements for analysis come out clearly:

Marginality: The hypothesis of marginality refers to the lack of links between the S&T system and the government and productive systems. This marginality is a direct consequence of the situation of underdevelopment and dependence of the country. The knowledge used by the scientific system is not incorporated or adequately utilized in the production of goods and services. The relations with the outside world, principally the developed countries, are much stronger; many activities are linked to the interests of the outside world rather than to national ones. As a consequence there is a very meagre response to the needs of the productive system, while activities are oriented toward areas of less relevance to national development. The subsectors of agriculture and of exact and natural sciences have the highest proportions of current expenditure, with 50% and 22% respectively. On the other hand, the disciplines with higher expenditure were agronomy with 24% and biology with 13%. The activity of experimental development accounted for only 8% of all projects and 5.5% of the total budget for S&T activities, which is much less than that of applied research, with 58%. Another indicator of marginality is the insufficient support given by the government sector to the scientific system, notwithstanding its majority participation in the R&D activities being carried out. In 1970 only S/250 million was dedicated to R&D. This shows a low level of expenditure.

Disarticulation: This second hypothesis refers to the lack of links among the R&D sector within the S&T system, as a principal consequence of the way it has developed. Systematic relations have not been developed and an integrated system does not exist. Many R&D institutions do not know about the activities of other R&D institutions; there is a lack of coordination among them because of the absence of a global plan for all activities in the system. This situation brings about an inadequate allocation of resources with regard to development priorities. These comments are supported by the various statistics and findings already reviewed. The type of relations among R&D institutions would seem to suggest that the S&T system in Peru is in a formative stage, facing the many problems derived from the social and economic characteristics of the society, the principal feature of which is the condition of dependence on the developed countries. But at the same time there are certain positive elements for a process of scientific and technical development, such as the recent incentive for R&D in industry (2% of net income), which has already increased S&T activity in industry and brought an increase in demand for university institutes.

Weakness: The survey results confirmed the conclusion of the previous 1970 survey regarding the weakness of the country's S&T system.

VENEZUELA[18]

Historical Background

Any analysis of the evolution of the Venezuelan science and technology system should refer to the different phases that the social and economic development of the country has gone through.

It is not possible to speak of a science and technology system before the petroleum phenomenon. Previous to the expansion and consolidation of the petroleum enclave, the country did not have the minimum activity that might allow it to speak about a process of technical and scientific development. The economy did not show a dynamism that might produce a demand for knowledge to be incorporated into the productive process. In fact, the Venezuelan economy from the colonial times to the 1920s, when oil started to be exploited, reproduces the pattern of countries that export raw materials and buy metropolitan manufactures. The technological level required for the agricultural production of cocoa, tobacco, and coffee was rudimentary; only in some cases might one speak of applications of techniques for cultivation or harvesting and storage, which required the transplant of simple technologies. In other words, from its beginnings as a country until the explosion of petroleum prices, Venezuela remained on the margin of the world development in science and technology.

Petroleum produced a significant modification at all levels of Venezuelan society. Because it was an extractive industry, functioning in an enclave, the consequences came indirectly. A new pattern of imports appeared, and a new entrepreneur class came into being, strongly linked to the state machinery and protected by it, a factor that was to be very important for the beginning stage of industrialization. On the other hand, the oil revenues opened up the possibility that large sectors of the population could have access to education.

Industrialization started late; only in 1958 did it gather momentum, although there had been a timid beginning in the middle of the 1940s. As in all Latin American countries, industrialization meant, in technical terms, high imports of foreign inputs and foreign technology. In Venezuela there was a peculiarity: whereas elsewhere in Latin America the lack of foreign exchange and the availability of cheap manpower gave a definite pattern to industrialization, in Venezuela these factors were reversed: capital was cheap and manpower rather expensive. These peculiarities suggest that a different development of science and technology activities could have taken place, even within the global development model followed, if more social pressures had existed. This could have meant a lower reliance on technology imports and a more significant development of local technological capacity.

The Institutional Basis of the Science and Technology System

Because of the very strong presence of the state in the allocation of resources for the S&T system, it is necessary to refer to the state organization for science and technology activities, and a distinction has to be made between S&T planning organizations and those that carry out S&T activities.

The most important organization is the Consejo Nacional de Investigaciones Científicas y Tecnológica (CONICYT), which is in charge of planning and coordinating the activities of the system. Although it must comply with the guidelines established by the Office of National Planning (CORDIPLAN), the position of CONICYT has improved in recent years with regard to its powers of decision and negotiation.

Some 90% of the organizations that undertake R&D belong to the state, 60% are in the universities, and 35% in ministries and other organizations. With regard to financial resources, the Venezuelan state supports some 90% of the total funding.

Universities have their own criteria for their research policies, although there is some beginning of cooperation with CONICYT in priority areas; in the rest of the public sector, research lines come out of programs set down by the institutions that carry them out, such as ministries and autonomous institutes.

The activities of control and registry of imported technology are discharged by the Superintendencia de Inversiones Extranjeras (SIEX), which is in the orbit of the Ministry of Development. This organization examines all foreign investment projects and technology contracts. There is also the Registro de la Propiedad Industrial, in charge of controlling licences, trademarks, and patents, within the same Ministry. These two organizations are in charge of controlling the country's technology, although at the level of the state enterprises and the regional development corporations there are units that are in charge of registry, evaluation, and technical assistance for their jurisdiction.

Regarding the training of human resources, there are 13 universities in the country, of which nine are state owned and the rest private. In addition, there are 20 technological institutes and university colleges in charge of technical training.

There is little or no coordination of the activities that have to do with human resources training; several entities are trying to carry out that function from different points of view, but are not able to channel and organize these activities within a coherent set of objectives.

Regarding the use of technology, the country does not have a central organism dealing with activities such as technical assistance, adaptation, and technological innovation. State enterprises, and the ministries that have to do with the production of goods, have technical offices, but these have no relations among themselves. The rest of such activities are carried out by technical departments in the different enterprises. The exception is at the level of the Comisión Venezolana de Normas Industriales (COVENIN), which is in charge of industrial standards.

There are in Venezuela 311 organizations devoted to research and development. Some 93% are in the public sector and only 7% in the private sector. On the other hand, 62% are within national universities, while there are practically no such units within the productive enterprises.

There is a concentration of organizations in the central area of the country, particularly the metropolitan region around Caracas, which has 120 institutes. In the rest of the country there is a concentration in the state capitals, such as Maracay, Maracaibo, Barquisimeto, and Mérida. Seventy-two institutes are devoted to medical sciences, 55 to agriculture, 33 to engineering, and 44 to biological sciences. Some 54% carry out principally applied research, 40% basic research, and only 5% experimental development.

Financial Resources Devoted to the Science and Technology System

Between 1965 and 1974, the total expenditure of the S&T system grew from B210 million to B498 million, for a 139% growth in that period. About 42% of the expenditure in 1974 was devoted to R&D activities, 4.1% to the transmission of knowledge, and 58.8% to activities that had to do with the utilization of science and technology. In 1970, of the expenditure devoted to R&D, 15.7% was in free basic research, 21.8% in oriented basic research, 60% in applied research, and 2.5% in experimental development.

About three-quarters of the research expenditure in 1974 went into institutes of the public sector (various ministries, the Instituto Venezolana de Investigaciones Científicas, CENDES, and CONICYT), and one-fourth to R&D performed at the universities.

Agrarian sciences received 19% of the total R&D expenditure, medical sciences 15%, engineering 12.7%, social sciences (economics and sociology) 15%, biology 13%, and other disciplines some 14%. If classified by field of application, the most important ones are agriculture with 30% of the expenditure and health with 19%, followed by industry with 11%. The proportions for petroleum, mining, and education were very low, not over 3% in each case.

The total R&D expenditure represented about 0.16% of the GNP in 1965 and had grown to 0.29% by 1974, for a total amount of $44.6 million. In terms of the total national budget, the R&D expenditure in 1974 was 1.43%.

Human Resources Employed by R&D Organizations

The public sector has the majority of the human resources that are engaged in research and development. Of a total of 5,165 individuals, graduates and nongraduates, 4,949 were in the public sector. The number of graduates per institution was 11.49 in the public sector, 5.66 in the private sector, and 7.98 in the universities. There were in all 3,451 graduates (of which 3,332 were in the public sector), and of these 2,536 were researchers, the rest being postgraduate students, teachers, technologists, technicians, and administrators.

The 2,536 researchers were divided in the following way: exact and natural sciences, 29%; agricultural sciences, 22%; medical sciences, 21.5%; social and human sciences, 12%; and engineering sciences, 10.4%.

The number of researchers per 1,000 inhabitants in Venezuela was 0.25, which is a relatively low figure in comparison with other countries. Furthermore, many researchers have very few years of experience, showing the youth of the stock. On the other hand, almost three out of four researchers did not have systematic graduate studies, mainly because of the lack of possibilities in Venezuela. R&D organizations in the natural sciences had the highest proportions of high-level researchers, 47%, whereas the social and human sciences had only 18% of postgraduate degree holders.

Final Remarks

The report of the Venezuelan STPI team suggests that the S&T system of Venezuela is marginal to the needs of the country. Contrary to what happens in developed countries, and to what may be postulated as an ideal situation, research and development in Venezuela does not play a significant role with regard to the global development of the society. It is thought that the contribution of scientific research has not been indispensable to the socioeconomic evolution of the country.

The concept of marginality may be used at two different levels, that of the research activities and that of the results produced by them. At the first level, one may examine the magnitude and orientation of the national potential of research and development; at the second level, the indicators are both the nonincorporation of the results that have been obtained and the irrelevant incorporation of the results.

The report points out that the potential of research and development is low, and that the people working on these activities have shown a low productivity. The orientation of this potential is to a large extent not in agreement with the objectives of the fourth national plan, showing a striking concentration on agriculture and health to the detriment of industry, mining, petroleum, etc.

Regarding the results, although there are few quantitative indicators, it would seem that the incidence of national research on different socioeconomic sectors is very low, as shown by the fact that 70% of the applied research and development projects were not applied in the period from 1965 to 1970, according to surveys carried out by CONICYT. The situation is especially serious in the priority areas such as education, hydrocarbons, and industry. Of 419 national projects applied between 1965 and 1970, a small figure by itself, only 9% were applied in the industrial sector, 4.5% in the priority industries, 0.9% in the hydrocarbon sector, and 5.2% in the education sector. The agricultural sector registered the highest number of applied projects, with 27.6%.

To this should be added that, in general, the projects that have received application have referred to aspects that did not have the highest importance for the development of the corresponding sector. Hence these applied projects are themselves marginal because their incorporation is not relevant to the field to which they are applied.

The explanation of this marginality of Venezuelan science rests, on one hand, on the very important flow of technology that is imported by industry, and on the other, on the fact that research topics are chosen by the researchers, because there is no scientific policy to orient this choice.

The country is essentially an importer of foreign technology, but not even the activities of control and adaptation of technology have levels of efficiency and capacity in accordance with the volume of that importation. There is a technical and institutional weakness in the organizations that control imports and the registry of industrial property; at the same time the indices of innovation flow, such as a list of innovations, also reveal the irrevelance and partial character of that flow.

The present development model, although explicitly attempting to obtain progressive independence with regard to technology imports, has an implicit orientation toward higher amounts of foreign technology, which implies a higher intensity in the technological ties of the country. The investment strategies in petrochemicals and iron and steel, plus the investment in capital goods industries, are conceived from a merely quantitative point of view, which forgets the technological variable as a definer of an explicit goal of autonomous development. In this sense, after a technological reading of the plans of Venezuela for the coming years, it would seem that only a very limited and marginal sphere of action will be assigned to the science and technology system.

MACEDONIA[19]

Historical Background

There was no organized scientific research work in Macedonia during the prewar period. Scientific activities were individual and were not incorporated in the guidelines of economic development.

It was only after the liberation that the country started the process of mobilization and formation of creative and scientific potential. The initial activity was related to research work in the human and natural sciences without much attention to the needs of economic development. The importance of agricultural activity, and the great proportion of rural population, impelled the start of research work in the agricultural field. Later, the switch to an industrial economy put a new accent on scientific and research activities. Industry acquired a leading role in development. Being concerned with the modernization and innovation of productive capacities, technological research work has become of prime significance and is regarded as crucial to lessen the technological dependence on other countries.

In Yugoslavia, and therefore in Macedonia, scientific investigations started in the electronics, electrical, and pharmaceutical industries. The metalworking, machine, and textile industries, energy generation, and transportation were the branches where research work started later.

The policy of intensive development of the country has given priority to the following branches of industry: chemical, electronics, electrical, pharmaceutical, ferrous and nonferrous metallurgy, food processing, petrochemical, energy generation, transportation, and communications. It may however be pointed out that most of the basic industries are based on imported technology.

Organization of Research

In 1967 the Macedonian Academy of Arts and Sciences was established. There are three units in it dealing with natural and mathematical sciences, social sciences, and medical sciences. The Academy lays down scientific policy and organizes numerous republican, federal, and international gatherings.

The first scientific research institutions in Macedonia were established immediately after World War II. The area of their work was mainly of a biological and socioeconomic character. Later on, their activity was extended to the field of mathematical and technical sciences. Research development centres have more recently been installed in the new industrial establishments. Two tendencies are now evident in the development of scientific research institutions: a slow growth of independent scientific research institutions and a rapid increase in the number of scientific research units in enterprises. These tendencies are in conformity with the basic intentions of the socioeconomic policy.

The independent research institutions are organizations of associated labour that regulate their own work and decide on their structure and status on the basis of the self-management principle. The work of scientific institutions is coordinated at the national level by the Committee for Coordination of Science and Technology, and at the level of each republic, and therefore of Macedonia, by the self-managing Community of Interest in the sphere of science. This Community is formed by working people directly or through their self-managing organizations or committees as users of scientific services, on the one hand, and by the working people in the organizations of associated labour in the field of science as renderers of those services, on the other. (By March 1974, this function was carried out by the Republic's Fund for Scientific Research Work.)

In Macedonia 23 independent research institutions were registered in the early 1970s, most of them of a relatively small size and endowed with few human and material resources. Ten of them worked in agriculture and forestry, seven in technical areas, five in the social sciences, and one in the natural sciences. In 1972 they completed over 300 projects, half of which were funded by enterprises through contacts. It has been noted that their work is frequently inefficient, which results in prolonged terms for carrying out projects, and efforts are needed to increase the efficiency and the rationality of work.

Scientific research is also carried out at the University of Skopje, with its 12 faculties, 89 departments, and numerous units. There are four institutes in the University: the Institute of Technology and Scientific Engineering; the Institute of of Social, Political, and Legal Research; the Institute of Mathematics (and its computer centre); and the Institute of Economics. These institutes are expected to apply modern scientific and technical achievements to the socioeconomic development of Macedonia.

The Faculty of Economics and the Institute of Economics participate in a great number of projects related to the development of the economy of Macedonia, and they analyze topical problems such as employment, regional development, integration, productivity of labour and problems of enterprises.

The Faculty of Law deals with the institutionalization of the categories of self-management and social organization and it carries out research work on social and political changes in society.

The Faculty of Medicine has 12 clinics with a fruitful activity, special attention being given to the peculiar medical problems of Macedonia.

The Faculty of Agriculture and Forestry has a long tradition of scientific research. The results of this activity have materialized in the modernization of agriculture. This faculty comprises the following individual scientific and research units:

- Institute for Agricultural Organization and Economics;
- Forestry and Wood Industry Institute;
- Institute for Advanced Cattle-Breeding;
- Agricultural Institute;
- Wine-growing and Production Institute;
- Fruit-growing Institute;
- Fish Institute.

The Faculty of Natural Science and Mathematics has ample possibilities for scientific and research work through its regular activities and those of its institutes:

- Institute of Mathematics;
- Institute of Physics;
- Institute of Chemistry with the following units: nonorganic and analytic chemistry, organic chemistry, and biochemistry;
- Institute of Biology including the following units: botanic, zoological, and physiological;
- Institute of Geography.

The Faculty is organized in a unique functional framework that assures a fluent collaboration and coordination among the institutes and their units in the same or a similar scientific field. The essential features of the Macedonian climate and people are the most frequent subjects of the studies, with a special attention to the needs and characteristics of the natural and material potentials of the country.

The Faculty of Architecture and Civil Engineering applies the modern forms and methods of creation and scientific work to the abundant forms of traditional architecture of the Macedonian people. Scientific and research work in this respect is in the charge of the following institutes:

- Institute for Testing of Materials;
- Institutes for Studies and Projects;
- Institute of Geomechanics;
- Institute of Geology.

The work of the scientific and research units of the Electrical Engineering Faculty and the Mechanical Engineering Faculty is of primary importance for rapid technical changes in the structure of the economy. Great efforts have been made for the provision of material and financial resources to support these prerequisites for scientific activities.

The role of the Technological and Metallurgical Faculty is of similar importance. However, development of the scientific research of this institution is not yet sufficient to meet the large demand and needs of the economy.

The Institute for Earthquake Engineering and Seismology and the Computer Centre were established with the help of the United Nations. The scientific results achieved have gained for the Institute a high international renown.

In the research and development units within enterprises, the scientific and research work is primarily concerned with the introduction of new technologies, either by transfer or by taking advantage of indigenous innovations. Other fields of work relate to more immediate problems of the enterprise - increases in efficiency, better organization, study of market possibilities, etc.

The most current form of organization of such scientific and research work is the development unit. The workers of the unit regulate their working rights in conformity with the interests of their enterprises.

These units have appeared rather recently in Macedonian industry and their number has rapidly increased, from 4 in 1965 to 13 in 1968, 20 in 1971, and 23 in 1973. Most of the units (20) deal with technical aspects of industrial production, whereas the remainder are engaged in agriculture and forestry. Some 90 projects were completed in 1972, of which 16 were in agriculture and forestry. The units are still in a developing stage and need to gather experience and expand their human and material resources. Their growth and consolidation are future concerns of scientific policy in Macedonia.

Scientists and Researchers

The Development Plans of Macedonia for the 1961-1975 period provided for an increase in the number of scientists and researchers from 570 in 1970 to 800 in 1975, which would represent 4.5 scientists and researchers per 10,000 inhabitants as compared with 9-10.5 for Yugoslavia as a whole. The shortage of personnel in scientific research institutions is obvious.

As a result of the increased participation of technical sciences and applied development research work, the number of technical staff in these institutions increases continuously. Top professionals from the productive sector are also engaged in research at scientific research institutions.

The number of scientific and technical personnel engaged in research during 1971-1972 was about 2,000, whereas the total number of qualified scientists and engineers in Macedonia amounted to 7,500.

It should be remarked that in 1972 Skopje University had 460 full-time and 50 part-time professors, almost half of which were doctors of science. The total full-time staff of independent research institutions reached 1,426 (of which 226 were scientists and researchers), and there were about 1,000 (140 scientists and researchers) in research units of enterprises, and 46 (11 scientists and researchers) in the Academy.

A positive tendency is the high increase of PhD's and MSc's in the independent scientific research institutions. Fluctuation of staff from the development units of the enterprises into the other research institutions is also observed. The greatest increase in personnel with the highest grades of education is in the university.

Although there is still a lack of technical staff, the structural changes in the disciplines show a tendency toward a greater engagement of scientists and researchers in technical fields.

Financing of Scientific Research Activities

There has been a continuous increase in expenditure on science and technology activities in Yugoslavia during the past 10 years. In 1945 this expenditure amounted to 0.84% of the national income, which increased to 1.06% in 1970 and 1.1% in 1972. The average annual increase in research and development funds is 12.1%, which is almost two times the increase in the national income. Although this seems rather large, it cannot be considered satisfactory in relation to the present requirements for R&D work. In this sense, Yugoslavia lags behind the developed countries of Europe and the world. R&D expenditures as a percentage of the GNP in Macedonia are below the Yugoslavian average.

The main sources for financing scientific research activities are the national fund for science and research, the enterprises, and their own income from scientific research organizations, which respectively account for one-third, one-half, and one-sixth of the total. There is a tendency toward an increase in the proportion of enterprise funding. On the basis of comparisons with other countries, the share of national funds would seem to be too small and should be enlarged substantially, particularly in view of the need to expand scientific research activities. Plans were in existence for increasing the total investments in science as a proportion of the GNP to 1.25% in 1975, 1.75% in 1980 and 2.4% in 1985, corresponding to an average annual growth rate of 12%.

Table 1: Selected Indices on the Situation of the Science and Technology System in STPI Countries.

Country	Number of Universities	Year	Number of Research and Development Institutes	Year	Number of Students in Universities (thousands)	Year	Total Stock of Scientists, Engineers, and Technicians (thousands)	Year	No. of Researchers (thousands)	Year	Total R&D Expenditures (thousands of US $)	Year	R&D Expenditures as % of GNP	Year	Payments for foreign technology (millions of US $)	Year	Number of Publishing Scientists	Year
Argentina	47	1973	134	1974	369	1973	2158	1972	7.1	1972	29.5	1972	0.3	1968	127.7	1969	834	1973
Brazil	57	1973	132	1969	320	1972	-	-	-	-	78.4[4]	1972	-	-	104.0	1970	734	1973
Colombia	60	1975	110	1971	165	1975	-	-	1.1	1971	12.4	1971	0.2	1971	26.7	1966	65	1973
Egypt	11	1975	197[2]	1973	241	1972	-	-	6.5	1968	-	-	0.2-0.5	1971	n.a.	-	559	1973
India	89[1]	1972	320[3]	1972	2473	1969	1187	1970	79.6	1970	228	1970	0.5	1971	52.3	1964	6086	1973
Korea	70	1973	120	1973	150	1973	550	1972	14.5	1972	30.5	1972	0.3	1972	9.5[5]	1972-1974	51	1973
Mexico	56	1973	312	1973	320	1973	1059	1971	4.1	1971	81.3	1972	0.2	1972	200	1968	479	1973
Peru	33	1974	193	1970	111	1970	145	1974	1.9	1970	6.5	1970	0.2	1970	12.4	1972	110	1973
Venezuela	10	1972	311	1970	70	1970	-	-	2.5	1970	44.6	1973	0.3	1973	6.1	1969	462	1973
Yugoslavia	1	1972	27	1973	-	-	7	1972	0.6	1970	8.6	1970	1.1	1970	n.a.	-	683[6]	1973

(1) Excludes a total of 3725 postsecondary colleges.
(2) Includes about 150 university departments engaged in research at the graduate level.
(3) Approximate figure based on a listing of research institutions in the UNESCO report, National science policy and organization of scientific research in India, Paris, 1973, pp. 79-104. Does not include a large number of research centres under state governments.
(4) Refers only to federal expenditures for research and development, to which private expenditures should be added.
(5) Average payments during the 2½ year period from 1972 to the first half of 1974.
(6) Refers to the Federal Republic of Yugoslavia and not to Macedonia alone, which would account for a small fraction of the Yugoslavian publishing scientists.

Sources: Column 1: Organization of American States, America en cifras 1974, Washington, D.C., 1975; Y. Hussein, Science and technology planning in Egypt, Cairo STPI Project, 1976; UNESCO, National science policy and organization of scientific research in India, Paris, 1978; DANE (Colombia), Boletín Mensual de estadística, No. 306, January 1977; various country reports for Phase 1 of the STPI project. Column 2: Various country reports for Phase 1 of the STPI project. Column 3: Same as column 1. Column 4: UNESCO, Statistical Yearbook 1974, Paris; data for Korea and Macedonia obtained from STPI reports. Column 5: Various country reports for Phase 1 of the STPI Project, and UNESCO, Statistical yearbook 1974, Paris. Column 6: Various country reports for Phase 1 of the STPI Project, and UNESCO, Statistical yearbook 1974, Paris. Currency conversions to current U.S. dollars were made using data from the ILO Yearbook of labour statistics 1976, Geneva. Column 7: Various country reports for Phase 1 of the STPI Project, and D. Crane, An inter-organizational approach to the development of indigenous technological capabilities; some reflections on the literature, OECD Development Center, Paris, December 1974. Column 8: For Argentina, Colombia, Mexico, and Venezuela: A. Nadal, Characteristics of Mexico's scientific and technological system in 1973, El Colegio de Mexico, STPI country report MCT/2, May 1974; for Peru: ITINTEC, Efecto del Proceso de importación de technología en el Perú, Lima, 1976, p. 33; for India: B. Behari, Economic growth and technological change in India, New Delhi, Vikas Publishing House, 1974, p. 209; for Brazil: F. Biato, A transferencia de tecnología no Brazil, Brasilia IPEA, 1973. Column 9: Derek de Sella Price and S. Gursey, Some statistical results for the numbers of authors in states of the United States and the nations of the world, New Haven, Connecticut, Yale University, 1975.

Table 2: The Peruvian Science and Technology System in 1970.

	No. of Institutions	R&D Expenditure (S/'000)	No. of S&T Personnel	No. of R&D Projects
Public Enterprises	2	5840	16	1
Private Enterprises	24	3758	94	15
Public Higher Education	100	86157	1066	576
Private Higher Education	33	20549	316	132
Government	32	127400	408	394
Others	2	6102	25	6

NOTES

(1) Main source: E. Roulet, Análisis de las características estructurales del sistema científico Argentino, Buenos Aires, STPI team, 1975.

(2) E. Roulet, Análisis de las características estructurales del sistema científico Argentino, Buenos Aires, STPI team, 1975.

(3) E. Roulet, op. cit.

(4) J. Katz, Transferencia de tecnología, aprendizaje local y crecimiento económico, Washington, D.C., BID, 1971.

(5) O. Oszlak, M. Cavarozzi, S. Sonnino, El INTI y el desarrollo tecnólogico en la industria Argentina, STPI project, 1976.

(6) On the matter of evolution of INTI, see STPI report compiled by S. Dain, The technological behaviour of state enterprises, Ottawa, IDRC, 1978.

(7) Official INTI documents, cited by Oszlak et al., op. cit., p. 17.

(8) Oszlak et al., op. cit., pp. 22-23.

(9) Sources: Brazilian STPI team, Phase I and II reports; and II Plan básico de desenvolvimento científico e tecnológico.

(10) Source: Colombian STPI team, Phase I report.

(11) IIT, Seminario sobre desarrollo de tecnología industrial - informe final, 1975; Instituto de Integración Cultural, Seminario sobre transferencia e innovación de ciencia y tecnológia, Medellín, Editorial Beout, 1972; COLCIENCIAS, Lineamientos para el desarrollo-cientifico-tecnológico en Colombia, Bogotá COLCIENCIAS, 1975; IIT., Tecnología del sector metalmecánico para las Unidades Asignadas & Colombia en la Decisión 57, Bogota, IIT, 1974.

(12) Source: Y.M. Hussein, Science and technology planning in Egypt, and other reports prepared by the Egyptian STPI team.

(13) Sources: NCST, An approach to the science and technology plan, New Delhi, 1973; NCST, Science and technology plan 1974-1975, Draft, Vol. 1, New Delhi, 1974; UNESCO; National science policy and organization of scientific research in India, Paris, 1972.

(14) Source: Korean STPI team, Science and technology and the development of Korea, Seoul, 1973.

(15) Sources: Papers by the Mexican STPI team, particularly Phase 1 report, Characteristics of Mexico's S&T system in 1973; and CONACYT, Plan nacional indicativo de ciencia y tecnología.

(16) From CONACYT, Plan nacional indicativo de ciencia y tecnología.

(17) Sources: Consejo Nacional de Investigación, Potencial científico-tecnológico del Perú, Washington, D.C., OEA, 1975; Instituto Nacional de Planificación, La investigación científico-tecnológica en el Perú, Lima, March 1976.

(18) Source: Venezuelan STPI team, Phase 1 report.

(19) Source: Macedonian STPI team, Phase 1 report, Skopje, 1974.

Appendix 1
INSTITUTES AND COUNTRIES PARTICIPATING IN THE STPI PROJECT

Argentina	Secretaria Ejecutiva del Consejo Latinoamericano de Ciencias Sociales (CLACSO) Country Coordinator: Eduardo Amadeo
Brazil	Financiadora de Estudos e Projetos (FINEP) Country Coordinator: Fabio Erber (until September 1974) and José Tavares
Colombia	Fondo Colombiano de Investigaciones Cientificas y Proyectos Especiales "Francisco José de Caldas" (COLCIENCIAS) Country Coordinator: Fernando Chaparro
Egypt	Academy of Scientific Research and Technology Country Coordinator: Adel Sabet (until July 1975) and Ahmed Gamal Abdel Samie
India	National Committee on Science and Technology Country Coordinator: Anil Malhotra (until June 1975) and S.K. Subramanian (until March 1976)
South Korea	The Korea Advanced Institute of Science (KAIS) Country Coordinator: KunMo Chung
Mexico	El Colegio de Mexico Country Coordinator: Alejandro Nadal
Peru	Instituto Nacional de Planificacion (INP) Country Coordinator: Enrique Estremadoyro (until February 1975) and Fernando Otero Technical Directors: Fernando Gonzales Vigil (until February 1975) and Roberto Wangeman
Venezuela	Consejo Nacional de Investigaciones Cientificas y Tecnologicas (CONICIT) Country Coordinator: Dulce de Uzcategui (until July 1974) and Ignacio Avalos
Yugoslavia (Macedonia)	Faculty of Economics, University of Skopje Country Coordinator: Nikola Kljusev

Appendix 2
SURVEY OF THE COUNTRY TEAM'S WORK

The organization, composition, and orientation of each of the country teams reflected the own interests and those of the institutions that hosted them, always within the framework of the STPI project concerns. A brief review of the approach and the work of each team may help to place the STPI project and the comparative reports in perspective. To complete the survey, a description of the field coordinator's office work is given.

ARGENTINA: The initial location for the Argentine team was the Department of Economics of the Catholic University. However, after some months, the university decided to withdraw its application and the country coordinator moved to the Argentine branch of the executive secretariat of the Latin American Social Science Council (CLACSO). The team was headed by Eduardo Amadeo, an economist, and two other members were appointed to work full time on the project. An advisory committee of several researchers and policymakers active in science and technology policy was formed. To carry out the research, the team relied on consultants who wrote reports on specific subjects that were integrated into a final report.

A significant change took place when the country coordinator was named president of the Instituto Nacional de Tecnologia Industrial (INTI), the national industrial technology institute, which is the largest and most important industrial research organization in Argentina. Mr Amadeo never relinquished his formal role as coordinator; after 6 months, he left his new post and resumed his position as country coordinator. Because most of the work was well under way, his absence did not substantially alter the team's pace, although the preparation of the Argentine synthesis report was postponed. Part of the team's work was reoriented to be most useful to the coordinator in his new position.

The Argentines focused on two branches of industry - machine tools and petrochemicals - but studied many broader issues. For instance, the reports include a document on the technological content of the 3-year development plan (1974-77), a study of the Argentine industrial structure, a description and brief analysis of technology policy instruments in Argentina, a study of the system for regulating technology imports, and several short reports on international technical assistance as an instrument of technology policy.

The structure of the Argentine scientific and technological system was studied in detail, as were the conditions under which it could be made more responsive to industry's needs. The Argentines covered the public sector, examining the possible role of the public sector as promoter of scientific and technological development. Detailed studies were carried out at two enterprises: one in charge of generating electricity in Buenos Aires (SEGBA) and the other in charge of generating and distributing gas for household and industrial consumption. Other contributions of the Argentine team were a study of the emergence and development of engineering and consulting firms in the chemical process industries, a detailed analysis of two research centres within the national industrial technology institute (INTI), and two short papers on capital accumulation and on the crisis of capitalism.

The Argentine team followed the methods guidelines; however, they produced a series of thematic reports on issues of actual and potential interest to policymakers in the country, coinciding with the themes selected for study in STPI.

BRAZIL: The Brazilian team was hosted at the research group of the Financiadora de Estudos e Projetos (FINEP), the state agency in charge of financing studies for investment projects and also the executive arm of the national fund for scientific and technological development. The first coordinator was the director of the research group, Fabio Erber. When he took a leave of absence from FINEP in September 1974, he was replaced by José Tavares, the new head of the research group. The group at FINEP had been carrying out research on science and technology policy for some time, and the STPI assignment was one of its tasks for 1973-76. Practically all of the work was done by members of the FINEP research group, although two or three reports were contracted to professionals outside FINEP.

From the beginning, the Brazilians decided to concentrate on the role of state enterprises in technology policy. They chose branches of industry that were dominated by state enterprises (oil and petrochemicals, steel, and electricity), conducting detailed interviews, analyzing existing data, and testing hypotheses systematically to cover issues such as the selection of equipment and processes, the purchase of engineering services, the performance of research and development, and the planning activities at these state enterprises.

In addition to the new material generated by the Brazilian team during STPI, several reports based on past research carried out by FINEP were made available to the STPI network. These included background reports on the organization and structure of the Brazilian science and technology system, a study on the machine tool industry, a report on the demand for services of 12 research institutes, and a background report on industrial policies in Brazil during the last 2 decades.

In parallel with the work for STPI, the FINEP team was also engaged in a research project on the diffusion of technical innovations in three industrial branches (pulp and paper, cement, and textiles) and they agreed to put their results at the disposal of the STPI network as an additional contribution.

The Brazilian team used the guidelines only as a general reference, given that most of their work went along different lines from those originally envisaged for the project. Nevertheless, the richness and variety of their material effectively upgraded the comparative reports.

<u>COLOMBIA</u>: No Colombian participant was present at the initial organizing meeting, and the Colombian application to join the STPI network was received later and formally accepted at the Rio meeting of the coordinating committee. The team was hosted by the Colombian Council for Science and Technology, COLCIENCIAS, and was headed by a sociologist, Fernando Chaparro. In spite of joining the STPI network late, the Colombian team caught up with the pace of work and finished all its work by the deadline.

COLCIENCIAS organized a special team with five members who devoted practically all their time to research in STPI. Several other consultants were also asked to prepare reports on issues of specific interest such as selected policy instruments. For example, a study was commissioned on the impact of tariff mechanisms; a report was prepared on the influence of price controls; and a preliminary analysis of the possible use of the state's purchasing power as an instrument of technology policy was also prepared. The branches chosen for study were all linked to agriculture: fertilizers and pesticides, agricultural machinery, and food processing, taking into consideration the interests of Colombian policymakers as perceived by the team. In these branch studies, the methods guidelines were closely followed.

Other reports prepared by the Colombian team include a study of science and technology planning, an analysis of implicit industrial technology policies, a conceptual framework for the study of consulting and engineering organizations, a series of reports on industrial branches based on discussions with panels of experts, a study of science and technology policies in the agricultural sector (to complement the analysis done for industry), and two essays on the process of industrialization in Colombia and its technological implications.

Five groups of policy instruments were studied in detail, and their impact on each branch was examined through interviews at various enterprises. All of the findings were integrated into the final report of the Colombian team.

<u>EGYPT</u>: Although an Egyptian representative participated in the initial deliberations leading to the STPI project, it was not possible to organize the team to carry out

research and prepare inputs for the international comparison. There were several administrative difficulties and staffing problems that prevented the organization of a working team. The host institution was the Academy of Scientific Research and Technology and the first coordinator was Adel Sabet, who was replaced by Gamal A. Samie in July 1975. The Egyptian team presented papers that were personal contributions based on past experience rather than the result of research carried out by a team; and research was not begun at the academy until the second half of 1976.

INDIA: The host organization in India was the National Committee on Science and Technology, and the first coordinator was Anil Malhotra, who was replaced in June 1975 by S.K. Subramanian. Mr Subramanian resigned in March 1976, and no one replaced him. No funds were requested to set up a country team in India, and the Indians provided background material that had already been collected as background for a new science and technology plan.

Three background documents were distributed along with the final S & T plan to all the teams in STPI. In addition, a report on foreign collaboration, a note on science and technology planning in India, a survey of engineering consultancy services, a report on the development of the electronics industry, and two papers on small-scale industries and technology transfer were distributed by the Indian coordinator. No empirical research was done following the methods guidelines, and the Indian contribution to the comparative reports reflects this.

SOUTH KOREA: The South Korean team was one of the first to be organized and was estalished at the Korean Advanced Institute of Science, KAIS, as part of the activities of its science, technology, and society program. KunMo Chung was named country coordinator and the team consisted of five other members. All but one of them had other academic duties and could allocate only a portion of their time to STPI research. Then, Graham Jones was hired to advise in the preparation of the report for phase 1.

The South Korean team advanced rapidly and completed its work in time for the Sussex workshop, following the methods guidelines and introducing modifications only where necessary. Two reports were produced corresponding to the requirements for phases 1 and 2 of the project.

The branches chosen for study were electronics, petrochemicals, and powder metallurgy, and a report was prepared for each one. In addition, the team prepared documents on engineering services and industrialization in South Korea, on the Korean Institute of Science and Technology, on transfer of technology in the electronics industry, on the interface between the science and technology plan and the economic development plan, and on state enterprises in technical development.

Although most of the work was done by the team located at KAIS, consultants were asked to deal with specifics. The team predominantly represented engineering and physical sciences, but an economist who was a senior government official, helped to relate the results to South Korean policymakers and to balance the other team members' biases.

MEXICO: The Mexican team was among the first to start working in STPI and was located at El Colegio de Mexico, an academic and social research and graduate training organization. Alejandro Nadal was country coordinator and there were four other members of the team who worked full time on STPI. The Mexican team initially followed the guidelines rather closely and was one of the first in suggesting modifications and changes as a result of contrasting concepts with preliminary research findings. In particular, the team found it difficult to interpret the results of interviews in enterprises using the schema proposed to study technological behaviour. The branches chosen for detailed study were capital goods, food processing, and petrochemicals.

A background report on the structure and evolution of the Mexican scientific and technological system was prepared, together with a description of the industrialization process and of agricultural development. Documents on particular subjects included a report on engineering firms, a study of the technology policy of PEMEX (the state oil monopoly), and progress reports dealing with hypotheses on the impact of policy instruments on technical behaviour at the enterprise level, a description of policy instruments in Mexico, etc.

Most of the findings of the Mexican team were integrated into the main final report, part of which was delivered at the coordinating committee in New Delhi (January 1976) and the rest at the Sussex workshop (June 1976). The work of the Mexican team covered practically all the research topics considered in STPI, and its contribution to the comparative report reflects this. The Mexican report was published in Spanish in 1977 and was awarded second prize in a contest for the best works in economics.

For various reasons, the Mexican team chose to limit its direct interaction with policymakers and followed its own research program. Results were made available to policymakers in the form of draft reports, and through the participation of the coordinator in one of the committees established to prepare the Mexican plan for science and technology.

PERU: The Peruvian team was established within the research group of the National Planning Institute. A series of administrative difficulties affected the progress of the team, including a change of technical director, when Fernando Gonzales Vigil was replaced by Roberto Wangeman in February 1975. Approximately two-thirds of the research was completed in time for the Sussex workshop.

From the beginning, the team decided to adopt a sectorial approach to the research. Efforts were focused on the study of industrial branches connected with the extraction and processing of minerals and with the provision of machinery for the mining industry. The steel industry was also studied, with emphasis on the state enterprise in charge of the largest steelworks. This meant that the guidelines were used primarily in sectorial studies and in the analysis of policy instruments.

Background reports on the situation of the scientific and technological system and on the evolution of Peruvian industry were prepared following the general framework put forward in the guidelines. In addition to these and the sectorial reports, the team prepared other documents, dealing with issues such as explicit and implicit science and technology policies, consulting and engineering capabilities, the possible use of state enterprises as instruments of technology policy, and the government administrative machinery for science and technology policy.

The Peruvian team was located within an official government organization, but its direct impact on policymaking is difficult to assess because it took the form of daily contact with government officials. On the basis of the sectorial reports on mining, a committee has been set up to review the findings of the STPI team.

VENEZUELA: The Venezuelan team was hosted by the national council of science and technology (CONICIT) and was among the first to start working. The team was initially dominated by sociologists, although economists increased their participation at later stages. The first coordinator, Dulce de Uzcategui, was replaced by Luis Matos, who was soon followed by Ignacio Avalos. Three other members worked full time, and the team was biased toward sociology and economics.

They progressed through two stages punctuated by a change in government. In the first stage, most of the background reports corresponding to phases 1 and 2 of the STPI methods were prepared, covering the science and technology, the political, the educational, and the economic systems. These reports were made obsolete by the change in government. In the second stage, the team tried to adjust to the new situation, repeating some of the earlier studies and continuing the research. However, the organization of a national congress on science and technology, which mobilized all the staff working at CONICIT, affected the team's progress.

The branches chosen for study were capital goods, electronics, and petrochemicals. In addition, reports were written on specific issues such as the governement organizational structure for science and technology policy, instruments for industrial science and technology policy, economic and financial policy instruments and their impact on technology, the purchase of capital goods in two industrial branches, and the relations between the financial system and technology policy. The Venezuelan team concluded its research shortly after the Sussex workshop.

The fact that the Venezuelan team was located in a government agency that took a very active role in science and technology policy after the change in government created both opportunities and problems. As a result of the new tasks undertaken by CONICIT, the pace and continuity of the STPI work was frequently altered. On the other hand, there was more possibility for actively contributing to policymaking. The Venezuelan contribution to the comparative reports reflects this situation.

YUGOSLAVIA (MACEDONIA): The Macedonian team was organized at the faculty of economics of the University of Skopje. A senior faculty member, Nikola Kljusev, was appointed coordinator. The team was composed of a very large number of faculty members and researchers who devoted part of their time to STPI. The tasks were subdivided and individual reports requested from various members of the team, although at a later stage two team members were asked to work full time on STPI.

The Macedonian team did not follow the guidelines, except in the preparation of a background report for phase 1. Individual reports were submitted on issues of interest to the STPI network, covering topics such as the problems of research and development in industrial enterprises, aspects of science and technology policy in Yugoslavia, the metallurgical industry in Macedonia, and the growth of engineering firms in Yugoslavia.

The Macedonian team's specificity is reflected in their relatively limited contribution to the comparative reports. At any rate, given the high degree of participation of professionals at all levels in policymaking in the Yugoslav self-managed economy, it is rather difficult to assess their contribution toward policymaking in conventional terms.

THE FIELD COORDINATOR'S OFFICE: In August 1973, at the first meeting of the coordinating committee, Francisco Sagasti was appointed field coordinator of the project and his office was established shortly thereafter and began operating in a limited way. Staffing was completed in April 1974 with the addition of two members.

The field coordinator's office was independent from the teams and was not engaged directly in empirical research. It offered organizational and technical support and contracted consultants to prepare reports on topics defined by the coordinating committee.

The field coordinator, first, drew up methods guidelines for phases 1 and 2 of the project. Background reports on technology policy in China, on technological dependence/self-reliance, on science and technology planning, on technology policies in Japan, and on technology transfer were also prepared, either by staff members of the field coordinator's office or by consultants. The guidelines for phases 3 and 4 of the project were prepared jointly by the field coordinator and a consultant. The office also organized the Sussex workshop and drafted the comparative reports. The field coordinator was also active in the board of the Peruvian Industrial Technology Institute (ITINTEC).

With the exception of the teams that were engaged in science and technology policy research as part of the activities of their institutions (the Brazilian and South Korean teams, for example), the teams were dismantled after the STPI project was completed. The field coordinator's office was closed in December 1976, and the comparative reports were prepared during 1977-1978, although some teams had not finished their work by April 1978. Even though most teams had concluded their STPI activities by the end of 1977, this does not mean that the team members left the field of S & T policy research and that their effort in STPI was not followed up. What was dismantled, as planned from the beginning, was the formal structure of the STPI project. The network of personal contacts remains in operation and most of the former team members are active in the field of science and technology policy, carrying the experience accumulated in STPI to their new positions.

Key to STPI Publications

STPI

Primary

(1) The STPI Project
(2) Methodological Guidelines
(3) Main Comparative Report
(4) Planning
(5) Chinese Technology Policy/ Industrialization

Modules

(6) S&T: Differing Schools of Thought
(7) Evolution of Industry
(8) Evolution of S&T
(9) S&T - Present Status
(10) Policy & Generation of Technology
(11) Policy for Imports
(12) Policy for Technology Demand
(13) Policy to Promote Industrial S&T
(14) Policy for Industrial S&T Support
(15) Industrial Technical Changes
(16) Industrial Technology Behaviour
(17) Technical Change Studies

Country Papers

(30) Mexico
(31) Korea
(32) Peru
(33) Colombia

Selections

(18) S&T Policy & Development
(19) Engineering Consulting & Design in LDCs
(20) Technology Transfer in LDCs
(21) State Enterprises & Technological Development

Background Papers

(22) El INTI en la Industria Argentina
(23) El Sector Maquinas Herramientas en la Argentina
(24) Los Instrumentos de Politica Cientifica y Tecnologica en Argentina
(25) Brazilian Machine-Tool Industry
(26) Los Bancos y Comercializacion de Tecnologia
(27) La Industria Petroquimica
(28) La Variable Tecnologica y las Variables Horizontales
(29) Indian Electronics Industry

A GUIDE TO THE SCIENCE AND TECHNOLOGY POLICY INSTRUMENTS (STPI) PUBLICATIONS

A. Primary Publications

(1) The Science and Technology Policy Instruments (STPI) Project (IDRC-050e) (out of print)
(2) Science and Technology Policy Implementation in Less-Developed Countries: Methodological Guidelines for the STPI Project (IDRC-067e) (out of print)
(3) Science and Technology for Development: Main Comparative Report of the STPI Project (IDRC-109e). (Also available in French (IDRC-109f) and Spanish (IDRC-109s).)
(4) Science and Technology for Development: Planning in STPI Countries (IDRC-133e)
(5) Science and Technology for Development: Technology Policy and Industrialization in the People's Republic of China (IDRC-130e)

B. Modules

These constitute the third part of (3) above and provide supporting material for the findings described and the assertions made in (3).
(6) STPI Module 1: A Review of Schools of Thought on Science, Technology, Development, and Technical Change (IDRC-TS18e)
(7) STPI Module 2: The Evolution of Industry in STPI Countries (IDRC-TS19e)
(8) STPI Module 3: The Evolution of Science and Technology in STPI Countries (IDRC-TS20e)
(9) STPI Module 4: The Present Situation of Science and Technology in the STPI Countries (IDRC-TS22e)
(10) STPI Module 5: Policy Instruments to Build up an Infrastructure for the Generation of Technology (IDRC-TS26e)
(11) STPI Module 6: Policy Instruments for the Regulation of Technology Imports (IDRC-TS33e)
(12) STPI Module 7: Policy Instruments to Define the Pattern of Demand for Technology (IDRC-TS27e)
(13) STPI Module 8: Policy Instruments to Promote the Performance of S and T Activities in Industrial Enterprises (IDRC-TS28e)
(14) STPI Module 9: Policy Instruments for the Support of Industrial Science and Technology Activities (IDRC-TS29e)
(15) STPI Module 10: Technical Changes in Industrial Branches (IDRC-TS31e)
(16) STPI Module 11: Technology Behaviour of Industrial Enterprises (IDRC-TS32e)
(17) STPI Module 12: Case Studies on Technical Change (IDRC-TS34e)

C. Selections

These are a selection of the numerous reports prepared for the STPI Project chosen as a representative sample of the various topics covered by the STPI Project in the course of the main research effort on policy design and implementation.
Science and Technology for Development: A Selection of Background Papers for the Main Comparative Report.
(18) Part A: Science and Technology Policy and Development (IDRC-MR21)
(19) Part B: Consulting and Design Engineering Capabilities in Developing Countries (IDRC-MR22)
(20) Part C: Technology Transfer in Developing Countries (IDRC-MR23)
(21) Part D: State Enterprises and Technological Development (IDRC-MR24)

D. Background Papers

(22) El INTI y el Desarrollo Tecnologico en la Industria Argentina (In press)
(23) El Sector Maquinas Herramientas en la Argentina (In press)
(24) Los Instrumentos de Politica Cientifica y Tecnologica en Argentina (In press)
(25) The Brazilian Machine-Tool Industry: Patterns of Technological Transfer and the Role of the Government (In press)
(26) Rol de los Bancos en la Comercializacion de Tecnologia (In press)
(27) Comportamiento Tecnologico de las Empresas Mixtas en la Industria Petroquimica (In press)
(28) Interrelacion Entre la Variable Tecnologica y las Variables Horizontales: Comercio Exterior, Financiamiento e Inversion (In press)
(29) A Planned Approach for the Growth of the Electronics Industry — A Case Study for India (In press)

E. Country Reports

(30) Instruments of Science and Technology Policy in Mexico (In press)
(31) Technology and Industrial Development in Korea (In press)
(32) Los Instrumentos de Politica Cientifica y Tecnologica en el Peru: Sintesis Final (In press)
(33) STPI Country Report for Colombia (In press)