INVESTING *in* KNOWLEDGE

Strengthening the foundation for research in Latin America

José Joaquín Brunner

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*C*apacity building and institutional development are the cornerstones of IDRC's policies on human resource development (HRD). Such policies aim to strengthen research capacity in the developing world to ensure the sustainable development of the scientific community. This book presents the results of the first of a series of studies being supported by IDRC on the role of the university in HRD.

Approaching the year 2000, our world is becoming more and more reliant on new knowledge. The author provides insight into the potential existing in Latin America to expand the "knowledge industry," to influence its evolution, and to link this with the essence of development. As well, the author illustrates the importance of a holistic perspective when building and maintaining research capacity in the developing world.

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Abstract

This book describes the training of human resources for research and development. It begins with an account of the advances and changes in scientific institutions in Latin America from 1960 to the present. The author presents and comments on the available quantitative data on training in the 12 countries covered in this study. He also analyzes the personnel engaged in science and technology activities in these countries, with special reference to one of the key variables in training: funding of higher education and of graduate and research programs. In addition, he discusses such topics as the productivity of science and the scientific communities. He concludes by setting Latin America's efforts to build its own research and development structures within the world context.

Résumé

Cet ouvrage fait le point sur la formation des ressources humaines pour la recherche et le développement. Il retrace les progrès et les changements enregistrés au sein des institutions scientifiques d'Amérique latine, depuis 1960 jusqu'à nos jours. L'auteur présente et illustre les données qui prennent la mesure de la formation dans les 12 pays considérés par l'étude. Il analyse également le profil du personnel engagé dans les domaines de la science et de la technologie dans ces pays, en s'arrêtant de manière particulière sur l'une des variables clés de la formation, à savoir le financement de l'université, des cycles supérieurs de l'enseignement et des programmes de recherche. Il traite enfin de la productivité de la science et du rôle de la communauté scientifique et conclut en rendant compte des efforts déployés sur le continent latino-américain pour établir des structures spécifiques de recherche et développement dans le contexte mondial.

Resumen

Este libro describe la capacitación de recursos humanos para la investigación y el desarrollo, comenzando con un recuento de los avances y cambios registrados en instituciones científicas de América Latina desde 1960 hasta el presente. El autor presenta y comenta la cantidad disponible de datos sobre capacitación existentes en los 12 países estudiados. Asimismo, analiza el personal que participa en actividades científicas y tecnológicas en estos

países, refiriéndose especialmente a una de las variables fundamentales de la capacitación: la concesión de fondos para la educación superior y programas de graduados e investigativos. Adems, se debaten tópicos tales como la productividad de la ciencia y de las comunidades científicas. El autor concluye su libro describiendo los esfuerzos que realiza América Latina para construir sus propias estructuras de investigación y desarrollo dentro del contexto internacional.

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Foreword

This study by José Joaquín Brunner will certainly provoke a wide range of thoughts and concerns in its readers. I cannot claim, in this preface, to comment on all the various ways in which the text can be analyzed; I will, instead, offer a number of remarks and reflections that, as is paradoxically the case with most prefaces, should really be read at the end, and not at the beginning, of the text that stimulated them.

My point of departure is to be found in one of the main conclusions reached in Brunner's work: that in Latin America, there is a relatively high degree of dissociation between scientific and technical development and the political and economic variables traditionally linked to such development. On one hand, Brunner notes that the various political regimes and levels of economic development, urbanization, and education expansion are matched, in Latin America, by similar organization and style in scientific and technical development. He also shows, however, that there is a sharp discontinuity between the behaviour of the economic, political, and educational variables and the indicators of scientific and technical development. This perception is reaffirmed at the end in the analysis of the responses to the economic crisis that, for the last 10 years, has afflicted the countries of the region.

This separation between the various levels of the social structure is no novelty in studies of Latin America. It has in fact been remarked upon as the principal characteristic of dependent or colonial societies. What is of most interest is Brunner's observation that this separation has become the main factor both in the growth and in the vulnerability of scientific and technical activities. It constitutes the main factor in their expansion inasmuch as it makes it possible to overcome the limits set by the low level of demand from the productive apparatus, the weak educational base of the population, or the hostility of the political authorities. But it is also the main factor in the vulnerability of these activities. It prevents the consolidation of firm bases for the systematic accumulation of achievements, which is only possible where there are stable programs and flexible feedback mechanisms with sources external to the simple corporate interest of the scientific community.

In a growth setting of this kind, Brunner provides an exhaustive analysis of the changes that have occurred in the last two decades. He quite rightly stresses that it is not a void that we are looking at, but rather a complex situation, in which a variety of people and institutions are employing a variety of articulating mechanisms and action strategies.

In development of this type, political will — expressed through the role of the State — and the economic and social conditions that have accompanied the process of industrialization have been of crucial importance. However viewed from *within* scientific and technical activity, this development took place in a setting in which certain characteristics, which are now dominant, had not yet appeared with such clarity. In this area, there are two aspects worth mentioning. The first is the noteworthy *acceleration* in the process of producing scientific and technical knowledge. The second is the changed relationship between science and technology. The distance separating them has quite obviously decreased, and this has led to important changes in institutional ways of "doing science." The places responsible for production (firms) are becoming increasingly places where knowledge too is produced. This is creating a natural tendency to apply the same logic to scientific and technical research as to the other products of economic activity.

The upshot is that there now exist a variety of possible scenarios for the future. One such is an even greater concentration of scientific and technical activities, involving the exclusion of the developing countries, or their inclusion only as consumers of products originating in the central countries. As an alternative to this scenario, there is another in which endogenous processes of technological creativity are stimulated, based on those established centres of capability which exist in a number of countries in the region. At the end of his book, Brunner sketches out the main lines of such a strategy. Here, I just want to add two further points. One, in a certain sense, involves the author's previous reasoning and the other the final stage of his argument.

With regard to the earlier phase of his analysis, we must ask if the separation that has so far characterized regional scientific and technological development will in fact persist. Brunner is right to point out that hopes cannot be based on a single model or the complete rationality of future strategies. Separation, when it takes the form of diversified actors, institutions, and methodologies, etc., turns out to have positive virtues. However, in the present contexts, both regional and international, it does not seem possible to generate sustained growth in scientific and technical activity, unless it is clearly articulated with development strategies, built on a basis of concerted action by all those involved: government, public corporations, universities, and the private sector.

From this standpoint, it would seem to be important to place on the agenda, when such problems are discussed, a question about the way in which the Latin American political classes perceive the role of science, technology, information, creativity, etc., in development strategies. This point, the reality of which is plain to see in the developed countries, is, as yet, only a hope in developing countries. Except in a certain modernizing rhetoric in some political speeches, there is nothing to suggest that such factors are viewed as having priority or that such a priority is being translated into concrete policy decisions. The need to cope with the challenges of the current crisis blocks the development of any medium- or long-term vision, in which investments in education, science, and technology make sense. If discussion of the role of education, science, and culture in development strategies is to be introduced into the sphere of the decision-makers, there will obviously have to be a serious review of the concrete mechanisms for action in such fields. This will involve, as a first requisite, examining management methods aimed at introducing such values as relevance, efficiency, responsibility for results, etc.

My second observation, which is more concerned with the specific consequences of Brunner's analysis of education policies, amounts to drawing attention to the importance of providing scientific training for the *entire* population. Only scientific training on a mass scale (i.e., beginning in elementary school, universal, and obligatory) can ensure the existence of a top group of creatively talented people able to function in a social context that provides them not only with stimulation, but can also control them effectively.

Such a notion suggests that the sphere of science and technology strategies is larger than that of the leaders of society. Latin America is faced with the double challenge of providing basic education for the whole population while developing its scientific and technological potential. One way, though not the only one, of ensuring that the modernization proposals, which argue for scientific and technological development, do not become entrapped in an elitist political logic consists, within the specifically educational context, of ensuring that creativity becomes a value inherent in the socialization of the entire population, and not just one segment of it.

Juan Carlos Tedesco
Director
Regional Education Office for Latin America and the Caribbean
Unesco

Preface

This study was prepared within the framework of a *Regional Consultation on Human Resources for Research in the Latin American Countries* sponsored by the International Development Research Centre (IDRC) of Canada. The purpose of the regional consultation was to "study the situation in a group of Latin American and Caribbean countries with regard to human resources for research, with a view to identifying the most important factors influencing the training and utilization of such resources."

The regional consultation involved three phases. In the first of these, IDRC's Regional Office for Latin America and the Caribbean (now in Montevideo, Uruguay) designed a questionnaire to obtain relevant national information. It was sent to organizations responsible for scientific and technological activities in the 12 countries selected and to national experts. The office also assigned to each country the responsibility for preparing a national report. Each national organization or expert had to organize the available secondary data in the country and evaluate previous studies of human resources for research.

The second phase was a meeting of technical consultants held in Bogotá, Colombia, in August 1986. At this event, the national reports were analyzed and the terms of reference were established for a discussion paper that would serve as the basis for the final meeting of the regional consultation. In addition, consultants were asked to write various supplementary papers.

The third phase of the consultation was a seminar held in Bahía, Brazil, in April 1987. The meeting was attended by the authors of the national reports and a group of experts. They jointly discussed the materials prepared in the course of the consultation. The seminar drew up recommendations and set up a Latin American network of persons and organizations interested in studying and developing policies on training human resources for research.

This book is the final version of the discussion paper prepared for the meeting in Bahía, Brazil. In preparing this study, I based my work on the national reports. These are referred to in the text as the base studies, and are as follows:

- **Argentina**: *Consulta regional sobre recursos humanos para la investigación en América Latina y el Caribe: estudio de caso* by the National Council of Scientific and Technical Research (CONICET), Buenos Aires, Argentina, July 1986.
- **Brazil**: *Recursos humanos para a pesquisa nos países de América Latina e do Caribe* by Tarcisio G. Della Senta, Brasília, Brazil, March 1987.
- **Chile**: *Capacitación de recursos humanos para la investigación: caso de Chile* by the National Commission for Scientific and Technological Research (CONICYT) (Sergio Montenegro, ed.), Santiago, Chile, October 1986.
- **Colombia**: *Política científica, formación de recursos humanos y su utilización en la investigación* by Pedro Amaya, Germán Mesa, and Alvaro Vásquez, Bogotá, Colombia, October 1986.
- **Costa Rica**: *Recursos humanos para la investigación: el caso de Costa Rica* by Mariano Ramírez, San José, Costa Rica, June 1986.
- **Cuba**: *Los recursos humanos para la investigación: su formación y utilización en la República de Cuba* by Fernando Vásquez, Havana, Cuba, 1987.
- **Dominican Republic**: *Recursos humanos para la investigación en los países de América Latina y el Caribe: caso de la República Dominicana* by the Secretariado Técnico de la Presidencia, Oficina Nacional de Planificación, Departamento de Ciencia y Tecnología, Santo Domingo, Dominican Republic, August 1986.
- **Dominican Republic**: *Recursos humanos para la investigación en República Dominicana* by the Consejo Nacional de Educación Superior, Santo Domingo, Dominican Republic, October 1986.
- **Ecuador**: *Recursos humanos para la investigación en los países de América Latina y del Caribe: monografía del Ecuador* by the Consejo Nacional de Ciencia y Tecnología (CONACYT), Quito, Ecuador 1986.

- **Guatemala**: *Consulta regional sobre recursos humanos para la investigación en América Latina y el Caribe: monografía nacional de Guatemala* by Rubén Nájera, Guatemala, Guatemala, June 1986.
- **Mexico**: *Recursos humanos para la investigación científica y tecnológica en México* by Jorge Elizondo, Mexico City, Mexico, July 1986.
- **Peru**: *Aproximación preliminar al estudio de los recursos humanos para investigación y desarrollo en el Perú* by Francicco Sagasti and Cecilia Cook, Lima, Peru, April 1986.
- **Venezuela**: *Recursos humanos para la investigación en Venezuela* by the National Council for Scientific and Technological Research (CONICIT), Caracas, Venezuela, August 1986.

The following supplementary papers were presented at the Bahía seminar:

- *Desarrollo de los recursos humanos para la investigación en América Latina* by José Joaquín Brunner (a revised version of this paper is the final chapter of this work).
- *Human resource development and development assistance: policies and practice concerning foreign students in OECD countries* by Hans Schutze.
- *Formação de recursos humanos para pesquisa no Brasil* by María Carlota de Souza Paula and Ana Lucia Assad Rios.
- *La crisis económica de América Latina situación actual, antecedentes y perspectivas* by Osvaldo Sunkel.
- *Innovación tecnológica y recursos humanos en la firma* by Jorges Vivas.

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Introduction

The subject broached here — training human resources for research and development (R&D) — is complex and vast. This study aspires to cover just one aspect of it: to describe the dimensions of the phenomenon and the context into which it should be inserted. It should, therefore, be seen as a working report rather than as an interpretative study.

The first chapter briefly compares the state of science as an institution in Latin America currently and at the beginning of the 1960s. This illustrates the progress and changes that have occurred. There is no attempt to situate these changes within the more general picture of worldwide scientific development, although the last chapter touches briefly on this aspect (see Fuenzalida 1971; Vessuri and Diaz 1986).

Chapter 2 presents and discusses the available quantitative data on human resource training for research and development in the 12 Latin American countries covered by the study. The size of groups with graduate training in these countries is presented and the distribution and occupational profiles are described for some of them. This chapter also analyzes, from each country, university enrolment, graduates, and nationals who are pursuing advanced studies abroad.

Chapter 3 is devoted to investigating the personnel engaged in scientific and technical activities in the countries in question. Information obtained directly from the regional consultation is used, as well as data from complementary sources.

On the assumption that graduate programs — or at least some of them — are the main local vehicle for training researchers in Latin America, Chapter 4 examines the actual state of these programs, their scope, the way they function, and the results produced. The chapter also describes the most salient characteristics of the teachers and students involved in the programs.

Chapter 5 deals with one of the key variables in the training of human resources for R&D in Latin America: funding for higher education, graduate programs, and research.

Chapters 6 and 7 provide contextual information that must be considered in the discussion and development of policies for training scientists and engineers for R&D. Chapter 6 analyzes the productivity of mainstream science, which is recorded internationally and produced essentially by developed countries, and the limitations of the mainstream approach as a means of measuring and analyzing Latin American scientific output. Criticism of the mainstream approach is widespread in Latin America but has not resulted in proposed new ways of understanding and measuring the productivity of science that is produced and disseminated locally. Therefore, I have not placed much emphasis on such criticism. Chapter 7 brings together some considerations on scientific communities, i.e., groups formed by scientists in a given specialization to maintain professional contacts, exchange information, give out awards and recognition, and, in short, advance knowledge.

The final chapter places Latin America's efforts to develop its own R&D structures in the world context of science and technology. The extent of these efforts and their limitations are analyzed, as are the possible consequences of the economic crisis at the beginning of this decade on investments in science and technology (S&T). The findings are used as a framework for the analysis of R&D policies, specifically the policies for training human resources in S&T.

The use of the term "human resources" in this study neither implies any special interpretation of the term nor endorses any of the theories or ideologies implicit in the discussions on the subject that took place during the 1960s and part of the 1970s. The term is used purely descriptively, maintaining continuity with the title of the regional consultation that gave rise to this book.

1

The Changing Picture

Innumerable explanations have been offered in Latin America for the scientific and technological backwardness of the region. In the 1960s, a start was made on identifying the educational factors that might have had something to do with the lag. It was recognized, however, that the deeper causes lay in "key factors which condition the general underdevelopment of the region" (Herrera 1970: 17).

This new concern was most certainly related to the requirements of modernization and to the simultaneous spread of uneasiness over the slow and uneven economic growth in Latin America (see ECLAC 1967). Public action in response to these demands and concerns took two forms. First, there was a widespread movement in support of planning for development. Second, in the field of education, systematic, sustained planning of the training of human resources was proposed (see Solari 1977).

Science and Technology in the 1960s

A key document from the Economic Commission for Latin America and the Caribbean (ECLAC) in 1967 justified the importance of and the need for planning education on the basis of six converging arguments (ECLAC 1967: 210–211):

➤ There will soon be explosive growth in the demand for education.

- ➤ Pressure to expand and democratize the coverage of the educational system is increasing.
- ➤ The future demand from the economic system for qualified personnel must be met.
- ➤ Ways of making the most efficient use of trained human resources must be found.
- ➤ It is imperative to plan ahead for the supply of educated personnel to meet development needs.
- ➤ Educational services can only achieve their ethical and social goals if they are distributed equitably.

In purely quantitative terms, the effort needed in the field of education seemed to be enormous. According to ECLAC (1967: 9) projections:

> By 1980 there will be a need for approximately 1.2 million highly qualified professionals, almost twice the present number, and their distribution over the various specialities will have to be very different from what it is now; the number of people with secondary education will almost have to triple and the internal make-up of this category will have to be modified to tailor training to changing economic and social requirements. This would improve the current unsatisfactory ratios between professional and support staff in many professions. In the vast category of workers in the production sector, the percentage of skilled workers will have to rise from 10% to a minimum of 15%, which means that the absolute figures must almost be trebled.

With regard to the situation in universities and higher education, ECLAC (1967: 177) indicated that lack of research "has been and still is the major shortcoming of Latin American universities." The budgetary, financial, and administrative organization of the universities, it was argued, did not favour research, nor did the traditional patterns of academic organization, the low level of professional training in the teaching body, or the isolation of higher educational institutions. The document concluded that far-reaching reforms were needed at this level of the educational system (ECLAC 1967: 179), which could only be successful

> as a result of national planning which would clearly determine the functions and products to be expected of it, so that internal planning in universities does not take place in a vacuum.

However, the specific problem of training researchers and properly qualified personnel for research and development (R&D) was not, at that time, at the centre of the discussion of educational planning and policies for S&T. A review of the educational goals contained in the plans in effect in the mid-1960s shows that most of them emphasized, at the level of higher education, quantitative growth in enrolment and, to a lesser extent, the problems of access to higher education (e.g., scholarships), investments, and physical plants (buildings, campuses, laboratories) (see ECLAC 1967: table 19).

However, the need to plan the scientific effort of the countries in the region was being raised insistently in specialist circles. Herrera (1970: 34), for example, suggested that policies on research should be formulated within the larger context of national planning, in three successive stages:

- Ranking the problems and needs of countries in order of priority to reflect national development strategies;
- Translating these economic and social needs into technical terms, thereby turning the problems into concrete targets for research; and
- Implementing the results of such research and incorporating them into the functioning economic system.

Other specialists stressed the need to proceed with the institutionalization of science and R&D. To this end, they proposed the creation, development, and reinforcement of a true S&T infrastructure, sufficiently complex and differentiated to tackle the challenges posed by the planners and demanded by the developmental spirit of the times. Sábato and Botana (1970: 62–63), for example, define this infrastructure and identify the following interrelated components:

- The educational system that produces the people who play the principal role in research (scientists, technologists, associates, assistants, workers, and administrators);
- Laboratories, institutes, centres, and pilot plants in which research is done;
- Legal and administrative mechanisms to regulate the operation of scientific institutions and R&D activities; and
- Economic and financial resources for their operation.

Finally, there was frequent insistence on the close relationship that ought to exist between this "scientific and technological infrastructure," in which universities played the central role, the production sector (firms), and the State. The State, especially, was called upon to "support teaching programs, universities and scientific institutes in developing countries" (Leite Lopes 1970: 54), while industry would experience more far-reaching and autonomous growth, which could enable the private sector to take a more decisive lead in R&D activities.

The dimensions

In the 1960s, the scientific and technological infrastructure in Latin America was negligible in size and unevenly distributed among the countries of the region. In 1965, only 1% of the economically active population in the region could be described as professional — a total of 600 000 people. Of these, 450 000 were working in different service sectors. Agriculture employed less than 3% (20 000) of these professionals. Mining employed a similar number; manufacturing employed around 8% (48 000); and construction and basic services each employed about 5% (30 000) of this group of professionals (ECLAC 1967: 123).

Only about 1 million people (1.4% of the economically active population) had either completed university or studied at the university level. Nearly 180 000 of these fell into the broad category of potential scientists and engineers, including civil engineers employed in the construction industry, science and mathematics teachers, and people working in other areas far removed from R&D activities (Urquidi 1970: 39). Rough estimates indicate that by 1960 there were 15 000 scientists and engineers working in R&D in the whole region. About 170 000 professionals with advanced training were estimated to be working in the field of medicine, including dentistry, and 90 000 were working in economics and the social sciences, including accounting and related fields of a semiprofessional character (ECLAC 1967: 30).

There were about 800 000 students pursuing university studies. In 1965, 70 000 of these graduated. Of the total number of graduates, 4 000 were in the natural or exact sciences and 8 000 were in engineering and technology. Graduates in medicine and related fields numbered 20 000 in 1965; in economics and the social sciences, the figure was close to 10 000.

At that time, the countries of the region invested around 0.2% of their gross national product (GNP) in science and the development of technology, i.e., roughly 0.70 USD (United States dollars) per capita. At that same time, Canada was spending around 22 USD per capita for the same purpose (Urquidi 1970: 41). In Latin America, moreover, this spending was limited almost entirely to six countries: Argentina, Brazil, Chile, Colombia, Mexico, and Venezuela.

In short, the scientific and technological infrastructure of the region in the 1960s was modest in size, its development was weak, and its institutionalization was only just beginning. Moreover, its output was modest, its worldwide impact slight, and its links to industry and government tenuous, despite the fact that regional scientific and technological activity depended largely upon government and upon public funding for its development.

The Institutionalization of Science

It is only in the last two decades that a beginning has been written of the history of science in Latin America, just as it was coming to occupy a position of greater importance in society. Looking only at the period following the Second World War, common patterns and dynamics in the institutionalization of science can be detected.

The first and most obvious is that science in the region was initially almost exclusively the affair of the universities, where it began to be a professional activity and to develop on a modern scale. In several countries, the first decisive steps toward establishing scientific research were, in fact, taken in the previous decade. This is illustrated by the existence of the Institute of Physiology at the National University of Buenos Aires, directed by Bernardo A. Houssay (winner of 1947 Nobel Prize for Medicine), and the Institute of Biophysics at the University of Rio de Janeiro, under the direction of Carlos Chagas Filho.

In the early stages, the growth of science in Latin America resulted from the work of small nuclei of foreign and national researchers. Generally, they had to operate in an environment that was hostile and, at best, indifferent (Brazil — Schwartzman 1979; Chile — Brunner 1988; Barrios and Brunner 1988; Courard 1986, 1987; Peru — Sagasti et al. 1985; Venezuela — Vessuri 1984a; for a complete collection of recent studies on this topic, see CLACSO 1987). These groups, which frequently originated in the field of medicine, subsequently gave rise to the first medical and biological research institutions. Their work developed in contact with foreign countries through programs of grants and foreign aid. In some cases, foreign aid became significant at an early stage (e.g., Brazil). Schwartzman (1979: 248) estimates that from 1930 to 1935 the Rockefeller Foundation made grants to Brazil totalling 1.7 million USD, all destined for the health sciences sector.

University enrolment began to grow rapidly in 1950. As a result, the universities became more complex and their teaching staff became more professional. They devoted more time to their work, and specialization and subspecialization intensified within the disciplines. Links with foreign countries, especially the United States, grew stronger.

Growth in the number of disciplines and specialities within disciplines, even when it occurred within the organizational model of a traditional university department, inevitably led to the establishment of disciplinary or specialist subcultures. This was a necessary condition for the creation of scientific communities, which then began to regulate their own activities on the basis of results that could be evaluated and to set standards for production, recognition, and promotion.

In turn, the core groups of professional scientists established their own scientific societies and even set up national associations of researchers. In Brazil, the Sociedade Brasileira para o Progresso da Ciencia (Brazilian society for the progress of science) was established in 1948. In Venezuela, the Asociación Venezolana para el Avance de la Ciencia (Venezuelan association for the advancement of science) was founded in 1950, and soon led to the publication of a specialized journal, *Acta Científica Venezolana*.

At the same time, governments expressed growing interest in the development of the sciences and set up special bodies to program and coordinate research activities. In general, the founding of these bodies reflected the budding capacity of local scientific communities and their most active sectors for lobbying and negotiation. They, in fact, managed to mobilize politicians and bureaucrats to set up these new public bodies for the purpose of promoting S&T activities. In a many countries in the region, it was a long time before such institutions assumed their final form. They grew slowly out of a succession of agencies, gradually becoming more specific about their goals and defining more narrowly their fields of action, until they came to focus exclusively on S&T development.

In Mexico, for example, the Consejo Nacional de la Educación Superior y la Investigación Científica (national council for higher education and scientific research) was founded in 1935. This was followed, in 1942, by the Comisión Impulsora y Coordinadora de la Investigación Científica (committee for the promotion and coordination of scientific research) and, in 1950, by the Instituto Nacional de la Investigación Científica (national scientific research institute). The Consejo Nacional de Ciencia y Tecnología (CONACYT, national science and technology council) was finally created 20 years later, in 1970.

In Brazil, the Conselho Nacional de Pesquisas (CNPq, national research council) was established in 1951. It was followed in subsequent decades by the Fundo Nacional de Desarrollo Tecnológico

(FUNTEC, national fund for technological development) and the Financiadora de Estudios e Proyectos (FINEP, studies and projects funding agency) of the National Economic Development Bank.

The course of events was similar in almost every country of the region. Uruguay in 1961, Chile and Venezuela in 1967, Peru and Colombia in 1968, Argentina in 1969, and other countries in the 1970s set up new institutions charged with planning, promoting, and coordinating S&T research. Almost everywhere, these new institutions profited from past local experience, and they absorbed or merged preexisting bodies or created new ones that would be redefined yet again at a later date.

Many authors have noted the relatively artificial nature of these institutions, pointing out the limited scope of S&T in Latin America and the negligible subsequent impact of the plans and activities of these national councils. Some, in fact, attribute this relative failure of national coordinating agencies to the dependent nature of Latin American society. They postulate that this dependence undermined such efforts precisely because local S&T had little independence (see Amadeo 1978). Further empirical information and a more refined analytical framework would be required before conclusions of this kind could be drawn.

What is certain, however, is that the establishment of national research and technology councils since the 1950s demonstrates growing public concern with respect to R&D. The public expressed a political will, no matter how limited, to foster such activities and provide them with government support. These activities chiefly took place in universities, which, because of prevailing Latin American tradition, had considerable independence. Because research resources were mainly channelled through university budgets, the coordinating institutions in question were created under severe constraints; only with time could they play a more significant role, at least in some countries in the region.

The Institutionalization of Research

The little I have said so far about the relationship between science and society, i.e., between research efforts on the one hand and economic structures and political actors on the other, should be enough to caution against any simple (or, worse still, simplistic) model explaining this relationship. For example, to say here that science is a social product, is to say very little. To assert that research activities depend on factors external to the practices of researchers is merely trivial. Even the polemic between "externalists" and "internalists" in the history of science is now, relatively speaking, out of date (see Kuhn 1982: chapter 5). Any current explanation of scientific development must explore, in the minutest detail, the specific internal and external elements that combine to affect the development of such intellectual undertakings.

Lastly, and inescapably, any rigorous approach to the sciences (historical, sociological, psychosocial, economic, or political) must always be concerned with special groups of professional practitioners: scientists, without whose activities such undertakings would not exist or would become incomprehensible. Students of the sciences and those wishing to influence and stimulate the growth of such groups must ask the following central questions:

- How are such aggregates of specialists formed and organized?
- How do their members become socialized, become incorporated into a collective professional group, and acquire identity within it?
- How do the groups operate, select their lines of activity, and earn recognition in the field of science?
- How do they obtain and mobilize resources and legitimize their claims?
- How are they connected to and constantly influenced by external factors such as industry, government, public opinion, the media, publishing houses, and the international academic market?

Probably none of these elements, if taken in isolation, has any direct connection with any given factor in the economic or political structure or the culture of a country. Each one interacts in a complex way with the other internal elements. All of them, moreover, interact in various ways with external factors and circumstances, including economic cycles, government decisions, cultural settings, wars, international conditions for cooperation or competition, developments in industry, changes in the educational system, progress in scientific activity, and experimental development in the central countries of the North.

The preceding survey of the development of the sciences in Latin America seems to confirm the need for a combined approach to human resources for research. In fact, the establishment, even tentatively, of small communities of specialists and the beginning of their institutionalization in universities (or public institutes) has provided the point of departure for professional S&T activities in the region. The internal dynamics of these communities have generally triggered the development of such activities. To function, however, they needed the convergence of other external factors: the expansion of the university structure; the professionalization of university careers; increased government spending on higher education; the crystallization of the efforts made by national research planning and coordinating institutions; the concurrent impact of international cooperation; etc.

Thus, over two decades, societies that differed greatly from one another, whose intellectual and cultural institutions had developed unevenly, that were run by different kinds of governments, sometimes even based on opposing principles, and in which there were differing degrees of urbanization and industrialization tended to converge upon a similar concern and adopted a similar style in developing their science and technology. It would be too easy to explain this phenomenon with a kind of "megastructure of dependence" that would supposedly have induced the same dynamics and similar effects everywhere. If pushed to its limits, the dependence theory — like universal theories of modernization, offering a metaexplanation of concrete processes in any society — tends to void history of its tangible content and transforms its actors, their conflicts, its structures, and their evolution into simple, potential forces subject to absolute determinism. It is more likely that such similarities are the result of internal components in the development of S&T activities and the existence of a common pattern of interaction with relatively similar external factors. In Latin America, for example, systems of higher education have changed significantly in the last 30 years.

The purpose here, however, is not to explore such broad and controversial topics. They involve concepts of history, with relatively irreducible theoretical assumptions, and with the values and expectations underlying the various approaches to studying the development of S&T activities. The purpose of this study is much more limited. It is to examine the current availability of human resources in Latin America for scientific and technological activities, their distribution in the various countries covered by this study, and aspects of their education and training. In other words, this book will identify, describe, and measure the changes produced in the scientific and technological infrastructure of the region from the 1960s to the present. Based on the accumulated information, a line of reasoning will be presented that can be used to define policies for the training of human resources for research to deal with the problems and challenges currently facing the region.

The New Circumstances: Context of the Debate

From the early 1950s to the beginning of the 1980s, Latin America developed unevenly but significantly. The pattern of production in the region has also changed. Today, Brazil and Mexico contribute about 60% of the regional gross domestic product (GDP); the countries of the Southern Cone (Argentina, Chile, and Uruguay), which contributed about 31% in 1950, now provide only 16% of the regional GDP. These changes have produced a relatively intense process of change in social and job stratification in all countries of the region. In most countries, nonmanual (white-collar) employment has grown, with an increase in the number of professionals and in the university-educated population. Today, it is estimated that there are 3.5 million highly qualified professionals in the region, about 90 000 of whom are engaged in R&D activities.

There are now almost 6 million university students in Latin America. In the early 1980s, about 486 000 students graduated each year, including 15 000 graduates in natural and exact sciences, 82 500 in engineering and technology, 74 000 in medical science, and 297 000 in social sciences and education.

In short, the context and magnitude of S&T have changed significantly in Latin America in the past 20 years. In 1960, the region spent about 0.2% of its GNP on R&D; by 1970, this figure had risen to 0.3%, equivalent to 498 million USD; by 1980, 3.7 billion USD was being spent annually on R&D, representing 0.5% of the regional GNP. This level of spending on R&D is equivalent to 10 USD per capita, which is more than 10 times the per-capita spending of 20 years ago. It is true that these changes have been more marked in some countries than in others. Even in the smallest countries, however, considerable progress has been made and the problems they are currently encountering are formidable. The aim of the following chapters is to present a comprehensive picture of these changes, to identify the major trends and dynamics, and, as much as possible, to quantify the different operating variables.

2

Human Resources at the Advanced Level

The universe of highly qualified human resources in Latin America is difficult to quantify. The measurement tools that are normally used are either too general and fail to break the information down to the necessary extent (as is the case with population censuses) or they are relatively exact but are always applied to limited local situations (e.g., censuses of scientific staff), using criteria and categories that make it impossible to compare the results on an aggregate level or between countries. Therefore, it is difficult to link the "macro" and "micro" aspects of these measurements. Another problem is that data banks at both levels tend to change their methods over time, making comparisons between periods difficult, sometimes even within the same country.

Having acknowledged these limitations, this chapter will identify the population of highly qualified human resources in Latin America. It is within this population that the scientists and engineers involved in R&D are to be found. Three aspects of the group will be discussed:

- The composition of, and changes in, the middle and upper levels of the economically active population (EAP);
- The educational and occupational profiles of professional groups; and
- Changes in enrolment and number of university graduates.

Qualified Personnel

Table 1 shows changes in the middle and upper levels in secondary and tertiary occupations as a percentage of the EAP for the countries covered by this study, except Cuba. The stratification scheme and the methodology used here to process the data are those of Filgueira and Geneletti (1981). Table 1 presents separately the changes in the different groups or categories in the middle and top levels. For this study, group A is of greatest interest; it is composed of employers, managers, administrative personnel, and professionals and technicians. The "professionals and technicians" subcategory accounts in all cases for the largest portion of group A. In 1980, it represented 10% or more of the EAP in the countries with a relatively higher degree of modernization or with a faster rate of modernization. In Chile and Uruguay, this subcategory decreased between 1970 and 1980; the number for Argentina remained virtually stationary. Undoubtedly, the existence of military regimes in these three countries has had an influence. They applied neoliberal development models that had a decisive effect on the so-called professional middle classes, slowing growth in postsecondary enrolment and the number of professional jobs in the bureaucracy of the public sector.

In countries whose modernization is advanced (Argentina, Chile, Costa Rica, and Venezuela), the proportion of workers in group A ranged from 8.5 to 15.6% of the EAP. In 1950, Argentina was already at 12.2%; the other countries in the advanced modernization category were around 6%. In large countries with rapid and unbalanced modernization (Brazil, Colombia, and Mexico), the high-level subcategory within the EAP rose to about 10% between 1970 and 1980. Medium-sized and small, partially modernized countries (Ecuador, Peru, and the Dominican Republic) also came close to this level.

The case of countries with "incipient modernization" is very different: the share of the highest category in 1970 ranged from 3.3% in El Salvador to 8.1% in Bolivia. Guatemala is slightly below the mean in this range; Nicaragua and Honduras are slightly above.

Job Distribution and Education Profile

In 1980, in Argentina, the EAP over 14 years of age was almost 10 million. Almost 1 million had complete or incomplete postsecondary education; almost 400 000 had completed university (Table 2).

Table 1. Middle and upper levels in secondary and tertiary occupations as a percentage of the EAP in 11 selected Latin American countries, 1950–1980.

	1950				1960				1970				1980			
	T[a]	A	B	C	T	A	B	C	T	A	B	C	T	A	B	C
Argentina	27.8	12.2	15.0	0.6	31.4	14.7	14.3	2.4	32.4	15.2	12.7	4.4	34.2	15.6	13.2	5.4
Brazil	13.2	2.2	8.5	2.5	14.5	7.6	6.6	0.3	17.9	6.7	8.4	2.8	24.5	10.0	12.0	2.5
Chile	20.7	6.2	8.7	5.8	20.1	7.3	9.1	3.7	25.4	10.0	11.6	3.6	32.3	8.5	15.6	8.2
Colombia	12.3	4.8	3.6	3.9	17.6	7.8	6.7	3.1	20.5	9.2	8.6	2.7	—	—	—	—
Costa Rica	14.1	5.5	6.7	1.9	19.5	7.4	8.9	3.2	23.5	9.1	10.4	3.2	29.2	11.4	12.5	5.3
Dominican Republic	—	—	—	—	11.8	3.4	4.7	3.7	12.2	3.5	6.8	1.9	—	—	—	—
Ecuador	9.7	3.5	3.7	2.5	12.4	3.8	4.2	4.4	16.4	6.5	5.5	4.4	22.7	9.7	7.5	5.5
Guatemala	6.0	2.7	2.4	0.9	9.0	5.1	3.1	0.8	11.0	5.0	4.3	1.7	—	—	—	—
Mexico	—	—	—	—	19.9	13.6[b]	6.3	—	22.4	10.4	9.2	2.9	—	—	—	—
Peru	—	—	—	—	16.4	5.1	5.8	5.5	21.1	8.0	7.7	5.4	29.7	9.0	12.9	7.8
Venezuela	16.3	6.7	5.5	4.1	23.9	8.0	10.5	5.4	29.4	10.2	14.0	5.3	—	—	—	—

Source: Rama (1984).

[a] T, middle and top levels in secondary and tertiary occupations; A, employers, managers and administrative staff, professionals and technicians; B, office workers, salespersons, and similar personnel; C, self-employed in business; T = A + B + C.

[b] Includes self-employed in business.

Table 2. Distribution of the EAP over 14 years of age by level of higher education and occupational group in Argentina.

Occupational group	Higher education				University			
	Incomplete		Complete		Incomplete		Complete	
Professionals	994	(1.6)[a]	7 357	(5.2)	19 239	(5.1)	245 118	(62.1)
Business managers and public officials	725	(1.2)	3 156	(2.3)	9 732	(2.6)	13 928	(3.5)
Teachers	14 841	(23.9)	83 154	(59.7)	29 852	(7.9)	42 742	(10.8)
Chiefs, supervisors, foremen	1 041	(1.7)	1 960	(1.4)	13 574	(3.6)	8 218	(2.1)
Technicians	4 898	(7.9)	12 220	(8.8)	39 673	(10.5)	22 067	(5.6)
Employees	25 719	(41.4)	17 489	(12.5)	146 337	(39.2)	28 677	(7.3)
Sales persons	6 580	(10.6)	6 453	(4.6)	67 082	(17.8)	14 440	(3.6)
Specialized workers	5 085	(8.2)	4 642	(3.3)	40 077	(10.7)	12 422	(3.1)
Labourers, apprentices	521	(0.8)	264	(0.2)	1 826	(0.5)	352	(0.1)
Domestics	409	(0.6)	170	(0.1)	729	(0.2)	208	(0.1)
Unclassified	1 283	(2.1)	2 520	(1.8)	7 155	(1.9)	6 516	(1.6)
Total	62 096	(100.0)	139 385	(100.0)	376 276	(100.0)	394 688	(100.0)

Source: 1980 census, special tabulation.

[a] Figures in parentheses are percentages of total in the educational category.

In Brazil in 1980, there were 1.8 million economically active people who had completed higher education (Table 3). The rural sector accounted for only 39 000 of this total. In 1980, Brazil had 64 000 people with graduate degrees (both master's degrees and doctorates). There were over 700 000 people employed in scientific and technical positions; their distribution is shown in Table 4.

In Chile in 1980, people with 10 or more years of schooling constituted 35.4% of the population, double the 1970 percentage (17.5%). For the male EAP, the percentage was 31.8%; for females, it was 44.3%. Table 5 shows the distribution of the Chilean work-age population by number of years of postsecondary studies and position in the labour force in 1984.

In Cuba in 1981, the EAP aged 15 to 49 years totalled just under 3 million. Table 6 presents the distribution of this population by level of schooling.

In Ecuador, the proportion of the EAP with 10 or more years of schooling has grown steadily in recent decades: 1960, 5.1%; 1970, 9.0%; 1980, 17.8%. According to the 1982 census, the EAP was distributed by level of schooling as indicated in Table 7.

Table 3. Distribution of the EAP by type of course followed, Brazil 1980.

Type of course	Number of people
General education	32 814 422
Special education	4 985
Professional education	2 074 122
Higher education	1 790 000
Biology and health sciences	307 703
Exact sciences and technology	271 464
Agricultural sciences	44 154
Human and social sciences	884 699
Literature and art	159 261
National defence	10 818
Other advanced degrees	111 901
Master's degree or doctorate	63 537
Biology and health sciences	14 763
Exact sciences and technology	13 878
Agricultural sciences	3 082
Human and social sciences	27 635
Literature and art	4 179
Not stated	474 927

Source: 1980 census, special tabulation.

Table 4. Number of people working in scientific and technical occupations in certain fields, Brazil 1980.

Area or field	Men	Women	Total
Exact sciences	25 611	5 810	31 421
Mathematics	193	85	278
Statistics	1 728	1 066	2 794
Systems analysis	14 709	2 724	17 433
Physics	393	116	509
Chemistry	4 939	1 377	6 316
Other	984	262	1 246
Geology	2 665	180	2 845
Biological sciences	2660	3 318	5 978
Biology	1 112	1 567	2 679
Pharmacology	1 548	1 751	3 299
Engineering	101 647	4 639	106 286
Agricultural sciences	18 749	1 612	20 361
Agronomy	12 330	756	13 086
Veterinary medicine	6 419	856	7 275
Health	120 077	57 404	177 481
Medicine	76 137	20 963	97 100
Dentistry	40 176	15 839	56 015
Nursing	785	10 507	11 292
Other medical specialties	722	7 223	7 945
Pharmacology	2 257	2 872	5 129
Social sciences	263 859	105 224	369 083
Economics	25 976	5 895	31 871
Administration	11 432	4 977	16 409
Architecture	7 764	4 506	12 270
Demography	229	473	702
Library sciences	1 422	14 945	16 367
Archaeology and museology	118	269	387
Literature and journalism	21 463	7 160	28 623
Law	77 864	20 606	98 470
Accounting	115 615	24 203	139 818
Social welfare	1 976	22 190	24 166
Human sciences	2 163	11 159	13 322
Sociology	747	1 478	2 225
Psychology	1 416	9 681	11 097
Total	534 766	189 166	723 932

Source: 1980 census.

Data from the 1981 censuses of Peru and Venezuela have been used to construct Table 8, which presents the distribution of the EAP by level of schooling in these two countries.

Table 5. Population (thousands) over 15 years of age with 13 or more years of schooling,[a] by position in the labour force, Chile 1984.

Years of schooling	In the labour force: Employed	In the labour force: Unemployed	In the labour force: Total	Outside the labour force	Total	% of total pop. ≥ 15
13–15	105.2	14.4	119.6	134.8	254.5	3.2
16–18	192.0	20.2	212.3	82.0	294.4	3.6
19 and over	10.2	1.1	11.3	3.8	15.2	0.2
Total	307.4	35.7	343.2	220.5	564.2	7.0

Source: National Statistical Institute survey, October–December 1984.

[a] Does not include persons whose level of schooling is not known (60 200 people, or 0.7% of the total population, are 15 years of age and over).

Table 6. Distribution of the EAP from 15 to 49 years of age by level of schooling, Cuba 1981.

Level of schooling	Number	%
None	50 437	1.7
Primary school	1 060 516	36.3
Secondary school	1 253 075	42.9
Technical and vocational education	230 272	7.9
Normal school	126 814	4.3
Higher education	198 828	6.8
Incomplete	84 456	2.9
Complete	114 372	3.9

Source: 1981 census, special tabulation.

Table 7. Distribution of the EAP by level of schooling, Ecuador.

Level of schooling	Number	%
None	351 042	15.0
Primary	1 222 460	52.1
1–3 years	372 614	15.9
4–6 years	849 846	36.2
Secondary	437 252	18.6
1–3 years	228 975	9.7
4–6 years	208 277	8.9
Higher education	193 915	8.3
1–3 years	85 268	3.6
4 years and over	108 647	4.7
Not stated	141 394	6.0
Total	2 346 063	100.0

Source: 1982 census, special tabulation.

Training Qualified Personnel

This section describes the process of training qualified human resources in Latin America. As in the preceding section, the comments on the tables are kept to a minimum, partly because sufficient literature is available that deals with the Latin American processes of growth, distribution, and differentiation in enrolment in higher education (Rama 1982; Tedesco 1983; Graciarena et al. 1984; Brunner 1985; Tedesco and Blumenthal 1986).

The information in this section is arranged as follows:

- Three general comparative tables are presented that contain relevant information on higher education in the countries under study (Tables 9–11).

Table 8. Distribution of the EAP by level of schooling, Peru and Venezuela 1981.

	Peru[a]		Venezuela[b]	
Level of schooling	Number	%	Number	%
None	1 515 513	15.2	257 400	5.7
Primary	4 135 466	41.4	2 523 673	55.5
Secondary or middle	3 041 972	30.4	1 390 224	30.6
Higher nonuniversity	335 150	3.4	—	—
University	650 083	6.5	—	—
Complete	—	—	177 273[c]	3.9
Incomplete	(319 097)	(3.2)	156 842[d]	3.4
Non stated	—	—	42 033	0.9
Unspecified	314 410	3.1	—	—
Total	9 992 594	100.0	4 547 445	100.0

Source: 1981 censuses of Peru and Venezuela, special tabulations.
[a] Population 15 years and over.
[b] Population 12 years and over.
[c] 4 years or more; no distinction is made between university and nonuniversity.
[d] 1 to 3 years; no distinction is made between university and nonuniversity.

- The changes in enrolment in selected Latin American countries are examined (Tables 12–15).
- The distribution of postsecondary enrolment is analyzed based on discipline (Tables 16–18).
- The number of graduates and their distribution by discipline is discussed (Tables 19–22).
- Changes in graduate programs and enrolment, and in the body of graduates are examined (Tables 23–26).
- Some information is given on the numbers of graduate scholarship holders studying abroad (Table 27).

General information

Table 9 provides some basic information on higher education (both university and nonuniversity) in Latin America. The estimate of postsecondary enrolment for Ecuador is undoubtedly too high (Pareja 1986). In any case, Table 10 shows changes in postsecondary registration, and the following section deals with this subject in detail. It is likely that, at this level of aggregation, the figures generally reflect orders of relative magnitude rather than exact quantities, especially as definitions of postsecondary enrolment or

Table 9. Basic information on university and nonuniversity postsecondary education in 12 selected countries in Latin America.

Country	Postsecondary students				Number of foreign students	Postsecondary teachers[b]
	Per 100 000 pop.	Number	% women	% technical[a]		
Argentina (1984)[c]	2 253	846 145	53	13 (83)	7 882 (80)	70 699 (12.0)
Brazil (1983)	1 140	1 479 397	50	22	10 829 (82)	122 697 (12.1)
Chile (1984)	1 660	188 665	43	38	625 (82)	15 131 (12.5)
Colombia (1984)	1 384	378 586	48	27	—	41 636 (9.1)
Costa Rica (1984)	2 381	60 288	—	15	—	4 500[d] (13.4)
Cuba (1984)	2 123	212 155	54	13	3 435	17 717 (12.0)
Dominican Republic (1982)	—	—	—	—	—	—
Ecuador (1984)	3 072	280 594	39 (82)	25	781 (82)	11 495 (24.4)
Guatemala (1982)	647	47 433[e]	—	—	1 017 (80)	—
Mexico (1983)	1 425	1 071 676	36	27	—	99 127 (10.8)
Peru (1982)	2 001	305 390	35	24	—	16 913 (18.1)
Venezuela (1984)	2 267	381 575	—	22	—	30 122 (12.7)

Source: Unesco Statistical Yearbook, 1986.

[a] Unesco categories 6 and 7: engineering, natural sciences, mathematics, computer sciences.

[b] Number of students per teacher is given in parentheses.

[c] Most recent year available.

[d] Estimate based on the figures for 1982 contained in the 1985 Unesco Statistical Yearbook. It is not known whether the figures include mathematics and computer sciences.

[e] Estimate.

Table 10. Postsecondary school enrolment and proportion of students in scientific and technical programs,[a] 1975–1983.

Country	1975		1980		1983	
	Total	% S&T	Total	% S&T	Total	% S&T
Argentina	596 736	—	491 473	46	580 626	—
Brazil	1 089 808	26	1 409 243	29	1 436 287[b]	—
Chile[c]	149 647	49	120 168	59	127 353	58[b]
Colombia	176 098	—	271 630	36	378 999	39
Costa Rica	33 239	29[c]	60 990	30[c]	54 257	26[c]
Cuba	82 688	—	151 733	40	173 403[b]	40[b]
Dominican Republic	28 628	39	—	—	—	—
Ecuador	170 173	—	269 081	44	264 353[b]	44[b]
Guatemala	22 881	43	50 890	—	47 433[b]	—
Mexico	562 056	63	897 726	58	1 071 676	54
Peru	195 641	36	306 353	42	305 390[b]	42[b]
Venezuela	213 542	40	307 133	39	366 620[d]	37

Source: Unesco Statistical Yearbook, 1985.

[a] Includes natural sciences, mathematics and computer sciences, medicine and health sciences, engineering, architecture and urban planning, industrial trades, transportation and communications, agriculture and fisheries.

[b] 1982.

[c] Only in universities.

[d] Estimate.

higher education are notably elastic and change from country to country.

Total postsecondary enrolment was 5.25 million. In 1984, for all of Latin America and the Caribbean, there were 5.9 million students at this level. This is 24 times the 1950 figure, when regional enrolment was barely 250 000 students (Tedesco 1985). Two countries alone, Brazil and Mexico, account for close to 49% of total enrolment in the 12 countries listed in Table 9.

The proportion of total postsecondary registrants represented by women varies from 35% in Peru to over 50% in Argentina and Cuba.

The proportion of students in advanced scientific and technical disciplines varies from country to country. In Argentina, Cuba, and Costa Rica, they represent 15% or less of the total enrolment. In Brazil, Venezuela, Ecuador, and Peru, they range from 22 to 25%. In Colombia and Venezuela, they account for 27%; in Chile, 38%. Here too, it is possible that statistical techniques have distorted the figures, making detailed comparative analysis difficult; however, the figures make it possible to identify broad national efforts to train scientific and technical personnel.

There is generally little information available on the number of foreign postsecondary students, although the figures are significant, at least in the cases of Argentina, Brazil, and Cuba.

The last column shows the approximate number of teaching personnel at the postsecondary level by country and the number of students per professor. Because of the lack of information on the types of teaching appointment (full-time, part-time), or on the distribution of professors by field of learning or by workload, it is difficult to reach more detailed conclusions on the basis of data presented. The number of students per professor is about the same in most of the countries studied, ranging from 9 to 14 students per teacher, except in Peru and Ecuador, where the ratio is 18 and 24, respectively.

Table 10 shows changes in postsecondary enrolment over the last decade and in the percentage of those students registered in scientific and technical programs, including postsecondary technical certificates, university and graduate degrees. In many cases, there was a sharp jump in enrolment from 1975 to 1980, which probably reflects the last stage in a growth process that began in 1950. After 1980, enrolment tended to stabilize, grow very slowly, and even drop in several countries, possibly as a result of the economic crisis that began at the beginning of the decade and that has limited public spending in general, and spending on education, especially postsecondary public education, in particular (see Chapters 5 and 8). For Latin America and the Caribbean as a whole, the annual growth rate for postsecondary education in the 1970s was 11.5%; in the first 4 years of the 1980s, it dropped to 5.1% per year.

Relative stagnation in postsecondary enrolment after 1980 can clearly be seen in Brazil, Ecuador, and Peru, after sharp expansion during the previous 5 years. There was virtual stagnation in Chile and Guatemala, the former showing slight growth after 1980 and the latter a slight decline. (In the case of Chile, however, the figures reflect changes only in university enrolment, unlike those of the remaining countries, which include total postsecondary enrolment.) Enrolment increased even after 1980 in Argentina, Colombia, Cuba, Mexico, and Venezuela, but decreased in Costa Rica. In two countries with post-1980 growth in enrolment (Mexico and Venezuela), the share of scientific and technical enrolment dropped; it grew, however, in Colombia along with growth in total registration, and remained the same in Cuba despite increased total postsecondary enrolment. In Costa Rica, total enrolment and the proportion in scientific and technical programs dropped, while in Peru, Ecuador, and Chile, the proportion held steady within relatively stationary enrolment.

Changes in postsecondary enrolment

The gross university enrolment rate (GUER), which, in many cases, includes nonuniversity postsecondary studies and should, therefore, be called the gross postsecondary or higher education rate, grew considerably in Latin America from 1950 to 1975; in some cases, growth continued up to the beginning of the 1980s, although generally at a slower pace.

The table prepared by Germán Rama in his study of the expansion and segmentation of Latin American university systems is well known (Rama 1982). It shows the trend in gross postsecondary education rates for a series of countries in the region over 25 years. The lowest GUER in 1975 was higher than the highest rate 25 years earlier (Table 11). Growth in postsecondary enrolment in the region was not correlated with the position of the countries in terms of population, degree of development, or necessarily with national per capita income (Rama 1982). This growth probably had more to do with the promotional role played by the State in this field, and with the processes of economic growth and occupational change, which favoured the emergence of a new and larger middle class, a phenomenon closely linked to dynamic growth of postsecondary education. It was the middle class who increased the demand for this type of education for their children and also

Table 11. Gross university enrolment rates (GUER[a]) and indexes of change in enrolment, 1950–1975.

	1975 GUER (%)			
1950 GUER	High (≥ 160)	Medium-high (100–159)	Medium-low (70–99)	Low (< 70)
High (≥ 25)	Argentina (723.3%)	Uruguay (278.6%)	Cuba (324.3%)	
Medium-high (20–25)	Costa Rica (2 193.3%) Panama (1 753.3%)	Peru (1 221.6%) Bolivia (996%)		
Medium-low (10–19)	Venezuela (3 094.2%) Chile (1 574.7%) Ecuador (2 682.9%)		Brazil (2 132.7%) Dominican Republic (2 021.7%) Mexico (1 477.8%) Colombia (1 761.3%)	Paraguay (1 070.6%)
Low (< 10)			El Salvador (2 368.3%)	Nicaragua (3 333.3%) Honduras (1 487.5%) Guatemala (929.2%)

Source: Project RLA/79/007 (Rama 1982).
[a] GUER is expressed as the number of students per 1 000 people aged 20 to 24 years.

pressed for greater geographical decentralization of institutions of higher education. Where the public sector did not respond to their demand for expansion of free higher education, they turned to, and subsequently supported, a dynamic private education "market" that would generate new opportunities for access to this level of education.

Table 12 shows changes in undergraduate and graduate enrolment from 1970 to 1984. Table 13 shows that the gross postsecondary enrolment rates increased unequally in the region between 1975 and 1984. In 6 of the 12 countries under study (Colombia, Cuba, the Dominican Republic, Mexico, Peru, and Venezuela), growth has been continuous over that period.

In Argentina and Chile, GUER dropped significantly between 1975 and 1980, but began to recover afterwards. In both cases, the drop is probably due to the policies followed by the respective military governments, which aimed at freezing growth in higher education enrolment (Brunner and Barrios 1987). In Argentina, however, GUER had by 1984 regained its 1975 level, while in Chile it had not. The expansionist policies of the public universities in Argentina, which offered more student places after the military regime, exerted a powerful influence and raised GUER for 1985 to 36.4%.

In the remaining countries, GUER grew between 1975 and 1980, but subsequently dropped, although not sharply. In Brazil, it fell by 0.6% between 1980 and 1983; in Costa Rica, it began to drop in 1981, but stabilized in 1983-84; in Guatemala, it began to fall in 1980; in Ecuador, it fell 4% between 1980 and 1983 with a slight recovery in 1984.

When the selected countries are ranked by their GUER in 1975 and 1984 (Table 14), it can be seen that there were various shifts over the period: Brazil and the Dominican Republic move down, relatively speaking, from group 3 to group 2; Cuba and Peru move up from group 3 into group 4; and Argentina drops in relative position from group 5 to group 4 (it regained first place the following year).

In any case, the average GUER in the region, which was 15% in 1985, having grown from 3% in 1960 to 6.3% in 1970 and 11.7% in 1975, is clearly below university enrolment rates for more highly developed countries, including the recently industrialized countries of Asia. Latin American rates compare with those prevailing in some countries of Eastern Europe, occupying an intermediate position between more highly developed countries with market economies and the much lower rates that are still found in Africa and some Asian countries (Table 15).

Table 12. Changes in undergraduate and graduate enrolment in 12 countries of the region, 1970–1984.[a]

Country	Level	1970	1975	1980	1985
Argentina	Undergraduates	254 456	507 716	393 828	416 571[b]
	Graduates	—	—	—	—
Brazil	Undergraduates	425 478	944 834	1 377 286	1 399 539
	Graduates	3 068	22 245	38 609	37 693
Chile[c]	Undergraduates	76 979	147 049	116 962	139 032
	Graduates	—	—	1 432[d]	2 835[e]
Colombia	Undergraduates	189 013[f]	156 795	230 159	314 376
	Graduates	1 530	2 585	4 546	7 576
Costa Rica	Undergraduates	6 950	25 542	38 231	42 329
	Graduates	—	—	—	—
Dominican Republic	Undergraduates	23 546[g]	41 352[g]	54 373[g]	—
	Graduates	—	—	—	—
Ecuador[h]	Undergraduates	38 313[i]	129 130[i]	262 550[i]	—
	Graduates	—	—	—	—

Guatemala	Undergraduates	23 425	30 490	42 698	51 920
	Graduates	—	—	—	—
Mexico	Undergraduates	211 826	412 837	731 291	939 513
	Graduates	4 088	13 868	24 313	35 390
Peru	Undergraduates	126 234[g]	195 641	306 353[g]	340 651
	Graduates	—	—	—	—
Venezuela[j]	Undergraduates	85 675	221 581	296 726	331 115
	Graduates	—	—	—	—

[a] Figures obtained in the base studies do not necessarily agree with those appearing in the Unesco statistical yearbooks (Table 9).
[b] University education only, basic or professional degree level. Total enrolment in postsecondary studies in that year was 846 145 students according to the figures given in the 1986 Unesco Statistical Yearbook.
[c] Data are from the CRESALC study (in press) and refer only to university enrolment.
[d] 1981.
[e] 1985.
[f] 1971.
[g] Data taken from Sagasti and Cook (1985).
[h] Includes university and polytechnic enrolment.
[i] Data obtained from the country report in the CRESALC study (Pareja 1986).
[j] Includes total postsecondary enrolment (universities account for 79.5% of the total for the latest year).

Table 13. Changes in gross university enrolment rate (GUER)[a] in 12 Latin American countries, 1975–1984.

Country	1975	1980	1984
Argentina	27.2	21.6	29.3
Brazil	10.7	11.9	11.3[b]
Chile	16.2	13.0	15.3
Colombia	8.0	10.6	12.8
Costa Rica	17.5	23.0	22.1
Cuba	11.0	19.5	20.1
Dominican Republic	10.1	10.8[c]	11.6[c]
Ecuador	26.9	36.5	33.1
Guatemala	4.3	8.4	6.4[c]
Mexico	10.6	14.1	15.2[b]
Peru	14.6	19.4	21.5[d]
Venezuela	18.1	21.4	23.4

Source: Unesco Statistical Yearbook, 1986.
[a] GUER is expressed as the number of students per 1 000 people aged 20 to 24 years.
[b] 1983.
[c] Figure taken from Tedesco (1987).
[d] 1982.

University enrolment by field of study

The strong growth in university enrolment over three decades (1950–1980) and its subsequent slower development, stagnation, or even decline, must be examined in terms of distribution by discipline to obtain a more precise understanding of its pattern of development.

The base studies contain some information on this subject, using an arrangement of the fields of study that differs from the one normally used by Unesco and the one most frequently used by the countries themselves. The following tables show the situation based on several different classification criteria.

Table 16 shows distribution of postsecondary enrolment by field of study, according to the classification criteria used in the national base studies for the most recent year available. This classification distinguishes between scientific and technical specialities (natural or basic sciences, agriculture and veterinary medicine, engineering and technology, health sciences); social sciences; law and the humanities; and other programs. It does not have a separate place for the field of education, which is generally very significant in the total; education is sometimes included under social sciences and sometimes under other programs.

Table 14. Distribution of the selected countries by gross university enrolment rate (GUER), 1975 and 1984.

1975		1984	
GUER under 5%		GUER under 10%	
Guatemala	4.3	Guatemala	6.4[a]
GUER 5–10%		GUER 10–15%	
Colombia	8.0	Brazil	11.3[a]
		Dominican Republic	11.6
		Colombia	12.8
GUER 10–15%		GUER 15–20%	
Dominican Republic	10.1	Mexico	15.2
Mexico	10.6	Chile	15.3
Brazil	10.7		
Cuba	11.0		
Peru	14.6		
Chile	14.5		
GUER 15–20%		GUER 20–25%	
Costa Rica	17.5	Cuba	20.1
Venezuela	18.1	Peru	21.5[b]
		Costa Rica	22.1
		Venezuela	23.4
GUER 20–25%		GUER 25–30%	
		Argentina	29.3
GUER 25–30%		GUER 30–35%	
Ecuador	26.9	Ecuador	33.1
Argentina	27.2		

Source: Unesco Statistical Yearbook, 1986.
[a] 1983.
[b] 1982.

Table 16 shows that, in most of the countries studied, post-secondary enrolment in natural or basic sciences ranged from 3 to 4%. In Colombia it was under 2% and in Peru it was over 5%, although these exceptions cannot be attributed to any special factor; their variation may be due to the way in which programs are classified. Enrolment in agricultural sciences ranged from 2 to 9%, depending on the country, with Brazil, Colombia, and Cuba at the low end of the range; Costa Rica, Chile, Peru, and Venezuela in the middle; and Ecuador and Mexico at the high end. Engineering and

Table 15. GUER in selected non-Latin American countries, latest year available.

Country	Year	GUER
Canada	1984	44.0
Czechoslovakia	1984	15.9
East Germany	1984	30.3
France	1984	26.8
Greece	1981	15.4
Hungary	1984	15.2
Israel	1984	34.2
Italy	1984	26.3
Japan	1984	29.6
Norway	1983	29.3
Philippines	1982	29.1
Poland	1984	15.9
Portugal	1982	11.6
Rumania	1984	11.7
South Korea	1984	26.1
Spain	1983	25.8
Sweden	1984	38.2
Thailand	1983	22.5
USA	1982	57.3
West Germany	1984	29.1
Yugoslavia	1983	20.2

Source: Unesco Statistical Yearbook, 1986.

technological studies attracted 15 to 30% of total enrolment. In this field, Cuba occupied the very lowest position, and Chile the highest. In most countries, about one-fifth of total enrolment was in the field of engineering and applied sciences. In most countries, one in ten postsecondary students was enrolled in health sciences, except for Colombia and Mexico, which were slightly higher than the regional average, and Costa Rica, which was lower.

It is difficult to draw any conclusions about social sciences, because the definition of this field varies too widely; in some cases it includes education, in others it does not. The same can be said for law and the humanities. From this standpoint, it would appear that the Unesco classificiation of postsecondary enrolment (see Table 18) is better for the purposes of regional comparisons and for following changes over time.

On the basis of the classification of fields contained in Table 16, it can be concluded that between one-third and one-half of the postsecondary students in all the countries studied were in engineering and technological programs, health sciences, and agriculture, with a small number in natural or basic sciences. Engineering

Table 16. Distribution (%) of postsecondary enrolment by field of study[a] in 11 countries in about 1984.

	1	2	3	4	Subtotal	5	6	7	Subtotal	Total enrolment
Argentina (1982)[b]	├──	48.2	──┤	9.2	57.4	28.3	14.3	—	42.6	411 113
Brazil (1982)	4.6	2.3	19.7	9.5	36.1	34.6	16.6	12.6	63.8	1 397 870
Chile (1985)[c]	4.3	5.8	32.6	10.3	53.0	37.1[d]	6.2	3.7	47.0	127 496
Colombia (1984)	1.3	2.6	19.1	13.2	36.2	29.7	10.0	24.1[d]	63.8	314 376
Costa Rica (1984)	4.0	4.2	17.5	7.2	32.9	36.5	27.7	2.9	67.1	42 329
Cuba (1984)	2.7	3.3	14.9	10.3	31.2	14.0	38.0[e]	16.8[f]	68.8	243 751
Ecuador (1980)[g]	3.2	7.3	15.5	11.2	37.2	18.0	6.1	34.1	58.2	262 550
Guatemala (1985)[h]	3.0	6.0	24.0	11.0	44.0	33.0	5.0	18.0	56.0	55 650
Mexico (1984)	3.0	9.5	27.4	14.4	54.3	42.7[d]	3.0[i]	—	45.7	939 513
Peru (1984)	5.5	5.2	22.1	9.6	42.4	31.4	15.3	10.4[d]	57.1	340 651
Venezuela (1982)	2.0	4.7	19.8	11.3	37.8	44.2[d]	1.4[i]	16.6	62.2	331 115

Source: CRESALC reports for Brazil (de Andrade Córdova et al. 1986), Ecuador (Pareja 1986), and Venezuela (Casanova 1986); Chile, statistical yearbook of the Council of University Presidents; base studies for other countries.

[a] 1, natural or basic sciences; 2, agriculture and veterinary medicine; 3, engineering and technology; 4, health sciences; 5, social sciences; 6, law and the humanities; 7, other.

[b] Includes only university enrolment. Categories 1 to 3 are combined.

[c] Includes only universities that receive government support and professional institutes created as a result of the restructuring of the old universities.

[d] Includes education.

[e] Refers only to pedagogy.

[f] Includes preuniversity and foreign students; also, physical education and art.

[g] Includes universities and polytechnics. Only law is included in column 6. Column 7 includes education, art, and other majors.

[h] Law is included with social sciences; other includes administration and communications.

[i] Includes only humanities and art.

and technological studies generally account for about half of the total national enrolment in these four scientific and technological areas. It is probable that social sciences and education account for about one-third of total postsecondary enrolment in Latin American countries. The remaining 20% is distributed among various programs, including law, administration and business, the humanities, art, etc.

The sharp rise in postsecondary enrolment in Latin American countries in recent decades was not simply the result of expanding registration in the different programs, but was basically due to a shift in growth in the different fields. Using the same classifications as in Table 16, Table 17 shows how the share of total enrolment

Table 17. Distribution (%) of enrolment by field[a] in six Latin American countries, 1950 to 1980.

	Science and technology			Social sciences and other professions			
	1	2	3	4	5	6	7
Argentina							
1955	3.2	1.5	12.9	28.9	19.1	29.4	5.0
1982	├── 48.2 ──┤			9.2	28.3	14.3	—
Brazil							
1954	0.6	2.9	11.2	26.3	8.8	27.6	22.5
1982	4.6	2.3	19.7	9.5	34.6	16.6	12.6
Chile							
1949	5.0	6.0	9.5	21.8	2.5	22.8	32.4
1985	4.3	5.8	32.6	10.3	12.9	6.2	27.9[b]
Colombia							
1950	6.0	2.9	15.5	36.2	2.7	24.2	12.5
1984	1.3	2.6	19.1	13.2	29.7	10.0	24.1
Guatemala							
1950	5.3	1.8	13.6	28.3	12.4	38.6[b]	—
1985	3.0	6.0	24.0	11.0	33.0[c]	5.0	18.0
Venezuela							
1950	27.6[d]	5.3	—	40.0	5.0	15.6	6.5
1982	2.0	4.7	19.8	11.3	29.3	1.4	31.5[b]

Source: For 1950s, Unesco et al. (1981); for 1980s, see Table 16.

[a] 1, natural or basic sciences; 2, agriculture and veterinary medicine; 3, engineering and technology; 4, health sciences; 5, social sciences; 6, law and the humanities; 7, other.

[b] Includes education.

[c] Includes law and education.

[d] Also includes engineering and technology.

Table 18. Distribution of postsecondary enrolment (thousands) by field of study,[a] 1960 and 1984.

	1	2	3	4	5	6	7	8	9	10	Total
Argentina											
1960	6.7	3.3	26.2	46.1	30.6	40.2	13.6	2.6	11.6	—	180 796
1983	43.8	23.5	99.6	51.1	10.8	59.2	26.2	7.7	4.2	78.6	403 978
Brazil											
1960	3.4	2.7	11.1	19.9	14.4	24.0	9.7	5.6	4.7	—	95 691
1983	159.1	40.6	207.7	132.1	218.2	139.8	149.3	111.3	30.7	293.5	1 479 397
Chile											
1960	0.5	0.6	1.5	2.1	1.7	1.6	—	3.6	0.9	—	12 517
1984	17.4	3.9	58.5	15.5	5.7	4.3	13.9	19.3	7.6	42.3	188 665
Colombia											
1960	1.6	1.5	5.4	4.1	2.2	4.0	1.1	0.4	2.4	0.02	22 660
1984	6.4	10.1	95.6	40.7	—[b]	46.4	2.7	76.4	8.4	102.4	389 075
Costa Rica											
1960	0.04	0.07	0.2	0.3	0.6	0.3	1.9	1.2	0.3	—	4 703
1984	3.9	2.3	5.8	3.3	7.0	3.1	11.1	5.7	1.2	10.8	54 456
Cuba											
1962	0.9	0.9	3.4	3.6	3.0	0.5	1.7	2.3	0.5	—	16 571
1984	4.3	16.8	34.1	25.8	14.8	2.9	2.8	92.5	1.2	16.8	212 155
Dominican Republic											
1961	—	0.05	0.8	1.3	0.9	0.8	0.2	—	—	—	4 086

(continued)

Table 18. Concluded.

	1	2	3	4	5	6	7	8	9	10	Total
Ecuador											
1960	0.4	0.5	1.8	2.4	1.1	1.5	0.4	0.8	0.5	—	9 361
1984	14.1	4.0	66.5	28.8	23.0	13.8	14.3	53.5	2.6	60.0	280 594
Guatemala											
1960	0.3	0.2	0.9	1.0	0.9	1.4	0.4	—	0.2	—	5 229
Mexico											
1961	5.3	2.9	18.7	17.8	20.3	12.3	3.6	4.5	8.3	0.5	94 073
1984	37.2	39.0	297.1	133.7	103.0	101.3	10.6	11.5	8.6	197.5	939 513
Peru											
1960	4.8	9.8	3.4	3.9	4.1	3.0	4.5	1.7	0.2	—	26 616
1983	16.2	20.7	63.0	27.9	52.7	20.6	4.4	24.0	0.2	75.6	305 390
Venezuela											
1960	0.4	1.1	4.6	5.1	5.6	4.0	2.2	2.2	0.8	0.3	26 477
1984	18.6	14.9	71.5	40.9	56.0	32.1	5.1	55.4	1.0	86.4	381 575

Source: Unesco statistical yearbooks.

[a] 1, natural sciences, mathematics, and computer sciences; 2, agricultural science and technology; 3, engineering and technological sciences, architecture and urban planning, industrial trades, transport, and communications; 4, medicine and health sciences; 5, social sciences, documentation, and social communications; 6, law; 7, humanities and letters, religion, and theology; 8, education and teacher training; 9, fine arts and applied art; 10, other unspecified programs (includes commerce and business administration, home economics, and training for the service sector).

[b] Included elsewhere.

Table 19. Students (%) awarded first degrees or diplomas[a] by field of study in a group of Latin American countries for the most recent year available.

	1	2	3	4	Subtotal	5	6	7	Subtotal	Total enrolment
Argentina (1981)		35.1		28.5	63.6	25.8	10.6	—	36.4	26 961
Brazil (1983)	14.1[c]	2.4	18.8	—	35.3	55.2	6.9	2.6	64.7	238 096
Chile (1985)	1.9	4.3	16.3	13.4	35.9	57.4[d]	4.0	2.7	64.1	20 673
Colombia (1984)	1.2	2.2	14.9	13.7	32.0	30.8	13.3	23.9	68.0	29 062
Costa Rica (1984)	2.4	9.4	13.1	30.4	55.3	19.0	24.5	1.4	44.9	16 242
Cuba (1984)	3.1	8.0	18.1	13.1	42.3	14.7	—	43.0	57.7	24 891
Dominican Republic (1985)	1.6	3.7	15.4	29.4	50.1	39.5	—	10.4	49.9	4 644
Guatemala (1985)	6.0	12.0	10.0	39.0	67.0	19.0[e]	4.0	10.0	33.0	2 175
Peru (1983)	3.2	5.4	20.8	13.0	42.4	32.1	14.8	10.5	57.4	16 513
Venezuela (1981)	—	—	—	—	—	—	—	—	—	18 261

Source: CRESALC report for Venezuela (Casanova 1986); statistical yearbook of the Council of University Presidents for Chile; base studies for all other countries.

[a] Figures for Argentina refer to degrees; those for Chile and Costa Rica refer to diplomas; in the other countries, sources do not distinguish between the two.

[b] 1, natural or basic sciences; 2, agriculture and veterinary medicine; 3, engineering and technology; 4, health sciences; 5, social sciences; 6, law and the humanities; 7, other.

[c] Appears as biology in the source document, probably includes medicine and health sciences.

[d] Includes education.

[e] Includes law.

Table 20. Graduates by field of study[a] in 11 Latin American countries, 1960 and 1984.

	1	2	3	4	5	6	7	8	9	10	Total
Argentina[b]											
1960	576	393	2 036	3 192	813	1 337	373	482	529	—	9 731
Brazil											
1960	697	474	1 601	3 952	2 099	3 332	2 589	1 930	903	—	17 577
1982	12 095	6 832	25 695	23 528	41 672	21 983	20 621	48 932	6 890	45 301	253 553
Chile											
1960	50	47	102	486	134	153	138	317	61	—	1 488
1984	1 822	357	4 240	2 704	744	377	2 038	4 391	770	2 813	20 256
Colombia											
1960	193	86	269	613	147	312	98	25	164	—	1 907
1984	666	919	7 988	4 608	—[c]	5 896	319	7 206	1 261	13 141	32 085
Costa Rica											
1960	5	8	21	20	6	24	6	379	6	—	475
1984	168	234	339	592	318	212	139	237	162	657	3 054
Cuba[d]											
1983	407	1 871	3 564	2 582	1 310	723	487	6 806	85	1 594	19 429
Ecuador											
1960	45	36	40	194	19	76	—	67	5	—	482
1981	—	1 252	1 471	2 077	1 538	858	179	6 892	86	2 304	15 441

Guatemala[b]											
1960	12	2	12	49	5	24	3	10	—	—	117
Mexico											
1960	239	47	818	1 341	9 054	588	12	3 201	113	1 343	16 756
1982	2 902	3 452	27 005	19 761	10 201	8 342	907	1 758	829	21 415	96 572
Peru											
1959	297	126	204	810	150	389	7	1 079	—	—	3 062
1982	231	788	1 127	2 177	801	898	17	1 973	2	2 435	7 463
Venezuela											
1958	14	46	246	632	306	287	114	52	44	—	1 741
1983	1 092	1 400	4 936	2 770	1 913	1 104	272	6 719	30	3 911	24 147

Source: Unesco statistical yearbooks.

[a] 1, natural sciences, mathematics, and computer sciences; 2, agricultural science and technology; 3, engineering and technological sciences, architecture and urban planning, industrial trades, transport, and communications; 4, medicine and health sciences; 5, social sciences, documentation, and social communications; 6, law; 7, humanities and letters, religion, and theology; 8, education and teacher training; 9, fine arts and applied art; 10, other unspecified programs (includes commerce and business administration, home economics, and training for the service sector).

[b] No data after 1980.

[c] Included elsewhere.

[d] No data for 1960.

shifted for different fields in certain selected countries. The early figures (around 1950) include education in the classification "other" to show the relative weight of social sciences and law (plus the humanities).

The main trends in postsecondary enrolment can be seen clearly in this table and are, moreover, well known (Unesco et al. 1981). Registration dropped in law and health sciences (6 and 4), but increased in social sciences (5) and education. The categorization of the latter has a strong impact on changes in the subsector of the social sciences and professions, law and the humanities and "other" specialities, because education is sometimes taught at university, but in other cases, its share of enrolment fluctuated, depending on the specific teacher-training policies followed in the different countries. The share of engineering and technology (3) has grown in all the countries, partly in response to the industrialization process in the region, and even more because of the growth in practical engineering and other technical fields that has occurred in some countries. On the other hand, enrolment in basic sciences (1) has remained more or less constant; some of the variations observed most likely reflect changes in nomenclature and other effects attributable to data collection and classification.

In short, it can be argued that the changes observed in the distribution of enrolment are generally in line with the changes that have occurred in job structures over the same period. Jobs are gradually shifting into the tertiary sector and this is also true of university enrolment. This explains the increase in the field of education and social sciences. It is also in these two areas that women's enrolment has been highest.

Table 18 shows changes in postsecondary enrolment between 1960 and 1984, according to the Unesco classification.

University and professional program graduates

Table 19 shows percentage of graduates by discipline for the most recent year available, categorized as in the base studies. Table 20 shows changes in the number of graduates over a longer period, based on the Unesco classification.

For Brazil, Colombia, and Peru, the ratios of undergraduate enrolment to graduations are relatively balanced at the level of the area subtotals. They are unbalanced for Costa Rica, Chile, Cuba, and Guatemala. In Costa Rica, Cuba, and Guatemala, natural science and technology graduates account for a higher percentage of total enrolment; in Chile the situation is reversed. Lack of data makes it impossible to examine this subject in greater detail. For example, to have even a rough idea of the output of the different disciplines and to be able to make comparisons between disciplines and between countries, it would be essential to know the number of student places available per study area 5 or 6 years before the year in which the number of graduates was counted. It would also be necessary to use a consistent method for quantification, depending on whether a degree or a diploma is earned. In general, the reports by CRESALC on higher education in Latin American countries contain valuable information, but as a whole they show that information is not sufficient to permit precise comparisons. Although individual studies of output in different specializations and institutions are available, more comprehensive studies, which include follow-up for a sufficiently long period of time, are not.

Taking Unesco data as the base, the changes in the body of graduates, by field of study, between 1960 and 1984, can be reconstructed. In 1960, most postsecondary graduates in seven out of ten countries had studied medicine; the majority in the remaining three countries (Costa Rica, Mexico, and Peru) were in education. By about 1984, in six out of nine countries, most graduates were in education; in the remaining three, most were in commerce and business administration (Colombia), medicine and health sciences (Costa Rica), and engineering and technology (Mexico).

The ratio between graduates in a given year and the total number of students enrolled in the same year is 1 : 6 in Brazil, and about 1 : 10 in Colombia, Cuba, Chile, and Mexico (Table 21). In Venezuela and Costa Rica, the ratio is about 1 : 15; in Peru, it is 1 : 29. The reasons why these ratios should be viewed with caution have already been discussed.

Table 21. Number of undergraduate students per postsecondary graduate in a given year for selected Latin American countries around 1984.

Country	Ratio of enrolled to graduated students
Brazil	5.83
Chile	9.31
Colombia	9.26
Costa Rica	17.83
Cuba	10.91
Mexico	9.72
Peru	29.08
Venezuela	15.80

Source: Tables 18 and 20.

Table 22 shows the number of graduates in the three levels of program and academic certification distinguished by Unesco: level 5 is diplomas and certificates that are not equivalent to the first university degree (practical courses that are usually short or intermediate in length); level 6 is the first university degree or equivalent diploma, including "doctors" when this title is issued to certify completion of a professional program as in the case of physicians and lawyers; and level 7 is advanced university degrees, usually specialized and graduate degrees.

Table 22 shows that for the countries for which information is available, the graduate category comprises the graduates of universities or equivalent institutions (level 6). It is only in Colombia and Venezuela that the proportion of level 5 diplomas is significant.

Graduate enrolment

For the purposes of this study, the trend in graduate enrolment in the region is more important than changes in undergraduate enrolment and distribution. Training for research is an important component of graduate programs. Although this subject will be studied more closely in the next chapter, quantitative information on changes in graduate enrolment will be presented here using data from the base studies and from various national sources compiled by Unesco. Table 23 provides a summary picture of graduate

Table 22. Number of graduates by level in 12 Latin American countries around 1984.

Country	Total	Level 5	Level 6	Level 7[a]
Argentina	—[b]	—	—	—
Brazil	253 553	—	244 639	8 914
Chile	20 256	1 462	18 581	213
Colombia	42 006	11 086	29 062	1 858
Costa Rica	3 054	168	2 670	216
Cuba	19 429	—	19 429	—
Dominican Republic	—[b]	—	—	—
Ecuador	15 441	—	—	—
Guatemala	—[b]	—	—	—
Mexico	96 572	—	96 572	—
Peru	10 499	—	—	—
Venezuela	24 147	5 082	19 065	—

Source: Unesco Statistical Yearbook, 1986.

[a] This column includes not only graduate programs in the narrow sense of the term (MA and PhD) but also specialized and postgraduate programs.

[b] No data available.

Table 23. Distribution (%) of graduate enrolment in certain Latin American countries by field of study for the most recent year available.

Field of study[a]	Brazil (1983)	Chile (1985)	Colombia (1983)	Mexico (1984)
1	20.0	25.3	6.3	9.8
2	7.6	3.8	—	3.2
3	13.9	6.8	7.4	17.3
4	12.7	11.4	18.5	5.9
Subtotal	54.2	47.3	32.2	36.2
5	18.0	14.2	53.2[b]	52.3[c]
6	21.8	16.4	14.5	11.4[d]
7	6.0	22.1[e]	0.1	—
Subtotal	45.8	52.7	67.8	63.7
Number of graduates	35 850	2 835	5 783	23 666
Graduates as % of under-graduates	2.5[f]	2.2	1.8[g]	2.5

Note: Figures for Brazil, Chile, and Mexico represent students in MA and PhD programs only; those for Colombia include specialized courses, which accounted for 63.4% of total graduate enrolment in 1983.

Source: CRESALC reports for Brazil and Colombia; statistical yearbook of the Council of University Presidents, for Chile; for Mexico, the base study.

[a] 1, natural or basic sciences; 2, agriculture and veterinary medicine; 3, engineering and technology; 4, health sciences; 5, social sciences; 6, law and the humanities; 7, other.

[b] Includes education (24.7%) and administration and economics (28.5%).

[c] Includes administration.

[d] Includes education.

[e] Includes education (19.2%) and art and architecture (2.9%).

[f] Graduate enrolment in 1983 over undergraduate enrolment in 1982.

[g] Graduate enrolment in 1983 over undergraduate enrolment in 1984.

enrolment for the most recent year available in four Latin American countries, broken down by field of study according to the categories used in Tables 16, 17, and 19.

As this table shows, about half of graduate students (working at the master's and doctoral levels) in Brazil and Chile are in natural sciences and technologies; in both cases, exact or basic sciences represent a substantial share. In contrast, in Colombia and Mexico, 60% of graduates are in social sciences and professions, humani-

Table 24. Distribution (%) and number of graduate courses in selected Latin American countries for the most recent year available.

	Brazil (1981)	Chile (1985)	Cuba (1985)	Dominican Republic (1985)	Peru (1984)	Venezuela (1982)
Distribution						
Natural or basic sciences	26.5	36.4	15.0	17.9	34.5	10.0
Agriculture and veterinary medicine	9.2	10.5	6.0	—	5.5	15.2
Engineering and technology	11.1	11.7	22.0	10.3	10.9	25.1[a]
Health sciences	22.7	7.4	22.0	15.4	4.5	11.8
Subtotal	69.5	66.0	65.0	43.6	55.4	62.1
Social sciences	18.1[b]	11.1	21.0	41.0	18.2	33.6[c]
Law and humanities	6.2[d]	14.8[e]	—	15.4	16.3	4.3[f]
Other	3.2[g]	8.0[h]	15.0	—	10.0[i]	—
Subtotal	27.5	33.9	36.0	56.4	44.5	37.7

Number						
Master's programs	736	139	—	19	68	187
Doctoral programs	285	23	—	—	42	24
Specialized and other	—	—	—	20	—	—
Total	1 021	162	2 262[j]	39	110	211

Source: Brazil, Moura Castro (1985); Chile, CRESALC report (in press); Venezuela, Casanova (1986); Cuba, Peru, and Dominican Republic, base studies.

[a] Includes courses in architecture.

[b] Includes professional social workers.

[c] Comprises social sciences (20.3%) and education (13.2%).

[d] Literature and linguistics only.

[e] There are 22 programs in humanities; law has 2.

[f] Humanities only.

[g] Comprises courses in education.

[h] Includes education (10 courses) and art and architecture (3 courses).

[i] Includes courses in education.

[j] Graduate courses do not necessarily lead to a degree; many are incorporated into on-the-job professional development programs.

Table 25. Distribution (%) and number of students awarded graduate degrees in certain Latin American countries for the most recent year available.

	Argentina (1985)	Brazil (1984)	Chile (1985)	Colombia (1984)	Costa Rica (1984)	Peru (1980)
Distribution						
Natural or basic sciences	16.8	—	21.2	4.2	4.1	33.3
Agriculture and veterinary medicine	2.0	—	3.4	0.5	11.0	4.3
Engineering and technology	15.2	—	5.6	3.7	5.5	—
Health sciences	23.6	—	23.2	10.7	59.3[a]	40.6[b]
Subtotal	57.6		53.4	19.1	79.9	78.2
Social sciences	37.4	—	27.6	50.4[c]	7.7	13.0
Law and humanities	5.0	—	16.5	14.7[d]	11.8	2.9
Other	—	—	2.5	15.8[e]	0.6	5.8[f]
Subtotal	42.4		46.6	80.9	20.1	21.7

Number						
Masters'	—	3 641	342	859	515	32
Doctorates	—	628	16	6	247[g]	41[h]
Specialized and other	—	—	—	983	910	—
Total	—	4 296	358	1 848	1 672	69

Source: Base studies for Argentina, Brazil, Colombia, Costa Rica, and Peru; statistical yearbook of the Council of University Presidents for Chile.

[a] The majority were awarded specialized medical degrees.
[b] All physicians.
[c] Includes law (the majority are graduates from specialized courses).
[d] Humanities and religious studies (the majority are graduates from specialized courses).
[e] Education and art (all MA graduates).
[f] Education.
[g] Includes physicians and lawyers.
[h] Includes physicians.

Table 26. Students awarded graduate degrees (level 7) by field of study for certain Latin American countries, 1975-1984.

Field[a]	Year[b]	Brazil	Chile	Colombia	Costa Rica	Ecuador
1	1975	416	32	—	25	23
	1984	2 148	51	87	—	—
2	1975	237	42	—	113	—
	1984	799	14	10	—	—
3	1975	783	2	—	70	10
	1984	1 114	17	68	—	—
4	1975	389	30	—	261	—
	1984	1 306	36	197	60	—
5	1975	—	—	—	64	—
	1984	1 041	11	—	1	—
6	1975	603[c]	12	—	138	259
	1984	696	16	258	—	—
7	1975	411	44	—	42	34
	1984	756	8	64	—	—

8	1975	—	—	—	26	—
	1984	724	28	293	—	—
9	1975	—	24	—	19	—
	1984	19	4	—	—	—
10	1975	—	—	—	15	—
	1984[d]	308	36	881	155	—
Total						
	1975	2 839	162	—	773	326
	1984	8 914	213	1 858	216	—

Source: Unesco statistical yearbooks.

[a] 1, natural sciences, mathematics, and computer sciences; 2, agricultural science and technology; 3, engineering and technological sciences, architecture and urban planning, industrial trades, transport, and communications; 4, medicine and health sciences; 5, social sciences, documentation, and social communications; 6, law; 7, humanities and letters, religion, and theology; 8, education and teacher training; 9, fine arts and applied art; 10, other unspecified programs (includes commerce and business administration, home economics, and training for the service sector).

[b] For Brazil, 1975 figures are actually 1974; for Costa Rica, 1976; for Ecuador, 1973.

[c] Includes social sciences.

[d] Mainly graduates from commerce and business administration courses.

ties, law, and art. In these latter two countries, a high proportion of students appear to be registered in education and in commerce and business administration. In all four countries, graduate enrolment represents only a tiny fraction of total university enrolment; this can be explained by the sharp growth in the latter and by the nature of graduate programs and courses, which are of relatively recent origin and are costly to develop.

Table 24 gives the number of graduate courses for a group of Latin American countries and their distribution by field of study using the categories defined for Table 16. The number of graduate programs has reached a significant level in several countries, Brazil being the outstanding example. The situation in Cuba is more difficult to evaluate because graduate courses there do not necessarily lead to a degree; many are incorporated into on-the-job professional development programs. No information is available for Mexico, where graduate courses have also increased dramatically. It can be deduced from Tables 23 and 24 that a significant number of graduate programs and courses in the region operate with small numbers of students.

The few available figures on MA and PhD graduates in Latin American countries are given in Tables 25 and 26. The information in Table 25 is for the most recent year available, and the classification of fields of study is the one described for Table 16. The data contained in Unesco statistical yearbooks on this subject are also sparse; they are presented in Table 26 (see description of categories for Table 18).

Scholarship holders studying abroad

Almost from the beginning, graduate studies and training for researchers and scientists have been part of an international undertaking for Latin American countries. The earliest academics in the region obtained their master's degrees or doctorates abroad, and even today, the most prestigious graduate studies are conducted in universities of the northern world. Latin American countries award foreign study grants through a number of channels, in addition to grants obtained through international cooperation. Little information on the subject is available. Although information from the countries that accept foreign students is more complete, it is not broken down sufficiently by the different levels of postgraduate study or discipline (Schütze, unpublished).[1] Table 27

[1] Schütze, H. Human resource development and development assistance: policies and practice concerning foreign students in OECD countries. (preliminary version, 1987)

Table 27. Graduate scholarships for studies abroad awarded by certain Latin American countries, 1975-1984.

Country	1975	1980	1981	1982	1983	1984	Annual average[a]
Brazil[b]	2 552	—	—	—	—	3 122	1 419
Chile	—	—	405	—	835	771	670
Colombia	658[c]	915	689	672	569	655	594
Costa Rica[d]	—	1980–1984 total, 185					37
Cuba	3 354[e]	—	—	—	—	7 647	3 667
Ecuador[f]	691	318	—	—	—	409	473
Mexico[g]	1971–1985 total, 20 000						1 333
Peru	—	—	248	—	—	—	248
Venezuela[h]	5 551	2 878	2 787	489	415	187	2 051

Source: Base studies.

[a] Includes only years for which information is available.

[b] 1975 figures cover 1975–1977 (de Souza Paula and Assad Rios, see footnote 7). In 1984, scholarships were awarded for 1 282 doctorates, 320 master's degrees, 269 specialized degrees, 302 postdoctorates, and 879 others. Regions of study were North America, 42%; Western Europe, 32%; other, 26%.

[c] Figure for 1976.

[d] Regions of study were North America, 52%; Western Europe, 36%; Latin America, 9%; other, 3%.

[e] Figure for 1977–1978.

[f] 15% are scholarships for secondary school studies abroad.

[g] Regions of study were United States, 50%; Western Europe, 39%; Latin America, 3%; other, 8%.

[h] Graduate scholarships for studies abroad awarded by the Gran Mariscal de Ayacucho Foundation. Figures for 1983 and 1984 are from CONICIT (1985).

Table 28. Region of study of postsecondary students from 12 Latin American countries (around 1983).

Country of origin	Total	USA	Canada	Western Europe[a]	Latin America and Caribbean[b]	Other[c]
Argentina	2 907	1 131	47	1 558	29	142
Brazil	6 182	2 438	111	3 026	29	578
Chile	3 185	992	51	1 943	149	50
Colombia	5 856	3 439	57	1 970	292	98
Costa Rica	1 084	619	30	246	131	58
Cuba	1 737	1 216	2	175	39	305
Dominican Republic	838	628	7	136	55	12
Ecuador	718	416	122	87	80	13
Guatemala	885	606	8	182	83	6
Mexico	6 947	4 682	222	1 819	130	94
Peru	3 548	1 763	44	1 493	129	119
Venezuela	8 865	6 042	167	2 573	48	35

Source: Unesco Statistical Yearbook, 1987.

[a] Includes Austria, Belgium, Denmark, Finland, France, Great Britain, Greece, Holland, Ireland, Italy, Portugal, Spain, Switzerland, the Vatican, and West Germany.

[b] Includes only Barbados, Cuba, Guatemala, Honduras, and Panama.

[c] Includes China, Czechoslovakia, East Germany, Hungary, Japan, Korea, Poland, and several African countries. Does not include the USSR.

gives some data on this aspect of training for Latin American researchers, but includes only grants awarded by the Latin American countries themselves.

Unesco data (Table 28) shows the number of students in 12 Latin American countries studying at the postsecondary level in a selected sample of 50 countries in all parts of the world. In this case, the figures represent not just scholarship holders, but the total number of students from these 12 Latin American countries who were studying abroad in about 1983 in a sample of host countries. A total of 42 752 students from the 12 Latin American countries were pursuing advanced studies abroad: 56% in the United States and 36% in Western European countries (not including Norway and Sweden). About half of the students counted came from Venezuela, Mexico, and Brazil.

3

Personnel Engaged in Scientific and Technical Activities

This chapter describes the distribution of scientific and technical personnel, i.e., people who are active in various fields of scientific research and experimental development.

Table 29 gives an overall view for the selected Latin American countries, in an attempt to gauge their scientific and technical capacity in the context of development and education in 1983–1985. These figures reveal once again a disconcerting situation in which variables that one might suppose to be interrelated show no correlation. However, this finding should be treated with caution as there are some problems with the figures presented. For example, the proportion of GNP spent on R&D is sometimes for a different year from the one for which per capita GNP is given. As will be seen later, this spending began to fluctuate widely just after 1980, at the beginning of the recession and the crisis affecting the economies of the region.

However, it can be seen that the countries that appear to be spending the highest proportion on scientific research and technology are not necessarily those with the highest per capita GNP. Instead, they are countries like Brazil and Cuba, which appear to have had the resolve and the political will to incorporate scientific development into their national development plans. Moreover, as

Table 29. Scientific and technical personnel and spending on research within the development context of certain Latin American countries, around 1984.

Country	GNP per capita	Manufacturing (% of GNP)	GSER	GUER	Scientists and engineers (per million population)		R&D (% of GNP)
					Total	In R&D	
Argentina	2 230	23.5	65	29.3	18 970	360	0.5[a]
Brazil	1 720	26.4	35	11.3[b]	11 231	256	0.6
Chile	1 700	20.1	66	15.3	7 466[c]	394	0.4[a]
Colombia	1 390	22.2	49	12.8	—	40	0.1
Costa Rica	1 190	18.8	42	22.1	—	171	0.1
Cuba	—	—	75	20.1	14 349	955	0.6
Dominican Republic	970	14.0	45	—	1 929[c]	—	—
Ecuador	1 150	8.3	55	33.1	7 110[c]	190[a]	0.3[a]
Guatemala	1 160	16.9	17	6.4	939[c]	348[d]	0.5
Mexico	2 040	22.6	55	15.2[b]	6 912[c]	101[c]	0.2[c]
Peru	1 000	25.5	65	21.5[b]	16 426	420	0.3
Venezuela	3 410	19.0	45	23.4	21 819	280	0.3[a]

Note: GNP, gross national product; GSER, gross secondary school enrolment rate; GUER, gross undergraduate enrolment rate. GSER and GUER are expressed as number of students per 100 in the same-age population.

Source: ECLAC (1986); World Bank (1986); Unesco Statistical Yearbook, 1986.

[a] In 1980.

[b] In 1982.

[c] In 1975 (no later information is available).

[d] Also includes technicians in R&D.

expected with the available data, it is not possible to establish a consistent correlation between high gross university education rates and the number of economically active scientists and engineers per million people. For example, the discrepancy in the figures for Ecuador may be due to the quality of the information available.

In addition, the degree of industrialization does not seem to be related to either the number of economically active scientists and engineers or the number of scientists and engineers engaged in research and development. This probably relates to the nature and characteristics of dependent industrialization, in which, during a lengthy phase, the endogenous processes of creating and applying knowledge are not a driving force. It can also be seen that the number of scientists and engineers engaged in research and development in the different countries varies as a proportion of the total number of economically active scientists and engineers. For each scientist and engineer engaged in R&D, there are over 75 active scientists and engineers in Venezuela, 52 in Argentina, 39 in Peru, and 15 in Cuba.

Using the same data base as the previous table, Table 30 reflects changes in scientific and technical personnel and spending on R&D activities in the Latin American countries covered by this study between 1975 and 1984, or around that time. Selected countries outside the region are included for comparison.

Before beginning a country-by-country analysis, reference should be made to Table 31, which is based on information processed and ranked by Sagasti and Cook (1985). It summarizes the available data on the scope of scientific and technical activities in selected Latin American countries at the beginning of the 1980s.

More recent information compiled by Unesco (Table 32) varies somewhat from that of Sagasti and Cook (1985), but there is broad consistency between the two sources.

Classified by sector of activity, science and technology personnel in the 12 selected countries are distributed as shown in Table 33, according to the most recent data compiled by Unesco. It should be noted that although the number of personnel per sector is expressed in terms of full-time equivalents, there are obvious under- and over-estimates in the country figures; Brazil, Colombia, and Chile are underestimated, Peru and Cuba are overestimated.

The scope of the information on scientific and technical person-

Table 30. Changes in number of scientific and technical personnel and in R&D spending in selected countries between 1975 and 1984.

Country	Scientists and engineers (per million pop.) Total	Scientists and engineers (per million pop.) In R&D	Technicians (per million pop.)	R&D spending (% of GNP)
Argentina				
1975	13 988	307	422	0.3
1980	18 970	360[a]	480	0.5
Brazil				
1975	—	75	—	0.3
1983	11 231[b]	256	—	0.6
Chile				
1975	7 466	583	—	—
1983	—	394	—	0.4[b]
Colombia				
1971[c]	—	50	27[d]	0.1
1982[e]	—	40	38	0.1
Costa Rica				
1984	—	147	—	0.1[a]
Cuba				
1980	6 309	585	679	0.6
1984	14 349[a]	955	885	0.6
Dominican Republic				
1975	1 929	—	—	—
Ecuador				
1973	7 110[f]	82	33	0.2
1979	—	190	155	0.3
Guatemala				
1975	939	52	74	0.2
1984	—	348[g]	—	0.5[a]
Mexico				
1975	6 912	101	137	0.2
Peru				
1975	—	137	139	0.4
1984	16 426[a]	420[a]	285	0.3
Venezuela				
1975	—	241	69	0.4
1983	21 819	280	164	0.3[b]

(continued)

Table 30. Concluded.

Country	Scientists and engineers (per million pop.) Total	Scientists and engineers (per million pop.) In R&D	Technicians (per million pop.)	R&D spending (% of GNP)
Canada				
1975	24 913	985	719[b]	1.1
1983	50 962[b]	1 298	735	1.4
India				
1975	1 211	89[b]	—	0.5
1983	2 829[b]	131	—	0.7
Israel				
1975	24 371	992	—	1.0
1980	—	3 991	—	2.5
Italy				
1975	10 330	679	492	0.9
1983	—	1 102	502	1.1
Korea				
1975	—	291	257	0.4
1984	2 426[b]	801	486[a]	1.1[a]
Norway				
1975	19 316	1 480	1 807	1.4
1983	23 787	1 884	1 814	1.4[h]
Spain				
1975	20 816[b]	174	128	0.3
1983	30 228	373	135	0.4
USA				
1975	10 797	2 467	203	2.3
1983	14 777	3 111	—	2.7[h]

Source: Unesco Statistical Yearbook, 1986.
[a] 1983.
[b] 1980.
[c] Excludes law, humanities, and education.
[d] 1978.
[e] Excludes the production sector.
[f] 1975.
[g] Includes technicians in R&D.
[h] 1984.

Table 31. Research personnel, projects, and units in a selected group of Latin American countries for the most recent year available.

Country and year	Researchers		Projects	Units
	Number	FTE[a]		
Argentina (1980)	18 929	10 486	11 243	1 866
Brazil (1984)	—	32 508[b]	8 030[c]	577[d]
Chile (1982)	4 530	—	3 111	228
Colombia (1982)	4 769	1 963	1 771	466
Costa Rica (1981)	850	411	737	13[e]
Cuba (1980)	11 400	5 700	1 393[f]	110[g]
Dominican Republic (1980)	100	—	351	65
Ecuador (1979)	766	—	556	—
Mexico (1984)	18 247	—	4 367	2 264
Peru (1980)	4 858	—	4 367	370[g]
Venezuela (1980)	3 673	2 156	3 400	556

Source: Sagasti and Cook (1985).
[a] FTE, full-time equivalent.
[b] 1982.
[c] Includes only projects under analysis and contracted for.
[d] Number of institutions where R&D was carried out in 1983.
[e] Number of institutions where 90% of R&D activities were conducted.
[f] Projects dealing with the 77 main research problems.
[g] Number of institutions where R&D activities were conducted.

nel in the selected Latin American countries compiled for this study is summarized in Table 34.

Argentina

According to Unesco information (Table 32), there were about 10 500 scientists and engineers active in R&D in 1982, that is, 360 per million inhabitants. The base study, however, reports only career researchers — a limited number of "people who conduct creative research and development at the separate levels of conception, design and execution." At present, the National Council of Scientific and Technical Research (CONICET) has a staff of almost 2 500 scientific researchers at different levels: assistant, associate, independent, principal, and senior researchers. A relatively large number of new people have been brought into the profession in the last 2 years; in the last competition (1985) there were 319 researchers, distributed as in Table 35.

Table 32. Scientific and technical personnel[a] in R&D in 12 Latin American countries for the most recent year available.

Country and year	Total S&T personnel	Scientists and engineers (S&E)	Technicians	Scientists and engineers per million population: Potential	Scientists and engineers per million population: In R&D
Argentina (1982)	—	10 486	—	535 656[b]	360
Brazil (1982)	32 508	—	—	668 911[b]	256
Chile (1984)	1 691	1 587	104	69 946[c]	134[d]
Colombia (1982)	2 107	1 083	1 024	—	40
Costa Rica (1982)	—	411	—	—	171
Cuba (1985)	19 543	10 305	9 238	139 469[e]	1 027
Dominican Republic (1970)	—	68	—	7 837[c]	—
Ecuador (1979)	3 301	2 049	1 252	48 559[f]	259[g]
Guatemala (1984)	2 699	—	—	5 551[f]	348
Mexico (1984)	46 146	16 679	29 467	291 812	216
Peru (1981)	—	9 858	—	—	273[h]
Venezuela (1983)	7 260	4 584	2 692	347 000[i]	279

Source: Unesco Statistical Yearbook, 1987.
[a] Does not include support staff.
[b] 1980.
[c] 1970.
[d] Unesco Statistical Yearbook (1986) reports 4 530 scientists and engineers in 1983, 394 per million population in R&D.
[e] 1981.
[f] 1974.
[g] Unesco Statistical Yearbook (1986), shows 190 scientists and engineers per million population for 1980.
[h] Unesco Statistical Yearbook (1986), reports 420 for 1983.
[i] 1982.

Table 33. Scientists and engineers in R&D by sector of activity in 12 selected Latin American countries for the most recent year available.

<table>
<tr><th rowspan="2">Country and year</th><th rowspan="2">All sectors</th><th colspan="2">Production</th><th rowspan="2">Higher education</th><th rowspan="2">General services</th></tr>
<tr><th>Integrated</th><th>Not integrated</th></tr>
<tr><td>Argentina (1982)</td><td>10 486</td><td>476</td><td>2 466</td><td>3 497</td><td>4 047</td></tr>
<tr><td>Brazil (1978)</td><td>—</td><td colspan="2">8 497</td><td>15 518</td><td>—</td></tr>
<tr><td>Chile (1984)</td><td>1 587</td><td>23</td><td>432</td><td>1 094</td><td>38</td></tr>
<tr><td>Colombia (1982)</td><td>1 083</td><td colspan="2">33</td><td>687</td><td>363</td></tr>
<tr><td>Costa Rica (1982)</td><td>411</td><td colspan="2">32</td><td>237</td><td>142</td></tr>
<tr><td>Cuba (1985)</td><td>10 305</td><td>514</td><td>4 131</td><td>1 705</td><td>3 955</td></tr>
<tr><td>Dominican Republic</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>Ecuador (1979)</td><td>2 049</td><td colspan="2">52</td><td>599</td><td>1 398</td></tr>
<tr><td>Guatemala</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>Mexico (1984)</td><td>16 679</td><td colspan="2">5 268</td><td>7 979</td><td>3 432</td></tr>
<tr><td>Peru (1981)</td><td>7 464</td><td colspan="2">896</td><td>3 600</td><td>2 968</td></tr>
<tr><td>Venezuela (1983)</td><td>4 568</td><td>347</td><td>117</td><td>2 961</td><td>1 183</td></tr>
</table>

Source: Unesco Statistical Yearbook, 1987.

Table 34. Summary of information collected in the base studies on the distribution of scientific and technical personnel in the selected Latin American countries.

Country and year	Distribution by field of study	Distribution by occupational field	Distribution by sector of activity	Distribution by academic level
Argentina (1985)	Partial	No	No	No
Brazil (1986)	Institutions	No	Institutions	Yes
Chile (1981)	Partial	Yes[a]	Institutions	Partial
Colombia (1982)	Researchers	No	Researchers	Yes
Costa Rica (1986)	No	Researchers	No	Yes
Cuba (1985)	No	—	Yes[b]	Partial
Dominican Republic (1980)	Projects[c]	No	Researchers	Yes
Ecuador (1979)	Researchers	Researchers	No	No
Guatemala (1983)	Researchers	Researchers	No	No
Mexico (1984)	No	Researchers	Institutions	Yes
Peru (1981)	No	Institutions	Researchers and Institutions	No
Venezuela (1983)	Yes	Yes	Yes	Yes

[a] With additional data from the CRESALC report (in press).
[b] With an ad hoc classification based on science and technology institutions.
[c] By type of research.

Table 35. Distribution by field of researchers in the CONICET research career, Argentina 1985.

Field	Researchers (%)[a]
Natural sciences	43.90
Physical sciences, astronomy, mathematics, and computer science	15.05
Chemistry	14.11
Biology	7.84
Earth sciences	6.90
Agricultural sciences and veterinary medicine	1.56
Engineering and technology	16.30
Health sciences	10.66
Subtotal	72.42
Social sciences	21.94
Economics, sociology, law, political science	10.03
History and anthropology	11.91
Humanities (philosophy, psychology, philology, and education)	5.64
Subtotal	27.58

[a] There were 319 researchers in this group.

CONICET also supports six research centres and 114 institutes, some of which are considered to be "centres of excellence" by the base study group. Examples are

- PLAPIQUI, Chemical Engineering Pilot Plant, Bahía Blanca;
- INGAR, Institute of Development and Design, Santa Fé;
- INTEC, Institute of Technological Development for the Chemical Industry, Santa Fé; and
- IIBBA, Buenos Aires Biochemical Research Institute.

Brazil

Although according to Unesco information (Table 32), the number of researchers engaged in R&D was 32 508 in 1982, Brazilian figures placed the total for the period 1983 to 1985 at 47 870. Their levels of education are shown in Table 36.

In 1986, there were 602 institutions engaged in scientific and technological research. They were distributed by sector as shown in Table 37.

Table 36. Number of researchers by level of education, Brazil 1983–1985.

Level	Number	%
Basic university degree	11 852	24.8
Specialized degree	6 831	14.3
Master's degree	11 925	24.9
Doctorate	7 136	14.9
Postdoctoral studies	1 804	3.8
No information	8 322	17.4
Total	47 870	100.0

Source: de Souza Paula and Assad Ríos (see footnote 7).

Table 38 shows the distribution of the institutions that conduct scientific and technological research projects by major field of knowledge. There appear to be more institutions than in the preceding table, but this is because many of them cover more than one area and are, therefore, counted more than once in Table 38.

Chile

The base study collected information on research units and their distribution, and partial information on the number of researchers in certain disciplines or areas of specialization (Tables 39 and 40).

According to the base study, 33.9% of these researchers are university graduates, 30.7% possess master's degrees, and the remaining 35.4% have doctorates.

Table 41, based on the CRESALC report on higher education in Chile, gives a more realistic quantification of the population of researchers (scientists and engineers) who work exclusively in the university system and in independent academic centres for the social sciences.

Sagasti and Cook (1985) report that there were 4530 scientists and engineers engaged in R&D in Chile in 1982, equivalent to almost 400 per million inhabitants (Table 31). However, according to figures published by Unesco, the total number of scientists and engineers engaged in R&D was only 1587 in 1984 (Table 32), an underestimate that does not correlate with the trends in the other figures provided by Unesco.

Table 37. Number of institutions by sector conducting scientific and technological research in Brazil, 1986.

Sector and type of institution	Number	%
Teaching	121	20.1
Higher education	110	18.3
Federal	44	7.3
State	18	3.0
Municipal	8	1.3
Private	40	6.6
Secondary education	8	1.3
Federal	4	0.7
State	2	0.3
Municipal	—	—
Private	2	0.3
Vocational training	3	0.5
Specializing in science and technology	121	20.1
Federal	32	5.3
State	68	11.3
Municipal	—	—
Private	21	3.5
Government	189	31.4
Federal	70	11.6
State	102	16.9
Municipal	17	2.8
Government corporations	61	10.1
Federal	33	5.5
State	28	4.7
Private sector	110	18.3
Foundations	10	1.7
Companies	78	13.0
Other	22	3.7
Total	602	100.0

Colombia

For Colombia, the base study contains fairly complete information, which is summarized in Tables 42 to 45. Table 42 shows the distribution of researchers among disciplines by field of training.

Table 38. Distribution of institutions conducting scientific and technological research projects by major field in Brazil, 1986.

Field	Number	%
Exact and earth sciences	155	9.8
Biology	261	16.5
Agricultural science and technology	294	18.5
Engineering and technology	362	22.8
Health sciences	115	7.3
Subtotal	1 187	74.9
Applied social sciences	195	12.3
Human sciences	175	11.0
Linguistics, literature, arts	28	1.8
Subtotal	398	25.1
Total	1 585	100.0

Table 43 shows the distribution of researchers by institutional sector.

The academic level of Colombian researchers is given in Table 44, which shows that less than one-third possess master's degrees or doctorates, whereas the majority have professional diplomas or have engaged in specialized studies. Table 45 correlates academic level of researchers with work sector.

It is worth calling attention to the fact that the data contained in the base study differ from the data provided by Unesco which show a total of 2 107 scientists and engineers engaged in R&D (Table 32), not counting those who work in the production sector who, according to the base study, number no more than 650.

Costa Rica

Tables 46 and 47 show the distribution of human resources engaged in scientific and technological research in Costa Rica. Table 46 gives the occupational disciplines of the researchers; Table 47 shows their classification by academic level. It should be noted that the Unesco statistics (Table 32) record 411 scientists and engineers engaged in R&D in 1982.

Table 39. Number and distribution of research units in Chile by institutional sector and principal discipline, 1986.

Discipline	Higher education	Production: Integrated	Production: Nonintegrated	General service	Total
Natural or basic sciences	149	—	—	3	152
Agricultural sciences and technology	47	3	8	2	60
Engineering and technology	124	9	5	2	140
Health sciences	144	1	1	1	147
Subtotal	464	13	14	8	499
Social sciences	130	—	—	18	148
Legal and administrative sciences	35	—	—	—	35
Humanities and the arts	85	—	—	5	90
Subtotal	250	—	—	23	273
Total	714	13	14	31	772

Table 40. Number and distribution of researchers in Chile for selected disciplines (around 1981).

Discipline	Number	%
Natural or basic sciences[a]	578	43.2
Agricultural sciences[b]	630	47.2
Engineering and earth sciences[c]	126	9.5
Total	1 334	99.9

[a] Includes only a few subspecializations in biology.
[b] Includes researchers working in this field in the various institutional sectors and not just in universities.
[c] Includes only two subspecializations in the case of engineers and, in general, only the university sector.

Table 41. Number and distribution of researchers in the university sector[a] in Chile (around 1981).

Discipline	Number	%
Natural or basic sciences	1 308	50.8
Biology	728	28.3
Mathematics	78	3.0
Physics	104	4.0
Chemistry	338	13.1
Earth sciences	60	2.3
Agricultural sciences and technology	369	14.3
Engineering and technology[b]	274	10.6
Health sciences	276	10.7
Subtotal	2 227	86.4
Social sciences	330	12.8
University system[b,c]	180	7.0
Independent centres[c]	150	5.8
Legal and administrative sciences[b]	20	0.8
Subtotal	350	13.6
Total	2 577	100.0

Source: CRESALC report on higher education in Chile (in press).
[a] Also includes the subsystem of independent academic centres in the field of the social sciences.
[b] Estimate.
[c] Includes economics, sociology, political science, education, and history.

Table 42. Distribution of researchers in Colombia by field of training, 1982.

Field of training	Number	%
Natural or basic sciences	1 525	32.0
Agricultural sciences	719	15.1
Engineering and technology	593	12.4
Health sciences	1 097	23.0
Subtotal	3 934	82.5
Social sciences	835	17.5
Total	4 769	100.0

Table 43. Distribution of researchers in Colombia by institutional sector, 1982.

Institutional sector	Number	%
University	2 594	54.4
Public	1 394	28.7
Private	627	13.2
Mixed economy	176	3.7
Total	4 769	100.0

Table 44. Distribution of researchers in Colombia by academic level, 1982.

Academic level	Number	%
Basic university degree	373	7.8
Professional qualification	1 364	28.6
Specialized degree	1 213	25.5
Master's degree	1 251	26.2
Doctorate	568	11.9
Total	4 769	100.0

Cuba

Unesco placed the number of scientists and engineers engaged in R&D in Cuba at about 10 000 (Table 32), or over 1 000 per million population. As can be seen immediately, the data from the base

Table 45. Distribution of researchers in Colombia by sector and academic level, 1982.

		Sector				
Academic level	University	Public	Private	Mixed	No.	%
Basic university degree	260	37	72	4	373	7.8
Professional qualification	664	499	135	66	1 364	28.6
Specialized degree	635	413	109	56	1 213	25.5
Master's degree	740	319	157	35	1 251	26.2
Doctorate	295	104	154	15	568	11.9
Total	2 594	1 372	627	176	4 769	100
%	54.4	28.7	13.2	3.7	100	

Table 46. Distribution of researchers in Costa Rica by occupational discipline,[a] 1986.

Discipline	Number	%
Natural or basic sciences	218	24.4
Agricultural sciences	73	8.2
Engineering	70	7.8
Health sciences	168	18.8
Subtotal	529	59.2
Social sciences	162	18.1
Humanities and law	147	16.5
Other	55	6.2
Subtotal	364	40.8
Total	893	100.0

[a] Includes active, inactive, and potential researchers.

Table 47. Distribution of researchers in Costa Rica by academic level, 1986.

Academic level	Number	%
Basic university degree	258	28.9
Master's degree	140	15.7
Doctorate	172	19.2
Specialized degree	14	1.6
Other and unspecified	309	34.6
Total	893	100.0

study are different, because they cover a total population of "persons working in science and technology," which numbers 40 183 people, including support staff, graduates of universities and high schools, and "other workers" (Table 48).

People in the category of researchers numbered 4 510 in 1984, a more realistic figure than the 10 000 in the Unesco statistics. Distribution by category is given in Table 49. Workers engaged in R&D, i.e., the population defined above and shown in Table 48, is classified by the various institutions that employ them in Table 50.

Table 48. Workers in science and technology in Cuba, 1981–1985.

Level	1981	1982	1983	1984	1985
Advanced[a]	10 073	11 174	11 290	13 837	15 808
Middle	8 199	8 422	8 704	9 134	9 656
Other workers	10 541	11 267	12 512	14 725	14 719
Total	28 813	30 863	33 506	37 696	40 183

[a] Total number of university graduates already engaged in research and development. "When they have left the university and are in their scientific work, they may train to obtain scientific degrees" (base study, p. 13). There are 132 doctors and 1 687 doctoral candidates.

Table 49. Number of researchers in Cuba by job category, 1984.

Category	Number	%
Principal researcher	416	9.2
Associate researcher	706	15.6
Assistant researcher	1 243	27.6
Research trainee	2 145	47.6
Total	4 510	100.0

Table 50. Distribution of workers in science and technology in Cuba by place of employment, 1981 and 1985.

	1981		1985	
Institution	Number	%	Number	%
Academy of Sciences	4 501	15.6	6 218	15.5
Public health	4 596	15.9	6 620	16.5
Higher education	7 387	25.6	9 919	24.7
Agriculture	3 904	13.5	5 013	12.5
Industry	4 697	16.3	7 395	18.4
Standardization	468	1.6	570	1.4
Construction	511	1.8	675	1.7
Sport	435	1.5	456	1.1
Other	2 314	8.0	3 290	8.2
Total	28 813	100.0	40 183	100.0

The Dominican Republic

The distribution of the personnel working in science and technology by institutional sector is shown in Table 51. Research projects (presumably in 1980) numbered 498; they are broken down by type

Table 51. Distribution of science and technology personnel in the Dominican Republic by institutional sector, 1980.

	Professional		Technical	
Sector	Number	%	Number	%
University	133	12.76	102	34.93
Public	909	87.24	190	65.07
Private	—	—	—	—
Total	1 042	100.0	292	100.0

Table 52. Distribution of research projects in the Dominican Republic by type of research, 1980.

Type of research	Number	%
Basic	7	1.4
Applied	260	52.2
Experimental development	49	9.8
Support	171	34.4
Unspecified	11	2.2
Total	498	100.0

Table 53. Nonuniversity research personnel in the Dominican Republic by sector and academic level, 1986.

	Academic level			
Sector	Basic degree	Graduate degree	Special	Total
Industrial agriculture	226	34	—	260
Energy	—	—		54
Dominican Institute of Technology	—	4	10	14
Population and Development Institute	—	3	—	3
Central bank	—	33	—	33
Total	226	74	10	364

of research in Table 52. An estimate of nonuniversity research personnel by sector and academic level is given in Table 53.

According to the base study, university researchers numbered 181, 52 of whom had advanced degrees: 9 were PhDs, 25 were MAs,

Table 54. Distribution of researchers in Ecuador by field of training and current field of work, 1979.

Discipline	Field of training		Field of work	
	Number	%	Number	%
Natural or basic sciences	365	20.9	409	23.4
Agricultural science and technology	503	28.8	485	27.8
Engineering and technology	429	24.6	418	23.9
Health sciences	98	5.6	96	5.5
Subtotal	1 395	79.9	1 408	80.6
Social sciences	281	16.1	274	15.7
Humanities and law	70	4.0	64	3.7
Subtotal	351	20.1	338	19.4
Total	1 746	100.0	1 746	100.0

Table 55. Number and distribution of researchers in Guatemala by field of training, 1978.

Discipline	Number	%
Natural or basic sciences	98	10
Agricultural science and technology	246	25
Engineering	247	25
Health sciences	49	5
Subtotal	640	65
Social sciences	295	30
Humanities	10	1
Other	40	4
Subtotal	345	35
Total	985	100

and 18 had specialized diplomas. Of the total, about 32% stated that they were working full-time on research (base study, Dominican Republic, October 1986). There are no comparable Unesco statistics.

Ecuador

The information for Ecuador collected in the base study is for the year 1979. It is summarized in Table 54, which shows the distribution of researchers by field of training and by field of work.

For the same year (1979), Unesco placed the number of scientists

Table 56. Distribution of researchers in Guatemala by field of work, 1983.

Field	Number	%
Natural resources and the environment	76	7
Agriculture	241	22
Industrial technology	—	—
Energy distribution and equipment	317	29
Housing	11	1
Health	131	12
Social, economic, and political problems	186	17
Commerce and services	11	1
Education	55	5
Natural or basic sciences	66	6
Total	1 094	100

Table 57. Distribution of researchers in Guatemala by academic level, 1978 and 1983.

	1978		1983	
Level	Number	%	Number	%
With an academic degree	521	53	611	56
Without an academic degree	464	47	483	44
Subtotal	985	100	1 094	100
With a postgraduate degree	121	12	—	—

Table 58. Distribution of researchers[a] in Mexico by field of work, 1974 and 1984.

Discipline	1974		1984	
	Number	%	Number	%
Natural or basic sciences	2 107	24.5	3 806	23.2
Agricultural science and technology	1 088	12.7	2 431	14.8
Engineering and technology	1 737	20.2	2 696	16.4
Health sciences	1 224	14.2	1 613	22.3
Subtotal	6 156	71.6	12 546	76.7
Social sciences and humanities	2 439	28.4	3 858	23.3
Total	8 595	100.0	16 404	100.0

[a] People conducting experimental research and development who have pursued postsecondary studies.

Table 59. Number and distribution of research units in Mexico by institutional sector, 1984.

Sector	Number	%
Federal government	66	10.4
Federal paragovernmental corporations	138	22.0
State governments	6	0.9
Public higher education centres	317	50.3
Private higher education centres	47	7.5
Paragovernmental corporations	5	0.8
Private corporations	37	5.8
Nonprofit institutions	11	1.8
International organizations	3	0.5
Total	630	100.0

Table 60. Distribution of researchers in Mexico by academic level, 1984.

Academic level	%
Basic university degree	49.7
Specialized degree	12.2
Master's degree	24.2
Doctorate	13.9
Total	100.0

Table 61. Distribution of research institutions in Peru by sector and scientific field, 1981.

Field	Government	State university	Production				Specialized	Total
			Specialized	Public	Joint	Private		
Natural sciences	36	48	5	4	—	21	9	123
Agricultural sciences and technology	43	45	—	1	1	11	15	116
Engineering	22	20	3	8	1	35	7	96
Health	20	13	2	—	—	—	3	38
Subtotal	121	126	10	13	2	67	34	373
Social sciences	55	100	49	1	—	1	82	288
Human sciences and humanities	8	25	7	—	—	—	8	48
Other	1	—	—	—	—	—	—	1
Subtotal	64	125	56	1	—	1	90	337
Total	185	251	66	14	2	68	124	710

Table 62. Distribution of human resources in science and technology in Peru by sector and job classification, 1980.

Sector	S&T personnel	S&T support staff	Administrative staff	Total
Government	2 968	3 538	4 512	11 018
University				
State	3 321	1 045	959	5 325
Private	279	108	55	442
Production				
State	175	104	255	534
Joint	—	3	36	39
Private	143	51	16	210
Specialized	578	215	235	1 028
Total	7 464	5 064	6 068	18 596

Table 63. Human resources and research and development projects in Peru, 1980.

Sector	Researchers		Projects	
	Number	%	Number	%
Universities	2 747	56.6	2 698	61.8
Government	1 430	29.4	1 207	27.6
Private centres and businesses	681	14.0	462	10.6
Total	4 858	100.0	4 367	100.0

and engineers engaged in R&D in Ecuador at about 2 000 (Table 32).

Guatemala

The base study contains information on the number and distribution of researchers in Guatemala by field of training, occupation, and academic level (Tables 55 and 56). Table 57 gives the distribution of Guatemalan researchers by academic level for two separate years. The Unesco statistics do not contain any comparable data.

Table 64. Distribution of scientists and technicians in Venezuela by field of training and academic level, 1983.

Field	Academic level									
	Basic degree		MA		PhD		No degree		Total	
Natural sciences	576	(32.6)[a]	320	(23.6)	1 023	(35.7)	411	(57.3)	2 330	(34.7)
Agricultural sciences and technology	356	(20.1)	300	(22.1)	1 470	(51.3)	60	(8.2)	2 186	(32.6)
Engineering	326	(18.5)	280	(20.6)	53	(1.8)	40	(5.4)	699	(10.4)
Health sciences	190	(10.7)	126	(9.3)	147	(5.1)	104	(14.5)	567	(8.5)
Subtotal	1 448	(81.9)	1 026	(75.6)	2 693	(93.9)	615	(95.8)	5 782	(86.2)
Social sciences	294	(16.6)	259	(19.1)	140	(4.9)	68	(9.3)	761	(11.3)
Other	25	(1.4)	72	(5.3)	35	(1.2)	34	(4.6)	166	(2.5)
Total	1 767	100	1 357	100	2 868	100	717	100	6 709	100

[a] Figures in parentheses are percentages.

Mexico

Mexican researchers were, in 1979 and 1984, distributed by occupational discipline as shown in Table 58. Table 59 shows distribution of institutions or research units by sector in 1984.

The Mexican base study contains information on the distribution of research personnel by academic level for 1984 (Table 60). The information on Mexico provided by Unesco (Table 32) is consistent with the information obtained in the base study.

Peru

Research institutions in Peru totaled 710 in 1981, and were distributed by discipline and sector as shown in Table 61.

The base study also contains information for 1980 on the distribution of science and technology personnel by sector and occupational category (Table 62). The numbers in the preceding table are lower than those given by Unesco for 1981 (Table 32), but they do reflect the information provided for around 1980 in other Unesco statistics.

A second estimate in the base study indicates that, in 1980 in Peru, there were 4 858 researchers and 4 367 projects distributed by major sector as indicated in Table 63.

Table 65. Number of scientists and technicians in R&D in Venezuela by sector of activity, 1983.

Sector	Number	%
Public	4 323	94.6
Higher education	2 853	62.4
Integrated production	274	6.0
Nonintegrated production	86	1.0
General services	1 110	24.3
Private	245	5.4
Higher education	68	1.5
Integrated production	73	1.6
Nonintegrated production	31	0.7
General services	73	1.6
Total	4 568	100.0

Table 66. Number of scientists and technicians in R&D in Venezuela by occupational field, 1980 and 1983.

Field	1980 Number	1980 %	1983 Number	1983 %
Exact and natural sciences	1 039	28.3	1 457	31.9
Agricultural science and technology	780	21.2	874	19.2
Engineering and architecture	633	17.2	727	15.9
Subtotal	2 993	81.5	3 616	79.2
Social sciences and humanities	552	15.0	802	17.6
Other and unstated	128	3.5	150	3.3
Total	3 673	100.0	4 568	100.0

Venezuela

The base study places the total number of scientists and technicians in Venezuela at 6 709 and those working on R&D at 4 568. This last figure agrees with Unesco statistics, which estimate about 4 600 scientists and engineers in 1983 (Table 32). The distribution of scientific and technical personnel is shown in Tables 64 to 66. Table 64 refers to all scientists and technicians, while Tables 65 and 66 refer exclusively to those working on R&D.

4

Graduate Programs

As was shown in Chapter 2, graduate enrolment and the number of people obtaining doctorates or master's degrees or participating in specialized courses has increased significantly in Latin America. Some countries have given strong impetus to graduate training, with impressive quantitative results.

However, available information is fragmentary and heterogeneous. There is no clear view of the relation between graduate programs and the training of scientific researchers. At best, there may be such a relation only for doctoral programs, which involve a very low proportion of graduate level students in Latin America.

Diversity and Heterogeneity

Graduate programs seem to have a variety of goals or objectives, including the following four, which differ greatly (Schwartzman 1981: 120).

- **Accreditation** to permit access to or promotion within institutions where graduate degrees are required, officially or unofficially, for certain positions or to ensure advancement within the hierarchy. In this case, the demand for graduates is institutionally determined. To a large extent, it is the result of bureaucratic regulation of the positions in institutions that form part of what may be called the "knowledge industry" (in the sense in which the term is used in the classic study by Machlup 1962).
- **Professional training** at advanced levels as an extension of degree program studies. The reasons for continuing studies vary

considerably. It may be in response to demands by the professional market for people who have continued their professional studies up to the graduate level; a strategy to keep people out of a saturated labour market for longer periods; compensation for gaps or shortcomings in training at the basic degree level; response to requirements for specialization arising either from the internal dynamics of the discipline or profession or from exogenous developments in the marketplace; or to increase level of expertise within a profession, which is growing as a result of earlier, less restricted access to higher education.

- **Conspicuous cultural consumption**, which aims at increasing the prestige of given groups in intellectual fields, offering them access to sophisticated studies backed up by degrees that confer a higher value on the academic training obtained at the undergraduate level.
- **Training in science and research**, which is often the only declared goal of graduate programs, although, in fact, they tend to have some of the objectives or to fulfill some of the functions described above.

It is impossible, given the poor quality of the information available and the paucity of Latin American studies on the creation and development of graduate programs, to offer a full discussion of each of the different types of programs. However, the diversity of goals and functions should be kept in mind when programs are analyzed, especially in the context of formulating policies for training new scientists.

Creation and Institutionalization

In a study sponsored by CRESALC in Brazil, Colombia, Mexico, and Venezuela, three questionnaires were administered to the coordinators of selected graduate programs (at the most advanced level in each country) and a sample of professors and students in these programs (Casanova 1986; de Andrade Córdova et al. 1986; Klubitschko 1986; Vélez B. and Caro 1986; Wuest Silva 1986). These in-depth studies permit a detailed discussion of the most salient features of graduate programs in the region, especially those leading to master's degrees and doctorates.

Modern graduate programs in Latin America, i.e., those that follow essentially the North American model for studies at this level, are a relatively recent creation. Generally speaking, they have been set up in the last 25 years, beginning in 1960. They began to increase in Mexico and Brazil a little earlier than in Colombia and

Venezuela, but in all four countries, expansion was greatest after 1970. The programs have come to cover most disciplines and a variety of specializations within them. The quality of the programs, insofar as can be established by evaluation studies, is uneven; a number of them have disappeared after only a few years of operation.

The strong growth in graduate programs, which generally occurred over a short period of time, can be explained mainly by the demand from institutional markets, especially the universities themselves, who made possession of a graduate degree the requirement for access to an academic career or for promotion within one. Thus, the increase in graduate programs in the region is closely linked to professionalization of academic careers (Brunner 1985), a phenomenon which is in turn linked to growth in university enrolment and the creation of a new stratum of intellectuals (academics) whose initial legitimacy is based precisely on the possession of academic diplomas. Graduate programs in all the countries studied were created after standards were established that tended to confer strategic value on graduate credentials for academic careers.

Furthermore, in most cases, the program coordinators who responded to the survey maintained that the graduate programs were created either exclusively for academic purposes, with no consideration given to nonacademic demands (i.e., factors external to the dynamics of developing the discipline itself or the demand by university professors for certification and credentials) or for mixed reasons combining academic objectives and those of the institutional market (or even the external labour market). It has not been the usual practice to conduct studies of market demand when establishing these programs. Such studies were carried out in only 15% of the cases examined in Brazil and in one-third of the programs reviewed in Venezuela.

The foregoing also explains why university professors themselves have been the most active promoters of these programs. The CRESALC study shows that, in each of the four countries, it was professors who worked to set up more than 60% of the programs, behaving in other words like active promoters. On the other hand, there was almost no instance of student pressure for the creation of such programs. The demand by the professors is clearly associated, in their own view, with the value of graduate degrees as a means of access to academic careers and promotion within them. About two-thirds of the professors interviewed during the CRESALC study stated that they were interested in obtaining advanced degrees for career purposes.

Another influence on the creation of graduate programs has been the prestige they confer on their respective disciplines and the academics working in them. It is well known that the academic world believes that a discipline is not solidly established until it has the capability to produce its own researchers at the highest level, i.e., through doctoral programs. In the four countries studied, about 70% of the people interviewed maintained that the creation of a graduate program in their discipline had helped to improve the prestige of that discipline within the university. A somewhat smaller, but significant proportion felt that such programs had also helped to secure their prestige in society.

Because the establishment of graduate programs is linked to matters of intradisciplinary and interuniversity prestige, their creation in one discipline or university can be expected to trigger reactions at a number of other points in the national academic system. As Klubitschko (1986: 31–32), the author of the CRESALC general survey study, said:

> Once a graduate program has been created in a specialization within a discipline, others will tend to be created in other specializations; when a graduate program is created in a related discipline, the other related disciplines will tend to follow suit; and lastly, when a graduate program is created in a university, other universities will move to establish their own graduate programs.

Competition is a major cause of change in academic systems (Clark 1983: chapter 5), regardless of whether this is acknowledged or accepted by the actors involved in such competitive dynamics. Representative percentages of the graduate program coordinators interviewed for the CRESALC study of the four countries acknowledged that intra- and interuniversity competition played a significant role in the creation of such programs; this admission was most frequently made in Brazil and less frequently in Venezuela, Colombia and Mexico, in that order. It is clear that the symbolic legitimacy of competition as a pattern of institutional behaviour, and the role assigned to it in the political and academic culture of each country are among the factors influencing this type of perception.

The CRESALC study shows that graduate programs especially during the early years of their development tended to establish external contacts (for various purposes). This was customary in Brazil and infrequent in Mexico and Colombia, with Venezuela occupying an intermediate position. In countries where such contacts existed, they were, in most cases, established with public sector institutions and only occasionally with organizations in the private sector. This is largely explained by the fact that most agreements are entered into for the purpose of obtaining grants or other resources needed to develop the graduate program. From the information available, there can be no doubt that, in each country where graduate programs have developed to a certain level, they have succeeded precisely because of support from the technocratic sectors of the government that are linked to higher education and national scientific development.

In Brazil and Venezuela, about half of the graduate programs studied had entered into agreements with foreign institutions in their early development stages, while the number drops to 29% in Colombia and to 19% for Mexico. As time went on and the initial period of operation came to an end, Venezuela was the only country in which there was a decline in the number of agreements. Their relative importance remained steady in the other countries, and increased in Brazil.

For most of the initial agreements, the home country of the other institutional party was the United States, followed by countries in Western Europe. The agreements frequently covered training and exchange programs for professors and, less often, joint research. Although national agreements are decidedly instrumental or financial in nature, agreements with foreign institutions are generally academic or substantive and concerned with the transmission of academic models, research experience, and knowledge. The presence of visiting professors during the early stages of the development of graduate programs confirms this. In Brazil, 85% of the programs had visiting professors during this stage; in Venezuela the figure was 71%, in Colombia 53%, and in Mexico 45%.

Graduate programs in Latin America have been created in diverse institutional contexts. Klubitschko (1986: 44) distinguishes three different contexts which, she says, generate different dynamics of institutionalization: old universities with strong academic traditions, both public and private; new public and private universities; nonuniversity research centres and institutes.

It appears that, in most of the countries, the dynamics of creating and institutionalizing graduate programs started in the old public universities that had the greatest prestige. The practice spread from these centres, depending on the nature of the educational system in each country, to other old public and private universities. At some point in the process, new universities with sufficient resources and enough staff with high academic status began to create their own graduate programs which, from the outset, were generally organized into departments, unlike the old universities with their more ponderous, traditional structures based on faculties and schools providing professional instruction. In the new universities, there is occasionally a clear separation between undergraduate and graduate levels, which may even have separate administrations. Institutionalization of graduate programs has occurred in nonuniversity research centres where the collective presence of a number of skilled researchers has made it possible to introduce advanced teaching programs, which are generally the only level of education offered by this type of institution.

In general, the criteria for institutionalizing graduate programs have varied and do not appear to have been based on long-term planning in any country. They have instead responded to demands and pressures, taking advantage of opportunities and resources, and in each case tailoring the creation of graduate programs to the possibilities and limitations of specific institutional contexts, which largely determine the ways in which these initiatives are organized and subsequently develop. Important in this type of process are the key role played by the core groups that initiate programs; the positions of leadership that are created within such groups; the ways in which initial conflicts are resolved; the kind of links established with the university and with centres of authority outside it; and the internal growth dynamics of the discipline itself and, therefore, the links between the national academic community working in that discipline and the international community that is similarly engaged.

Teachers

The CRESALC study (Casanova 1986; de Andrade Córdova et al. 1986; Klubitschko 1986; Vélez B. and Caro 1986; Wuest Silva 1986) also compiled information on the professors who teach in the graduate programs of the four countries surveyed.

Fifty per cent of the professors in these programs have been with their universities for 12 to 14 years. A significant number (about 25% in each country) began working at their universities between 1975 and 1978, depending on the country in question.

Obviously, professors in the graduate programs have less seniority: the average is slightly over 8 years in Brazil, almost 6 years in Mexico, and a little over 5 years in Colombia and Venezuela. Moreover, 25% of the professors in the graduate programs were hired in or after 1979 in Brazil, 1980 in Venezuela, 1981 in Mexico, and 1982 in Colombia.

Most of the professors teaching graduate courses who were interviewed have master's degrees or doctorates. In Brazil, 91% hold doctorates. In Colombia, only 40% have doctorates, while 52%

have master's degrees and the rest basic degrees. In Mexico, 68% hold doctorates and 26% master's degrees. In Venezuela, the figures are 65 and 32%, respectively. It is interesting to note that, except in Brazil, a large number of professors in these programs do not hold doctorates; this reveals less about their ability, which is not necessarily associated with the possession of a degree, than about the potential demand in the academic market for more advanced courses at the graduate level.

In all four countries, acquisition of doctorates by the professors is a recent phenomenon. About 75% of PhDs in each country received these degrees between 1970 and 1979, while the remaining 25% obtained them after 1979. This shows that the creation of the programs occurred at about the same time as the advanced training of the professors teaching them.

Looking at the countries in which the professors studied for their graduate degrees, data from the CRESALC survey show that, in Brazil, 70% of the master's degrees were obtained in that country, while the figure for doctorates was 49%. In Colombia, where doctoral studies did not exist at that time, 31% of the professors obtained master's degrees in the country; in Mexico, the figures are 55% for master's degrees and 46% for doctorates; and in Venezuela, 24 and 11%, respectively. Generally speaking, the number of professors who received their master's degree in their own country is significant in all four countries. At the doctoral level, this relation is found in Brazil and, to a lesser extent, in Mexico. This confirms the view that indigenous master's degrees are playing an increasingly important role in the certification of local academic staff, although a significant number still obtain their doctorates abroad. In other words, the highest level of training for researchers is still strongly international, although the information is insufficient to determine how valid this statement is for each of the different disciplines and specializations.

The workload for professors in the graduate programs studied varies widely from one country to another. In Brazil, 80% said that they worked exclusively in these programs. This number drops to 67% for Venezuela, and plunges drastically to 30% in Mexico and 25% in Colombia. In these last two countries, however, about 45% of the people surveyed said that they worked full time, but this workload often allows them to hold more than one job. In other words, part-time teachers (with workloads ranging from half time to hourly teaching) play an important role in graduate programs: in Colombia, such teachers accounted for 31% and, in Mexico and Venezuela, for 22% of the total academic staff involved.

In short, professors in graduate programs are a relatively new group, with high academic credentials. The core of this group — those with doctorates — have completed a major part of their studies abroad. Professors at this level appear to be highly stable in their positions, but it is only in Brazil that most of them work exclusively in graduate programs. This leads to the belief that, in many cases, the professors in these programs do not systematically conduct research, a matter that will be discussed later. However, most of the people interviewed declared that they preferred to work on research (in terms of interest) rather than teach or at least to combine the two activities.

Students

The age of students in the graduate programs studied averaged about 30 years. The great majority were between 25 and 35. The difference between the average age of candidates for master's degrees (28 years) and that of doctoral candidates (33.6 years) was greatest in Brazil. In Venezuela, the difference is between 30.5 and 31.5 years. In Mexico, the situation is reversed, with doctoral students being, on the average, younger (28.6 years) than candidates for master's degrees (29.4 years).

The proportion of women in the graduate programs studied ranged from 42% in Brazil to 27% in Mexico, with 35 and 32% in Venezuela and Colombia, respectively.

With respect to social class of graduate students, the CRESALC study shows that close to one-third came from families where the father had attended only primary school or was illiterate. Only in Columbia were students, whose fathers had only primary schooling or less, in the minority (21%). Students from families in which the father had high school education accounted for 49% in Colombia, 35% in Venezuela, 30% in Mexico, and 25% in Brazil. Students whose fathers had basic degrees accounted for 33% in Brazil, 26% in Mexico, 22% in Venezuela, and 19% in Colombia. Between 9 and 13% of students came from families in which the father had also pursued graduate studies (the proportion was lowest in Brazil and highest in Mexico). It can, therefore, be concluded that graduate students in the four countries studied by CRESALC displayed social mobility, measured in terms of their parents' education, and that there is a strong reproductive tendency at the higher educational levels.

When asked why they were pursuing graduate studies, a high proportion of those surveyed (75% or more) answered that their main reasons were academic. As might have been expected, they did mention the need for a diploma to obtain a good job. As observed, this need played a decisive role in the expansion of graduate programs. However, private reasons do not necessarily coincide with public needs and strategies.

With regard to the type of work that students expected to engage in when they had completed their graduate studies, almost half said they hoped to become teachers: Brazil, 56%; Mexico, 46%; Venezuela, 45%; Colombia, 42%. A slightly smaller number said that they would like to become researchers: Colombia, 49%; Venezuela, 41%; Mexico, 39%; Brazil, 35%. Between 8 (Brazil and Colombia) and 14% (Mexico) hoped to work in administration or other careers. This same preference for academic activities, with teaching predominating, was confirmed when responses by candidates for master's degrees and doctorates were analyzed separately, except in Venezuela where interest in research is higher among doctoral candidates.

About 50% of the students interviewed expressed a preference for working in universities once they had completed their studies; the proportion increased to 72% in Brazil. A desire to work in public administration was relatively strong among the Mexican students (21%), less so in the other countries: Colombia, 16%; Venezuela, 11%; Brazil, 4%. In Venezuela, 20% of the students wished to work in the private sector (private enterprise), this compared with 17% in Mexico, 16% in Colombia, and 11% in Brazil. Finally, some preferred to work with international and regional organizations: Colombia, 18%; Venezuela, 15%; Brazil, 13%; Mexico, 6%.

A large percentage of graduate students were working while studying: Colombia, 82%; Mexico, 63%; Venezuela, 58%; Brazil, 38%. Candidates for master's degrees and doctorates were in very similar situations. Only in Brazil, at the time of the survey, did the paradoxical situation exist that there were proportionately more doctoral candidates working than candidates for master's degrees. Apparently many doctoral candidates were completing their studies and had already returned to the workplace (de Andrade Córdova et al. 1986: 136–137). A high proportion of the working students held full-time jobs: Venezuela, 76%; Colombia, 70%; Mexico, 57%; Brazil, 48%. A significant number of Latin American graduate students work while studying and, for many of them, their jobs require a considerable portion of their time.

The preferred place of work of students engaged in graduate studies in the four countries is the university: 49% in Venezuela and 37% in Colombia, with Brazil and Mexico also falling within this range. After universities, the workplaces chosen by graduate students, in descending order of preference, were the public service, a combination of government and university, and private enterprise.

Indications are, then, that many graduate students can only study part time. This was true for 64% of students in Colombia, 55% in Mexico, 49% in Venezuela, and 29% in Brazil. A significant number of students attend classes in the evening: Venezuela, 23%; Columbia, 17%; Mexico, 4%; Brazil, 3%. According to Klubitschko (1986: 123–129), only Brazilian students had sufficient time to devoted to graduate studies. In Colombia, on the other hand, only 35% study full-time, and half the students in this group still work either full-time or part-time. Almost a third of Colombian students study part-time during the day, and almost half of these hold full-time jobs. Among Colombian graduate students, 17% attended part-time courses in the evenings or at night, and most of these worked full-time.

The situation in Mexico and Venezuela was halfway between the optimum of Brazil and the least favourable situation in Colombia. In Mexico, almost 44% of the students studied full-time, and only 10% of this group had problems with incompatible timetables. Of the graduate students who studied half-time during the day, about a third had difficulties with their timetables. Half of the evening and night students held full-time jobs. In Venezuela, half of the graduate students studied full-time, and only 16% of them had timetable difficulties. On the other hand, most of the students studying part-time during the day had such problems. Of the students in evening or night programs, 70% held full-time jobs.

In Brazil, Mexico, and Venezuela, the student–teacher ratio was relatively uniform, ranging from 2.6 to 3.1 students per professor. In Colombia, however, the ratio was 6.8 students per professor. The student–teacher ratio was similar for all four countries in the area of the exact sciences and biology (ratios ranging from 1.3 to 2.8), but differed sharply in engineering, agriculture, and the social sciences. In these fields, the ratio was considerably higher in Colombia than in the other three countries.

Training in Research

The CRESALC study contains interesting information on the kind of training for research that may be included in graduate programs in the four countries. The following is a commentary on the main conclusions of the study.

The professors interviewed said that the most widely used form of teaching in their graduate courses was the formal course or lecture series. The predominance of this traditional method of teaching, which also prevails at the undergraduate level, was acknowledged by 72% of professors in Venezuela, 60% in Mexico, and about 65% in Brazil and Colombia. The students were as aware as their teachers, or even more so, of the predominance of these nonparticipatory forms of teaching (80% in Colombia and Venezuela, 51% in Brazil, and about 65% in Mexico reported this method as the one most widely used).

Even so, a significant proportion of students in the four countries stated that they take part more or less regularly in fieldwork, oral preparation and presentation of topics, submission of reports and monographs, etc. In other words, they acknowledged that they were involved in practices that indicate that their training activities are relatively autonomous.

The opinions of professors and students alike were solicited with regard to the existence of explicit mechanisms for teaching research methods. About 80% of the professors in Brazil and Venezuela, 74% in Mexico, and 60% in Colombia responded that such mechanisms did exist. The students' responses displayed the same national patterns as those of their teachers, although the proportion of affirmative replies was lower (ranging from 68% in Brazil to 53% in Colombia); the percentages in all cases were higher for doctoral students than for other graduate students. Differences among the various disciplines and fields of study were negligible.

The professors and students who said that there were explicit mechanisms for teaching research methods in the individual graduate programs were asked what these specific mechanisms were. Two were mentioned: courses on research methodology and technique, and supervised participation in research projects. The second appears to be the most widely used in each country, accounting for over 80% of affirmative replies from the professors. On the other hand, the proportion of professors mentioning courses on methodology ranged from 65% in Colombia to 44% in Mexico. The pattern of student responses was similar. Among different disciplines, participation in research was acknowledged (by the professors) to be the main means of teaching research in all the countries, except for social and human sciences in Venezuela, Brazil, and Colombia, where the principal method was a course on methodology.

The students were also asked about the extent to which they actually participated in research projects. Affirmative replies ranged from 81% in Brazil to 61% in Colombia, with Mexico close to the lower end, and Venezuela further up the scale at 69%. The level of the program significantly affected responses in Mexico, where almost all doctoral candidates had engaged in practical research while, at the master's level, only half of the group had done so.

There was a great deal of variety in the research activities of these students. In Brazil, they covered a wide range, including preparation of monographs, participation in their professors' research projects, work in the library or laboratory, and conducting field studies. In Colombia, the range was narrower, with 43% working in libraries or laboratories, 30% on field studies, and 24% in the category "other." In Mexico, the distribution breaks down into participation in projects (37%), preparation of monographs (23%), and work in libraries or laboratories (20%). In Venezuela, there is emphasis on preparing monographs (42%), followed by participation in projects (25%), and library and laboratory work (19%).

In Brazil and Venezuela, professors and students were relatively positive about the extent to which the bibliographies used in their courses were scientifically up-to-date. In Colombia and Mexico, the professors were less satisfied with this aspect, while the students were less critical than their teachers.

Graduate Research

Most graduate programs included research projects. This was the case with 100% of the programs in Brazil, 91% in Venezuela, 85% in Colombia, and 73% in Mexico. In each of the countries studied, the program coordinators said that, during 1983, an average of six projects per program had been completed, and an average of from four (Brazil) to eight (Colombia) new projects had begun. In Brazil, 875 projects were underway in the 28 programs covered by the CRESALC study and another 115 were about to start.

Most of the professors involved in graduate programs were themselves engaged in research projects. In Brazil, 94% said they were working on a project at the time of the survey; in Venezuela the figure was 82%; in Mexico, 72%; in Colombia, 57%.

According to the teaching professors in graduate programs, the people who engage in research in these programs vary, depending on the country. In Brazil and Venezuela, the actors most often mentioned were "professors working by themselves," followed by "thesis students," then "professors jointly with graduate students." In Colombia, "thesis students" predominated, followed by "professors with graduate students." In Mexico, there was a fairly even balance among all categories of arrangement, including "professors with other professors and assistants." In social sciences and the humanities, individual activities were most frequently cited as the type of research arrangement in Brazil, Colombia, and Mexico. In other fields, teamwork was clearly more important. When graduate professors directly involved in research were asked about their own ways of working on current projects, only a minority said that they were working alone. The vast majority were working in groups, although this tendency was less pronounced in the fields of social sciences and the humanities. The practice of incorporating graduate students into research teams appeared to be well established in the four countries covered by the CRESALC study.

When identifying the factors that influenced the choice of research topics, the graduate program coordinators in all four countries mentioned the researchers' interests as the primary factor; 53% of professors in Brazil ranked this as the most important factor. The proportion was only 30% in Venezuela, although this factor was second only to scientific significance attributed to the research by the graduate program. This last factor (i.e., scientific significance attributed to the research) was also considered to be of great importance in Colombia. The overall aims of university authorities were considered to be the most decisive factor by 29% in Mexico, 13% in Colombia, 17% in Venezuela, and 0% in Brazil. Practical requirements of graduate work constitute a decisive factor in the opinion of 27% of coordinators in Venezuela, 16% in Brazil, and less than 10% in Mexico and Colombia. The policies of national planning bodies and science and technology agencies were considered to be the determining factor by 16% of coordinators in Brazil, 7% in Colombia, 5% in Mexico, and 0% in Venezuela.

Most graduate program coordinators interviewed stated that there were priority research areas in their programs, with some 70% holding this opinion in Brazil, Mexico, and Venezuela, and about 60% in Colombia. The professors agreed, but to a lesser extent: about 70% in Brazil, 55% in Colombia and Mexico, and 40% in Venezuela.

As for the intended use of research, most professors in each country acknowledged that the results of their research were intended mainly for publication in international and national academic journals. The degree of internationalism is highest in Brazil and lowest in Colombia. National journals were mentioned most frequently in Venezuela followed by Brazil. "Internal reports" were cited by a majority of professors in Brazil and Mexico, by 46% in Colombia, and by 35% in Venezuela. Documents published by the university itself were mentioned frequently in Colombia, but rarely in Brazil.

Research products as inputs into the private sector were mentioned by about 15% in Brazil, Mexico, and Venezuela, and by 22% in Colombia. Inputs into the public sector were mentioned by 22% in Colombia, 27% in Mexico, 30% in Venezuela, and 31% in Brazil.

Evaluation of Graduate Programs

It is possible to draw some conclusions from the CRESALC report about the perceptions of the professors, coordinators, and students of the way in which the programs function.

- The infrastructure required for the operation of the programs (libraries, laboratories, computers) was judged negatively in all the countries, and with particular harshness in Colombia. With regard to physical space, opinions were positive in all the countries, except Brazil.
- The student–teacher ratio was regarded by both teachers and students as generally satisfactory.
- Except for Brazil, the majority of the professors thought that academic standards should be higher in graduate programs.
- Students shared professors' opinion that financial resources available for research were insufficient.
- Standard used to measure the quality of research should be "much higher" according to 46% of professors in Colombia, 32%, in Mexico and 27% in Venezuela. In Brazil, only 10% agreed with this assessment. In Brazil, 38% of professors and over 40% in the other three countries believed that standards should be "somewhat higher." Half the professors surveyed in Brazil, 30% of those in Venezuela, 25% in Mexico, and 10% in Colombia thought that standards should remain as they were.
- With regard to the differences between undergraduate and graduate levels, over 90% of program coordinators in Brazil believed that there is a great difference between the two. However, only a slight majority of the coordinators in the other three countries agreed. Among the professors, 71% in Brazil believed that the programs were very different; 61% were of this view in Mexico, 41% in Venezuela, and only 23% in Colombia. Less than half the students in each country thought that the two level were very different: about 50% in Brazil and Mexico, 27% in Venezuela, and only 16% in Colombia. There were doctoral candidates in Colombia and Venezuela who believed that their graduate courses were "more of the same thing" that they had in their undergraduate courses.

In a study conducted in Brazil, based on regular evaluations of graduate programs (Moura Castro 1985: 38), the view is expressed that, in general, the degree of academic excellence attributed to a program is usually the result of a combination of the following factors: professional competence of the professors (as shown by their degrees or equivalent qualifications); the amount of time spent by the professors on a program, especially by those who are responsible for teaching the courses that form its core; and scientific output of the staff involved in a program (quality, volume, and regularity of articles, books, and research reports published, and presentations at scientific conferences). However, factors related to the teaching process itself, such as the student–teacher ratio, do not appear to have a special impact — an exception being the work schedule of the most outstanding teachers.

Quality of Graduate Programs

No information is available at the regional level on the evaluation and accreditation of graduate programs. The problem is in measuring the quality of these programs, which, as Schwartzman (1981: 136) has pointed out, always has an impact on the distribution of prestige, institutional support, and resources. There is generally an adversarial element in the nature of evaluation processes. It is important to know what yardsticks can be used to measure the quality of these programs, who has the authority to make evaluations, and what the effect of an evaluation will be in terms of distribution of resources and prestige.

The problem of measuring the quality of teaching has been approached from widely different angles, and this is not the place to enter into a scholarly discussion of the subject. According to Tedesco (unpublished),[2] at least two points can be distinguished with regard to measuring the quality of teaching:

- A specific, intrinsic aspect of the learning process, in which quality should be measured by cognitive results and, in the case of research, by the recognition accorded by academic peers to the production of published findings; and
- An external or institutional angle, in which quality is measured by the social significance of the "products," in terms of developing knowledge to attain disciplinary goals, educating professionals to meet the demands of the labour market, socializing

[2] Tedesco, J.C. Calidad y democracia en la enseñanza superior: un objetivo posible y necesario. (unpublished)

values and attitudes according to defined cultural criteria, or proposing solutions that result in practical progress in controlling and changing the exterior world.

The first can be called scientific quality in the strict sense of the term and the second is quality viewed as social significance.

In the case of graduate programs, quality evaluation is particularly complex because of the diversity, mentioned above, of the goals or purposes pursued by these programs. Assessing the quality of programs whose goal is to meet demands for culture is different from evaluating those that aim to provide qualifications for working in hierarchical institutions or for professional development or specialization, or those that offer research training. The criteria must vary in each case and the way in which the two abovementioned aspects of evaluation are combined may differ from one program to another. It is not sufficient, for example, to say that ideally graduate programs in Latin America should aspire to maximum quality in terms of academic excellence and social significance, although this may be desirable. In practice, this would mean that the ideal is for each country to have a single model for graduate programs, governed by identical criteria and guided by an identical set of values. This position cannot be defended, not only because it clashes with the actual, very heterogeneous state of graduate studies in the region, but also because academic quality from one field of learning to another will tend to be measured by different yardsticks, depending on the cognitive structure and the social organization of the disciplines taught (see Whitley 1982).

In practice, once evaluation systems with a certain claim to universal, global applicability have been put in place, specific indicators must be sought that will express the substantive quality and, to some extent, the significance of the programs evaluated. It is a question of finding ways to evaluate graduate programs so that public resources can be distributed according to criteria that are socially legitimate and also legitimate within the scientific community.

Moura Castro (1985: chapter 3) has pointed out that there are two main approaches, distinguished by the kind of people who participate in the evaluation process and the instruments they use. The most common approach involves peers recognized for their prestige in the discipline, who act as judges of research projects, teaching programs, and the results achieved. This method, known as peer review, is based on the expertise of the judges and the recognition they have obtained as distinguished scientists within the discipline. The second approach involves the staff of public evaluation agencies, who generally employ more markedly quantitative evaluation criteria to measure capability, utilization of resources, productivity of the scientific work, etc.

Depending on the country and the unit to be evaluated (projects, publications, institutions, groups, individuals), combinations of these two methods may be used, involving, simultaneously or successively, members of the community itself and the staff of the specialized agencies. There are many possible combinations and many ways of institutionalizing them (Moura Castro 1985: chapter 3 and bibliography).

Again, little information is available on the ways in which the quality of graduate studies in Latin America is accredited. In some countries, there does not appear to be any specific agency responsible for evaluating graduate programs, and each university is allowed to apply its own specific regulations and to determine the allocation of resources to the programs as part of the normal management of its graduate program budget. This appears to be the case in Colombia and Chile, where legislation is limited to regulating the conditions for setting up such programs, for receiving grants, and occasionally (in Colombia) for defining certain requirements governing curricula (for Colombia, see Vélez B. and Caro 1986: 46–49; for Chile, see Brunner 1986a). In other countries (e.g., Brazil), a national system for evaluating graduate programs has been taking shape.

There is, in fact, an evaluation system in Brazil, administered by Coordenaçao de Aperfeicoamento de Pessoal de Nivel Superior (CAPES) and covering all master's and doctoral programs in the country (over 1 000). Since 1977, CAPES committees have been grading the different graduate programs, a process that has become more complex as their number and the fields they cover have increased. The CAPES system distinguishes between collection of basic data on each program, which is the responsibility of its staff, and program evaluation per se, which is conducted by external examiners who are distinguished members of the academic community. The data are collected using a standardized questionnaire and, some years ago, were computerized for more expeditious processing by the external examiners, who are the people responsible for the final judgement on quality. Programs are given a grade, A to F, which has an influence on the distribution of resources and grants to the different programs, and inevitably influences their prestige. Each evaluation contains a commentary and may include recommendations. It is assumed that this instrument will not necessarily lead decision-making authorities to focus all their attention and resources on the programs receiving the highest marks, but that it will lead to support for programs with lower marks, for the very purpose of boosting the potential they have not yet developed or to introduce a better regional balance, etc.

Evaluation systems like this, which make it possible to assess the quality of the courses taught no matter what criteria are used to define this quality, merit more attention in studies of graduate programs and their practical organization and operation. It is clear that the use of these systems does not, by itself, ensure the quality of the programs, nor does it say very much about their potential for future development. However, if the goal is to use graduate programs for training researchers, it is necessary to identify the ones that are most suitable for this purpose, then send signals to potential candidates, the community, and the authorities responsible for distributing resources on what should be the thrust of policies for the training of scientists.

Innovations

Some innovative experiments at the graduate level merit at least passing mention, precisely because they relate to the training of researchers. The short account that follows is not exhaustive and is based on fragmentary information available at the time this report was written.

Regional experiments in social sciences

Both the Latin American Social Sciences Council (CLACSO), a nongovernmental regional agency, and the Latin American Faculty of Social Sciences (FLACSO), an intergovernmental organization, have carried out varied and interesting experiments in graduate training in certain social science disciplines.

From 1958 to 1973, FLACSO offered masters' courses in sociology and political science at its campus in Santiago, Chile, where professionals from almost all the countries in the region came for periods of 1 or 2 years to be trained as teachers or researchers, just at the time when the process of professionalizing the social sciences on this continent was beginning. Over that period, more than 400 social scientists were trained, most of whom returned to their countries of origin, where some went into research and, subsequently, graduate teaching.

After 1973, FLACSO continued these training programs, but decentralized them. It established masters' programs in sociology and political science in Mexico, offering a variety of specializations.

In Argentina, it has been offering a similar program with participation of professors from a number of independent academic centres in Buenos Aires. In Ecuador, it has offered masters' programs in developmental social science and in Andean history. It instituted a graduate diploma in international relations in Costa Rica. In Brazil, a doctoral program in social sciences, with specialization in Latin America, has been set up under an agreement between FLACSO and the National University of Brasilia. In conjunction with CELADE, FLACSO offered a masters' program in population studies in Chile and, for a number of years, it has had a national program there for training young members by the tutorial method.

For the last 20 years, CLASCO has offered masters' courses in various subjects through travelling programs organized in conjunction with national institutions. Even more interesting are CLACSO's various programs of grants for researchers who are just starting out, which permit them to work for a year in a national institution under the guidance of a tutor, acquiring real experience in the research process (Provoste 1987).

A regional graduate training program in biology

This program, first established for the Andean countries of Bolivia, Chile, Colombia, Ecuador, and Peru, was later joined by Venezuela and Argentina. It receives support from the United Nations Development Programme (UNDP) and the Organization of American States (OAS). There were three main reasons for creating this program (Niemeyer 1978):

- Fostering the basic sciences, particularly biology, is considered indispensable for development and welfare of the countries of the region.
- Supporting graduate education can produce a significant multiplier effect in the development of basic biology even when resources are scarce.
- Bolstering intraregional cooperation for progress in research in basic biology and in the teaching of the science is both possible and necessary.

The program has operated successfully for a number of years, promoting graduate teaching in the countries involved and, in particular, developing doctoral programs in the most advanced fields of biology in each of the participating countries.

Joint programs with universities in developed countries

In some cases, a university in a leading country has been willing to share responsibility with an academic institution in a sourthern country for organizing and implementing a graduate program. It reserves the right to award degrees, but cooperates with the Latin American institution in all aspects of training of students, which takes place almost entirely in their countries of origin under the guidance of professors of their own nationality.

In Chile, for example, an agreement was reached in 1986 between the Interdisciplinary Program for Research on Education, a private, independent academic body, and the University of Wales, through University College, Cardiff, to share the Welsh university's doctoral program in education. The Chilean students are admitted through jointly established procedures, then work in their own country under the tuition of Chilean professors. Once a year, the Chilean students must go to Cardiff for discussions with their Welsh tutor. The final examination is written at the University of Wales, which awards the degree.

Training programs for young researchers

In the social sciences, because of the special conditions created by government intervention in universities during the military regimes, independent academic centres devoted mainly to research were set up in several countries in the Southern Cone (Brunner and Barrios 1987). A number of them have developed graduate courses leading to various types of diploma, the main objective being to train young researchers. These courses are based on various combinations of seminar participation and on-the-job training through involvement in specific research projects.

Students in these programs have received grants and have been given the opportunity to work intensively on their studies in environments where there are bodies of researchers concerned exclusively with academic work. The relatively marginal nature of this kind of experience is, however, evident. Generally, the certificates issued are not legally recognized at the national level, although sometimes they are accorded de facto recognition by foreign universities that accept graduate students from these courses directly into their doctoral programs. On the other hand, access to a formal career in research is increasingly restricted to those with a doctorate, which makes the training acquired under these kinds of programs insufficient, regardless of their quality or of how much the individual student has actually learned.

The Graduate Commission on Science and Engineering for Latin America and the Caribbean

This organization, with headquarters at CONICIT in Venezuela, represents an initiative that began in 1981. It supplies information on graduates in basic sciences and engineering in the region to interested institutions. It serves as a mechanism for disseminating information on the availability of grants and study facilities in the system. It supports research initiatives that could strengthen graduate programs, and detect research areas in which there are gaps, with a view to promoting their development in connection with the various graduate programs.

On-the-Job Training

Although it appears that most Latin American researchers are trained in universities and that many of them remain there afterwards to work, especially at the graduate level, another source of training and work — the industrial sector — must not be overlooked.

In the world as a whole, the industrial sector, including public and private corporations and the research institutes that serve them, has assumed a central role in R&D to the point where it has become the major recipient of R&D funding in developed countries (ECLAC/UNIDO 1985). In these countries, the production sector is the main generator of science and technology, accounting for 75% in Switzerland and between 60% and 70% in countries such as the United States, the Federal Republic of Germany, and Great Britain. Greece and Portugal are the only OECD countries where the involvement of the industrial sector in science and technology activities is marginal.

It is also common knowledge that, in most developed countries, spending on R&D through the industrial sector is concentrated in large companies, although some medium-sized and small companies also play a role. In particular, it is in the manufacturing sector, which generates less than a third of industrial production in developed countries, that the largest nonmilitary R&D spending occurs; "technological density" (i.e., the ratio of the manufacturing sector's spending on S&T to manufacturing output, divided by the ratio of total spending on S&T in the industrial sector to industrial output) is highest in that sector — three or four times the average in the whole production sector.

Within the manufacturing sector, the metallurgical and chemical industries spend the most on S&T; in these sectors, technological density is up to six times the average for production activities. In contrast, although spending on R&D by the production sector has been growing in Latin America, manufacturing companies and their leading-edge industries do not play an important role in such activities. This is partly due to lack of leadership and dynamism in private national enterprise and to lack of coordinated initiatives at the regional level. These are prerequisites for embarking on large-scale programs, as has been shown by the experience of European countries and as the recent cooperative agreements between Argentina and Brazil seem to demonstrate.

Looking at the 50 largest companies (by sales volume) in Argentina, Brazil, Chile, Colombia, Mexico, and Venezuela, it is apparent that government-owned companies account for over half of sales in Chile, Mexico, and Venezuela, and come close to this proportion in Brazil. Foreign-owned companies account for over a fifth of sales by the 50 largest companies in Colombia, Brazil, and Argentina, while private national companies have the major share of sales only in Colombia (53.8%). Private national companies account for one third of sales in Chile, one fourth in Argentina and Mexico, one fifth in Brazil, and for only 18.3% in Venezuela where government-owned companies account for 72.9% (ECLAC/UNIDO 1985).

Ownership in the manufacturing industry by private national enterprise is higher in these countries, but so is that of foreign enterprises. Of the 50 largest manufacturing companies (by sales volume), foreign companies own over half in Argentina and Brazil, close to a third in Chile, and about 28% in the other three countries. Private national enterprise controls 71% in Colombia, 54% in Chile, almost half in Venezuela, and only 16% in Brazil.

This structural situation in the manufacturing industry in Latin America appears to have affected the dynamism of R&D activities, making efforts at innovation and applied research relatively marginal. However, processes that have been termed minor technological innovations, or incremental or domestic technological changes have occurred in manufacturing companies. In countries, such as Argentina, Brazil, Mexico, and Colombia, where there is significantly complex and technologically sophisticated export manufacturing process, there appears to be a simultaneous process of growth in the sale of technology "through licences, complete plants and sales of equipment, which include a major domestic technology component" (see Vivas, unpublished,[3] p. 16 and bibliography,

[3] Vivas, J. Inovación tecnológica y recursos humanos en la firma. (preliminary version, 1987)

especially the works of J. Katz). However, this development of endogenous technological capacity is not the result of systematic R&D efforts of the type known in more developed countries. It is, rather, a matter of creating home-grown technological capacity gradually and incrementally out of daily production activities, stimulated by one or more of the following factors conditioning local business behaviour:

- the need to solve problems that hold production back at certain stages;
- the need to improve the quality of products to be more competitive;
- the need to reduce production costs and to obtain a better capital–labour combination;
- the need to substitute or adapt technological processes so that local raw materials can be used; and
- the need to diversify output.

These demands require a response from a company's technical and engineering staff, and may lead to innovative processes involving: product engineering, production-process engineering, and industrial organization and production planning.

These activities may be undertaken formally by special departments or sections within a company. If so, they will take the form of explicit R&D activity; if not, they will continue to be informal or routine learning activities within the production process itself.

Taking this broader view of the concept of technological change, some authors have asked themselves what the new training requirements are in the field of engineering and its various specializations. It seems clear that, if domestic technological change is understood as an incremental process of learning by the company itself, then senior staff implement a training process that may supplement the training received at university and such a process can only take place in a company.

If this kind of learning is to be facilitated, it appears that the basic training received at university cannot be considered in isolation. A distinction should at least be made between training in basic sciences, training in basic applied science, specialized technological training, and graduate training (research).

The potential for learning in a company does not merely lie in adapting job requirements to the technological training received at university, because that training is, undoubtedly, the most static element in the learning process. Technological changes are continually occurring in companies and take some time to appear in academic training programs. Also, the connection between the different components in university training and jobs in companies will vary depending on the nature of the company, especially if the job is in the plant's production group, in production engineering, or in R&D.

There appears to be one factor that facilitates learning in a company: previous research experience gained at the graduate level. Regardless of the occupation of the scientist or engineer, that person would appear to be in a better position to participate in the processes of domestic technological change in he or she has had previous training in research. Seen from this standpoint, most engineers probably have insufficient training, becuase they do not, as a rule, receive training in research, and their courses are acquiring an increasingly specialized, professional focus without a broad base in pure and applied science.

To sum up, instead of an additional channel for training researchers, there is a particular set of circumstances in a given company that may make it possible to develop a capacity for research and innovation, on the assumption that previous university training facilitates the necessary learning processes and that jobs in the company require such development and make it possible.

A number of the larger countries, especially Brazil and Mexico, which together account for more than 60% of regional manufacturing, have discovered a different need: that of channeling resources and efforts into the production sector and, in particular, into manufacturing, to systematically foster R&D activities. The purpose is not to create technological self-sufficiently, which is only a dream in current conditions of world development, but to generate endogenous technological capacity that will give the countries more autonomy and sustained growth, and enable them to be more efficient in selecting and adopting external technologies (on the notion of the endogenous nucleus of technological advance, see ECLAC/UNIDO 1985 and ECLAC 1985).

5

Funding Research

In the 1970s, the number of scientists and engineers engaged in research and development worldwide increased from 2.6 million (in 1970) to 3.8 million (in 1980) (Table 67); developing countries accounted for 7.9 and 10.6% in these two years, respectively (Unesco 1985). Total spending on research and development was 62 million USD in 1970, with developing countries accounting for 2.3%; in 1980, it was 208 million USD, with developing countries accounting for 6%.

Engineers and scientists in Latin America and the Caribbean represented 1.5 and 2.4% of the world total in 1970 and 1980, respectively; spending on research in these countries accounted for 0.8 and 1.8%, respectively. In absolute figures, the number of engineers and scientists in Latin America increased from 38 411 in 1970 to 90 036 in 1980. During this same period, spending on R&D in Latin America rose from about 500 million to about 3.8 billion USD.

Even if these aggregate figures are treated with the necessary caution, it is apparent that Latin America and the Caribbean lag behind the world as a whole with respect to research and development; the effort made by the region between 1970 and 1980 is also apparent (see Chapter 8). By way of comparison, expenditures on research and development in Latin America in 1970 were about the same as R&D spending by the United States in 1920; the value for 1980 is a bit higher than that of the United States for 1950 (Machlup 1962: 155–156). In 1920, the United States spent only 0.09% of its GNP on research and development; in 1940, 0.37%; in 1950, 1%. Strict comparisons with Latin American figures cannot be made

Table 67. Number of scientists and engineers engaged in research and development and R&D spending, 1970 and 1980.

	Number of scientists and engineers		R&D spending	
	Thousands	Per million population	USD (millions)	% of GNP
Worldwide				
1970	2 608	712	62 101	2.04
1980	3 756	848	207 801	1.78
Africa				
1970	19	56	188	0.34
1980	41	91	1 156	0.36
Asia				
1970	458	219	4 572	0.99
1980	703	271	31 230	1.08
Europe				
1970	573	1 250	15 739	1.70
1980	839	1 735	70 649	1.79
Oceania				
1970	22	1 160	497	1.10
1980	34	1 472	1 953	1.11
USSR				
1970	928	3 822	12 987	4.04
1980	1 373	5 172	32 421	4.67
North America				
1970	570	2 515	27 620	2.59
1980	675	2 679	66 646	2.33
Latin America and the Caribbean				
1970	38	135	498	0.30
1980	91	251	3 745	0.49

Source: Unesco Statistical Yearbook, 1987.

because of the fluctuating value of the American dollar over this period.

Current Situation

The only comparable data on the resources allocated to research and development by each country are those compiled by Unesco, which were presented to the Second Conference of Ministers

Responsible for Applying Science and Technology to Development in Latin America and the Caribbean (Unesco 1985). These are used as the basis for the following tables. In its 1987 Statistical Yearbook, Unesco gives relatively complete data on this subject for only four of the countries covered in this study (Table 68).

The information given in Table 68 is expanded in Table 69, although not always for the same years. A basis of comparison is established by using the nominal value of the United States dollar for the given year. Table 69 also shows total expenditures on research and development (most recent year available) for each of the countries included in the study, and expenditures per scientist and engineer engaged in these activities.

The marked differences between countries in expenditures per scientist and engineer may well be the result of computational errors (under- or overestimating the number of scientists and engineers or incorrect accounting of R&D expenditure), or may be correct, at least in order of magnitude (Table 69). As a basis for comparison, Table 70 shows expenditure per scientist and engineer working in R&D in certain developed countries.

Table 71 shows a breakdown of expenditures by sector of activity as follows: the production sector, including domestic and foreign industries and businesses producing and distributing goods and services (R&D activities integrated into production); public and private institutions whose R&D activities provide major but indirect services for certain kinds of economic activities (R&D activities not integrated into production); the higher education sector, which includes postsecondary teaching centres and institutes, hospitals, and other R&D agencies providing services for such centres and linked to them; and the general service sector, which includes all centralized and decentralized government agencies, regardless of their field of activity, but excludes institutions of higher education.

On the basis of data in Table 71, it is no longer clear, as is still often asserted, that most R&D activity in Latin American countries takes place in the universities. In terms of spending, the higher education sector does not account for more than 36% of total outlay on these activities in any of the countries studied, except Mexico and Costa Rica; in most the range is 15–25%. The production sector (generally nonintegrated activities) spends more than half of the R&D budget in Chile, Cuba, and Venezuela, and about 40% in Argentina. In all these countries, public institutions that provide services to the economic sector (both public and private) are the highest spenders in that sector. Finally, the general services sector spends more than half of total resources in Brazil, Colombia, Ecuador, and Peru.

Table 68. Spending on R&D in selected countries for the most recent year available.

Country and year	Currency[a]	Total (thousands)	Capital costs (thousands)	Operating costs (thousands)		
				Personnel	Other	% of total
Argentina (1981)	pesos	2 321 932	—	—	—	—
Brazil (1982)	BRC	305 500 000	—	—	—	—
Chile (1980)	CLP	4 665 400	992 700	3 672 700		78.7
Colombia (1982)	COP	2 754 273	—	—	—	—
Costa Rica (1982)	CRC	81 333	—	—	—	—
Cuba (1985)	CUP	182 478	44 184	83 690	54 604	75.8
Ecuador (1979)	ECS	856 090	280 915	380 012	195 163	67.2
Guatemala (1983)	GTQ	44 797	—	—	—	—
Mexico (1984)	MXP	159 331 000	24 696 000	134 635 000		84.5
Peru (1984)	PEI	159 024 000	—	—	—	—
Venezuela (1984)	VEB	1 361 640	—	—	—	—

Source: Unesco Statistical Yearbook, 1987.

[a] BRC, Brazilian cruzeiros; CLP, Chilean pesos; COP Colombian pesos; CRC, Costa Rican colons; CUP, Cuban pesos; ECS, Ecuadorian sucres; GTQ, Guatemalan quetzals; MXP, Mexican pesos; PEI, Peruvian inti; VEB, Venezuelan bolivars.

Table 69. Total spending on research and development and average annual spending per scientist and engineer (S&E) engaged in R&D.

Country and year	Total spending (thousands)		Spending per S&E	No. of S&E
	Local currency	USD	(USD)	
Argentina (1980)[a]	1 480 000 000 pesos	808 517	85 107	9 500
Brazil (1982)[a,b]	305 500 000 BRC	1 771 900	54 507	32 508
Chile (1980)	4 665 400 CLP	121 300	26 955[c]	4 500[c]
Colombia (1978)[b]	735 783 COP	18 718	5 499	3 404
Costa Rica (1979)[d]	—	—	22 609	320
Cuba (1981)	111 614 CUP	134 473	19 677	6 834
Ecuador (1979)[e]	753 444 ECS	30 138	10 822	1 533
Guatemala (1977)	13 526 GTQ	13 526	43 633	310
Mexico (1973)	1 227 618 MXP	102 209	17 335[f]	5 896[f]
Peru (1980)[e]	34 295 902 PEI	119 693	18 434	6 525
Venezuela (1981)[g]	1 012 170 VEB	235 795	64 197[h]	3 673[h]

Note: See footnote *a* to Table 68 for currency definitions.
Source: Unesco (1985).
[a] Estimated.
[b] Excludes data on private enterprise.
[d] Excludes data on the production sector.
[e] Includes science and technology services. Discrepancy with the same figure in the preceding table is due to correction of the source.
[g] Public spending only; does not include military spending on R&D.
[c] Estimates based on other sources; the number of scientists and engineers is for 1985.
[f] Data for 1974.
[h] Data for 1980.

Table 70. Number (thousands) of scientists and engineers in R&D and annual spending (USD, thousands) per individual in these two categories in five developed countries.

Country and year	No. of scientists and engineers in R&D	Average annual spending per individual
France (1980)	74.9	120.2
West Germany (1981)	128.2	112.3
Japan (1980)	302.6	70.1
Great Britain (1981)	95.7	107.6
United States (1980)	651.7	96.1

Source: NSF (1986).

Table 72 gives a breakdown of the sources of financing for R&D. In all countries, the public sector is clearly the chief provider of resources for R&D. Table 73 displays the distribution of R&D funding, by field of study, in postsecondary institutions, which carry out a significant share of basic research in Latin American countries.

It is also worthwhile to look at the funding by type of R&D activity (Table 74), distinguishing between basic research, applied research, and experimental development. For comparison, some countries from outside the region have been added to draw attention to the relatively low spending within Latin America on experimental development activities. Table 75 contains additional important information gathered in the individual base studies.

Research Funding and Higher Education

The CRESALC study on graduate programs in four Latin American countries discussed earlier (de Andrade Córdova et al. 1986) noted that a high percentage of the professors in the programs surveyed stated that they had obtained financial support for their research. In Brazil, the figure was 83%; in Colombia, 52%; Mexico and Venezuela, about 60%. In all cases, support went primarily to researchers working in exact sciences and biology, somewhat less went to engineering and agricultural science, while researchers working in social sciences and the humanities received the least financial assistance. In some countries of the region, however, social sciences and humanities still receive significant support: in Guatemala, for example, and, to a lesser extent, in Ecuador, Colombia, and Mexico (Table 73).

Table 71. Total spending on R&D by sector (%) for the most recent year available.

<table>
<tr><th rowspan="2">Country and year</th><th rowspan="2">Total</th><th colspan="2">Production</th><th rowspan="2">Higher education</th><th rowspan="2">General services</th></tr>
<tr><th>Integrated</th><th>Nonintegrated</th></tr>
<tr><td>Argentina (1981)</td><td>2 321 932 pesos</td><td>20.4</td><td>20.6</td><td>21.9</td><td>37.1</td></tr>
<tr><td>Brazil (1982)</td><td>305 500 000 BRC</td><td colspan="2">30.1</td><td>16.5</td><td>53.4</td></tr>
<tr><td>Chile (1980)</td><td>4 665 400 CLP</td><td>2.5</td><td>56.0</td><td>36.6</td><td>4.9</td></tr>
<tr><td>Colombia (1982)</td><td>2 754 273 COP</td><td>1.5</td><td>—</td><td>15.3</td><td>83.1</td></tr>
<tr><td>Costa Rica (1982)</td><td>81 333 CRC</td><td colspan="2">12.7</td><td>45.9</td><td>41.4</td></tr>
<tr><td>Cuba (1985)</td><td>182 478 CUP</td><td>3.1</td><td>55.0</td><td>4.9</td><td>37.0</td></tr>
<tr><td>Ecuador (1979)</td><td>856 090 ECS</td><td colspan="2">3.0</td><td>14.5</td><td>82.5</td></tr>
<tr><td>Guatemala (1977)</td><td>13 526 GTQ</td><td>—</td><td>—</td><td>17.0</td><td>—</td></tr>
<tr><td>Mexico (1984)</td><td>159 331 000 MXP</td><td colspan="2">30.3</td><td>50.6</td><td>19.1</td></tr>
<tr><td>Peru (1980)[a]</td><td>—</td><td colspan="2">17.2</td><td>9.3</td><td>73.5</td></tr>
<tr><td>Venezuela (1977)</td><td>883 545 VEB</td><td>1.1</td><td>68.9</td><td>28.2</td><td>1.9</td></tr>
</table>

Note: See footnote *a* to Table 68 for currency definitions.
Source: Unesco Statistical Yearbook 1987.
[a] Data from Unesco (1985).

Table 72. Source of funding (%) for research and development for given years.

Country and year	Public	Private	Foreign	Other
Argentina (1981)	95	—	1	4
Brazil (1982)	67	20	5	8
Colombia (1978)	72	—	10	18
Costa Rica (1978)[a]	100	—	—	—
Cuba (1985)	97	—	3	—
Ecuador (1979)[b]	69	5	16	10
Guatemala (1974)	60	4	26	10
Mexico (1984)	15	1	1	83
Peru (1984)	48	27	21	4

Note: Data for Chile, Dominican Republic, and Venezuela not available.
Source: Unesco (1985); Unesco Statistical Yearbook, 1987.
[a] Refers only to current spending in the higher education sector.
[b] Includes science and technology services.

The CRESALC study showed that the sources of financing were mainly of two types: the universities themselves and the national public sector. In Brazil, almost all researchers stated that they had received national public funding, while in Colombia and Venezuela, the majority received funding from their universities. In Mexico, there was a balance between the two sources of funding. Table 76 shows the sources of funding for the four countries of the CRESALC study.

As the corresponding national studies of graduate programs show, there are variations in each country that should be considered. For example, in Brazil, professors teaching graduate programs and program coordinators differed sharply in their perception of the most important sources of research funding in a given program. It is very likely, as the authors of the study argue (de Andrade Córdova et al. 1986: 100), that the researchers themselves are not well informed about the funding of the projects they are conducting. The funds arrive through institutional channels and their source may not necessarily be stated.

In Brazil, research is mainly supported through agreements with agencies outside the universities, particularly public agencies such as Financiadora de Estudios e Proyectos (FINEP, studies and projects funding agency) and the Conselho Nacional de Pesquisas (CNPq, national research council).

Colombia, as noted above (de Andrade Córdova et al. 1986) is at the opposite extreme with regard to the number of professors in graduate programs who carry out research projects. Only half

Table 73. Spending on R&D by the higher education sector in various scientific and technological fields (%).

Country and year	Exact and natural sciences	Engineering and technology	Health sciences	Agricultural sciences	Social sciences and humanities	Other
Argentina (1980)	30	15	25	15	10	5
Brazil (1974)	50	14	11	13	12	—
Colombia (1971)[a]	17	12	37	10	24	—
Cuba (1981)[b]	—	8	7	7	6	72
Ecuador (1973)	28	28	21	—	22	—
Guatemala (1974)	5	14	—	11	70	—
Mexico (1973)	41	14	8	16	21	—
Venezuela (1977)	13	55	8	10	5	9

Note: Data for Chile, Costa Rica, Dominican Republic, and Peru not available.
Source: Unesco (1985).
[a] Excludes law, human sciences, and education.
[b] Current spending only.

Table 74. Current spending by type of R&D for the most recent year available (%).

Country and year	Total spending[a]	Basic research	Applied research	Experimental development
Argentina (1980)	1 480 800 pesos	25.5	45.6	28.9
Cuba (1985)	182 478 CUP	16.0	77.0	7.0
Mexico (1984)	134 635 000 MXP	13.0	51.0	36.0
Venezuela (1977)	755 561 VEB	38.4	59.1	2.5
Israel (1975)	803 000 pounds	48.2	—	51.8
Italy (1982)	4 108 706 ITL	15.8	39.1	45.1
Japan (1983)	6 478 369 JPY	14.6	25.4	60.1
Republic of Singapore (1984)	144 700 SGD	3.4	26.2	70.4
South Korea (1981)	293 131 000 KRW	24.0	28.8	47.2
Spain (1984)	98 107 361 ESP	20.5	42.7	36.8
USA (1983)	86 204 600 USD	12.5	25.5	62.0
West Germany (1983)	37 420 000 DEM	20.5	—	79.5

Source: Unesco Statistical Yearbook, 1987.

[a] CUP, Cuban pesos; MXP, Mexican pesos; VEB, Venezuelan bolivars; ITL, Italian lira; JPY, Japanses yen; SGD, Singapore dollars; KRW, Korean won; ESP, Spanish peseta; USD, United States dollars; DEM, German deutsche marks.

Table 75. Source of funds for R&D by institutional sector for the most recent year available.

Country, year, and currency	National sources				Foreign sources[a]	Total	%
	Own income	Govern-ment	Private sector	Subtotal			
Chile (1984) (USD, millions)							
HES	—	—	—	—	—	48.0	57.9
GSS	—	—	—	—	—	25.5	30.7
PS	—	—	—	—	—	1.1	1.3
Other[b]	—	—	—	—	—	8.4	10.1
Total	—	—	—	—	—	83.0[c]	100.0
Colombia (1982) (COP, millions)							
HES	1 516.4	72.6	184.6	1 773.7	874.6	2 648.3	96.1
GSS[d]	41.6	1.1	3.3	46.1	17.3	63.4	2.3
PS	41.2	—	0.2	41.4	1.2	42.6	1.6
Total	1 599.2	73.7	188.1	1 861.2	893.1	2 754.3	100.0
%	58.1	2.7	6.8	67.6	32.4	100.0	
Costa Rica (1984) (CRC, millions)							
HES	322.8	56.2	8.9	387.9	42.5	430.5	76.2
GSS	14.0	59.2	—	73.2	50.5	123.7	21.9
PS	—	—	—	—	10.8	10.8	1.9
Total	336.8	115.4	8.9	461.1	103.8	565.0	100.0
%	59.6	20.4	1.6	81.6	18.4	100.0	
Dominican Republic (1986) (USD, millions)							
HES	182.7	248.6	—	431.3	208.0	639.3	25.2

GSS	448.3	—	—	448.3	1 450.0	1 898.3	74.8
Total	631.0	248.6	—	879.6	1 658.0	2 537.6	100.0
Ecuador (1977) (ECS, millions)[e]							
HES	—	—	—	—	—	127.0	14.0
GSS	—	—	—	—	—	512.7	56.4
PS	—	—	—	—	—	269.1	29.6
Total	—	—	—	—	—	908.8	100.0
Guatemala (1983)[f]							
HES	—	1.8	0.6	2.4	0.4	2.8	18.9
GSS	—	8.4	0.3	8.7	3.2	11.9	80.4
PS	—	—	0.03	0.03	0.07	0.1	0.7
Total	—	10.2	0.93	11.13	3.67	14.8	100.0
Mexico (1984)[g]							
HES (%)	69.4	24.9	0.5	94.8	0.3	—	—
GSS (%)	79.8	7.6	2.0	89.2	4.6	—	—
PS (%)	99.0	0.1	0.2	99.3	0.09	—	—

Note: HES, higher education system; GSS, general service sector; PS, production sector.
Source: Base studies.
[a] Loans and gifts.
[b] Private sources, generally with foreign support.
[c] Equivalent to 0.43% of GDP.
[d] Includes science and technology services.
[e] Figures are in millions of 1979 sucres.
[f] Currency not specified; probably GTQ millions.
[g] Percentages do not total 100% because the category "other" was not included.

Table 76. Sources of research funding (%) for professors in graduate programs, 1983.[a]

Source	Brazil	Colombia	Mexico	Venezuela
University budget	50.4	83.3	49.3	77.9
National support				
Government	92.1	41.7	39.4	55.8
Private	10.1	16.7	5.6	11.6
Organization (public or private)				
Latin America	1.4	0	2.8	0
Regional	5.0	0	1.4	1.2
Outside Latin America	6.5	16.7	1.4	2.3
International	8.6	12.5	4.2	9.3
Number of respondents	139	24	71	86

Source: Klubitschko (1986).
[a] Data are based on affirmative answers to a choice of yes/no.

stated that they were conducting research at the time of the study, and only half of these had received financial support for their work (Vélez B. and Caro 1986: 86). Of those who did receive funding, professors at private universities fared better than those at publicly funded universities. Unlike the situation in Brazil, most support for researchers comes from the resources of the universities themselves, both public and private. In Colombia, too, there were discrepancies between the views of the program coordinators those of the professors who teach in the programs. The latter tend to undervalue the contribution made to their research by the public sector.

To help in understanding the evolution and scope of research in the HES, it is useful to look at figures on funding for higher education in the countries of the region. Table 77 shows changes in public spending on education (PSE) and on the share of this going to universities (PSUE). The data show some basic trends.

- Costa Rica, Cuba, and Venezuela consistently spent over 5% of GNP on education. In the 3–5% range, there is Chile, Peru, and probably Ecuador, although in each country, spending follows a different pattern. The remaining countries spent about 3% or less of GNP on education. Argentina, Brazil, Colombia, and Mexico were at the upper end of the range: the Dominican Republic and Guatemala were consistently lower.
- The proportion of educational spending going to universities in

Table 77. Public spending on education (PSE) as a % of GNP and spending on university education (PSUE) as a % of total public spending on education, 1960–1985.

Country	1960	1970	1975	1980	1983	1985
Argentina						
PSE	2.5 (59)	1.9	2.5	3.6	2.5	4.2 (84)
PSUE	—	21.0	30.2	22.7	16.1 (82)	
Brazil						
PSE	2.6 (59)	3.3	3.0	3.4	3.2	2.9 (84)
PSUE	9.8 (51)	59.3	23.6	30.4 (78)	19.9	20.8 (84)
Chile						
PSE	2.4 (59)	6.4 (72)	4.1	4.6	5.8 (82)	4.4 (84)
PSUE	8.1 (50)	37.9 (69)	25.2	33.2	27.6 (82)	20.3 (84)
Colombia						
PSE	2.1 (59)	1.6	2.2	1.9	3.0	2.9
PSUE	16.9 (61)	23.9	10.5 (73)	24.1	22.3	22.2
Costa Rica						
PSE	4.0	5.4	6.9	7.8	6.0	4.9
PSUE	—	10.5[a]	24.4	26.1	25.8	41.4
Cuba[b]						
PSE	—	—	5.7	7.2	6.3 (82)	6.2
PSUE	—	—	—	6.9	10.6 (82)	12.9

(continued)

Table 77. Concluded.

Country	1960	1970	1975	1980	1983	1985
Dominican Republic						
PSE	1.6 (59)	2.8	2.0	2.2	2.1	1.8
PSUE	10.9 (51)	21.3	22.0 (76)	23.8	22.2	20.8
Ecuador						
PSE	1.7	4.0	3.2	5.6	3.7	3.6 (84)
PSUE	18.6 (51)	10.0	10.7	15.6	—	17.8 (84)
Guatemala						
PSE	2.2	2.0	1.6	1.8	1.8	1.8 (84)
PSUE	—	13.1	19.9 (76)	18.4 (82)	—	
Mexico						
PSE	1.6	2.6	3.8	3.0	2.7	2.6
PSUE	1.0 (50)	10.4	12.6	26.5	28.8	29.2
Peru						
PSE	3.4 (56)	3.8	3.5	3.3	3.3	2.9 (84)
PSUE	3.7 (49)	16.7 (68)	15.7 (74)	—	—	—
Venezuela						
PSE	4.0	4.9	5.2	5.1	6.5 (82)	6.6
PSUE	17.4 (51)	25.5[a]	37.0	34.6	43.1	43.4

Source: Unesco statistical yearbooks.
[a] Figures from Unesco, ED-79/Mindelac/Ref. 2, Paris 1979.

most countries reached a peak from 1975 to 1980, with subsequent declines or variations, except in Brazil, Costa Rica, Cuba, Mexico, and Venezuela, where spending on higher education continued to grow. Based on the most recent information available, Cuba channelled less than 15% of its education budget into universities; Argentina, Brazil, Chile, Colombia, the Dominican Republic, Ecuador, and Guatemala spent 15–25%; and Costa Rica, Mexico, and Venezuela spent over 25%. Most countries fell into the intermediate group, at the higher end of the range, with about 20% of public expenditure on education going to universities.

➤ Contrary to general belief, the trend detected by Jallade (1978), from 1964 to 1975, has still not come to an end. He points out that, during this period, public expenditure on university education increased in 13 out of 20 countries in the region and dropped in only 5. In the 20 OECD countries over the same period, expenditure dropped in 10 and held steady in 5. Taking a sample of 10 out of the 12 countries covered in this study for which information is available, from 1980 to 1985, it is evident that most of them increased their spending on higher education, measured as a percentage of total public spending on education. On the other hand, in 8 of the 12 countries studied, total expenditure on education dropped over the same period (measured as a percentage of a GNP that also fell in most of the countries); education spending held steady in one country and increased in only three.

6

Research Productivity

Latin American research, especially research conducted in the higher education sector, is destined primarily for publication and circulation among specialized publics who can respond intelligently and, thus, afford recognition to scientific authors and establish their reputation.

The CRESALC study on graduate programs in four countries (de Andrade Córdova et al. 1986) provides a table of the responses of professors in these programs with regard to the destination of the output of the research carried out within them (Table 78).

The researchers themselves perceive their work as intended, above all, for academic use, as distinguished from use in the public or private sectors for patenting inventions. It is not clear whether these latter targets reflect a nonacademic interest in making an impact on the socioeconomic environment but, they show a "deviation" from prevailing criteria in the university research community, whose members seek recognition through scientific publication. This drive is so strong that, even in areas where one might expect a different or more varied destination for research results and other motivation among researchers (e.g., applied agricultural research), the same academic orientation continues to prevail (Velho 1985).

Table 78. Destination (%) of research output conducted at the graduate level in four Latin American countries, 1983.

Expected destination	Brazil	Colombia	Mexico	Venezuela
Internal reports	51.6	45.7	50.9	35.5
University doctorates	24.8	56.5	27.7	39.7
Technical journals				
National	68.9	56.5	56.2	74.3
International	78.3	41.3	59.8	72.8
Books				
National	27.3	21.7	25.0	29.4
International	6.8	2.2	6.3	14.7
Other publications	13.7	19.6	32.1	2.2
Patents	6.8	4.3	16.1	3.7
Application				
Public sector	31.1	21.7	26.8	30.1
Private sector	14.9	21.7	17.0	14.7
Outside Latin America	6.8	4.3	10.7	8.1
Number of respondents	161	46	112	136

Source: Klubitschko (1986).
[a] The percentages in each column correspond to affirmative replies to a yes/no choice.

National Cases

Despite what has been said above, researchers who publish in national and international scientific journals represent only a fraction, sometimes a small one, of the members of the national academic community. In the CRESALC study on graduate programs, the data show that in three countries (results were not obtained for Brazil in this case) about 85% of the professors interviewed had published at least one article in a national journal; between 10 (Colombia) and 19% (Venezuela) in a Latin American journal; between 25 (Colombia) and 50% (Mexico and Venezuela) in a North American journal; and between 12 (Colombia) and 42% (Mexico) in a European journal.

There were also differences related to discipline. In the exact sciences and biology, there appear to be closer links with international North American and European journals. With regard to the social sciences, there are differences among the countries, but there are more contacts with Latin American journals. In the case of engineering and agricultural science, one to three out of every four professors stated that they had published at least one article in a Latin American journal.

However, if this question is examined in greater detail, the likely finding will be that the results are more varied across the range of specializations and countries. For example, a study by Freites and Roche (1983) shows that, in a broad sample in the Venezuelan scientific community in around 1977, about 25% of the people interviewed had never published. Earlier studies in the same country showed even higher figures: 39.5% in 1969 and 36.5% in 1973. These figures should not be considered striking; in Spain in 1980, a study showed that 20% of a sample of the scientific community had never published an article; the proportion of nonpublishing professors in India was a significant 17%; and in Turkey, it represented 67% of researchers over the period 1933–1966. A Mexican sample revealed 27% nonpublishers in mathematics, 23% in physics, and 25% in earth sciences. A similar study in the United States showed that 10% had not published anything in the 7 years between 1958 and 1965, and 4.9% had not published anything in the 12 years from 1958 to 1969 (Roche and Freites 1982; Freites and Roche 1983: note 21, p. 209).

A recent study by Sagasti et al. (1985: Tables 32–34) showed that, in the case of four Peruvian academic communities, the proportion of researchers who had never published in national or international journals was almost half for mathematicians, a third for scientists working in seismology, 15% for economists, and 10% for biologists. According to the same study, researchers in biology and economics who published nationally were much more numerous than those who published internationally; the ratio was closer to one for the mathematicians and seismologists. In the opinion of the Peruvian researchers interviewed, there had been no major increase in frequency of publication in the different areas in the period 1978–1982 compared to the previous 5 years. Only in economics did a majority believe that there had been an increase publication in national journals; a third held the same opinion with respect to international journals.

Data on the situation in Brazil (Moura Castro 1985: 58) show that teachers in graduate programs publish an average of 0.87 articles per year, i.e., each publishes at least one article every 13 months. If the institutions are ranked by per capita production of articles for

1982 (total production divided by the number of teachers), the first place is held by the Brazilian Centre for Physics Research (2.96 articles per teacher), followed by five other institutions with production of more than two articles per professor. In 13 institutions, researcher produced one to two articles a year. However, the vast majority of institutions had an average production of less than one article per person per year. According to Moura Castro's study, the most productive institutions were frequently the most specialized. With certain exceptions, average productivity is lower in large universities, which is not unexpected. One possible reason is that the most productive institutions tend to be the smallest and most specialized, especially when they operate with a number of researchers who are working full-time or concerned entirely with their research and are not overburdened with teaching activities.

A study of academic sociologists recently conducted in Chile (Brunner 1986b) showed that somewhat less than half published articles in foreign journals at an average rate of almost one article per year. The number who had published books abroad was very small: only 13%, at the rate of 1.5 books in 3 years. However, almost 80% of the academics interviewed had published an average of one article per year in the most recent 3 years, in the form of a working paper; 70% had averaged one article per year in a specialized national journal over the same period; and a third had published a book in Chile on average in that period. This relatively high productivity suggests that scientific production is highly influenced by mechanisms for obtaining resources, the degree of "outside" orientation of the researchers, the kinds of subsidies distributed, and the evaluation mechanisms involved. A closer study of this subject would require an examination of the frequency of publication by researchers in a given discipline or institution to see whether high productivity is related to where the material is published; and whether there are factors affecting different publication trends within a given specialization, among specializations, and among countries.

Latin American Production in the World Context

The contribution of Latin American countries to worldwide publication and internationally recognized knowledge (mainstream science) is insignificant. The region accounts for about 1.3% of the world's scientific authors (Table 79). These figures have been discussed from different points of view, especially by Third World

Table 79. Number of scientific authors in Latin America and the Caribbean compared with world total, 1973 to 1980.

	Latin America and Caribbean	World
1973		
No. of scientific authors	3 139	269 545
% of world total	1.17	
1977		
No. of scientific authors	4 154	382 067
% of world total	1.09	
1980		
No. of scientific authors	5 768	454 864
% of world total	1.27	

Source: Sagasti et al. (1983).

critics, but they at least serve as a frame of reference for making comparisons and studying changes in mainstream scientific production over time and from country to country.

The Third World position on the science map has been studied by Garfield (1983) in a well-known article. Taking 1973 as the base and looking at the period from 1973 to 1978, Garfield looked at 2 500 scientific journals (out of the estimated 50 000 published that year throughout the world, although Garfield is convinced that 90% of them were insignificant) and reviewed the approximately 353 000 articles listed in the *Science Citation Index* (SCI) in 1973 and the approximately 2 million citations from them during the following 5 years by country or region of origin (Table 80). The countries of the industrially developed world account for 84% of the articles listed in 1973 by the SCI and for 90% of the citations in the following 5-year period (Table 80).

Table 81 shows the countries in which the authors worked, based on the same sample of articles as the preceding table (note that the location of the author is determined by the place of work indicated by the first author of a listed article). Authors working in the industrially developed world account for almost 83% of the total and 92% of the citations listed from 1973 to 1978.

In 1973, only two Third World countries, India and Argentina, ranked among the first 25 countries in the world by number of articles written by their authors. India is the place of origin of almost half the articles from the Third World listed by the SCI in

Table 80. Region of origin of articles published in scientific journals and listed in the Scientific Citation Index in 1973.

	% articles in SCI 1973	% citations 1973–1978	Impact[a]
USA	48	60	6.9
Great Britain and the developed Commonwealth	16	16	5.5
Western Europe	15	10	3.4
USSR	6	2	1.4
Eastern Europe	3	1	1.9
Japan	3	2	2.9
Scandinavia	2	2	7.6
Third World[b]	2	—	0.8
Other	1	—	1.4

Source: Garfield (1983).
[a] The average number of times each article was cited over the period.
[b] Includes 122 developing countries.

Table 81. Location of the authors of the 1973 Scientific Citation Index articles by region.

	% articles in SCI 1973	% citations 1973–1978	Impact[a]
USA	43	54	6.9
Western Europe	17	14	4.6
Great Britain and the developed Commonwealth	16	17	5.9
USSR	7	2	1.6
Third World	5	2	2.3
Eastern Europe	4	2	2.5
Japan	4	3	4.1
Scandinavia	3	4	7.4
Other	2	2	5.2

Source: Garfield (1983).

1973. There were 93 Third World countries producing one or more articles that year, but only 30, including India and Argentina, appear as the country of origin of more than 50 articles. The Latin American countries covered by this study that were among this latter group are shown here in descending order by number of articles listed in SCI in 1973: 2. Argentina, 1 526; 3. Brazil, 812; 5. Venezuela, 589; 6. Chile, 565; 7. Mexico, 535; 22. Peru, 59; 28. Colombia, 54. Jamaica (77 articles) and Uruguay (57 articles) should be added to the list.

For 1973, it has been calculated that Latin American contribution to total Third World production was 26.9%, accounting for 30.4% of the total impact of articles from the Third World (Arends, T., cited in Krauskopf et al. 1986). It has also been established that, for 1978, of the articles whose first author is a Latin American (about 3 100), 92% were from only five countries: Brazil, Argentina, Mexico, Chile, and Venezuela (Garfield 1983).

It should be noted that, of 16 000 articles published by Third World countries in 1973, 85% were in English and 11% were in Spanish. It is also known that Third World articles published in English have more impact: the average impact of articles published in English is 2.6; articles published in Spanish, on the other hand, have an impact of less than 1.0. Jamaica, Guatemala, and Panama are the only Latin American and Caribbean countries that are included among Third World countries whose articles have an impact of over 4.0. Mexico, Brazil, Colombia, and Argentina have an impact over 2.5, but under 4.0.

The need to use English as the lingua franca of mainstream science has become even more apparent since 1973. In 1978, the SCI listed 22 000 articles from Third World countries, 92% of which were published in English. For 1981, the respective figures were 27 000 and 92%.

Somewhat over a third of the articles from Third World countries listed by the SCI were printed in journals published in the Third World. The percentage of articles published in national journals by the Latin American countries that publish most frequently is as follows: Argentina, 75%; Brazil, 13%; Venezuela, 80%; Chile, 51%; Mexico, 35%; Peru, 27%; Colombia, 0.3%.

The impact of articles published in domestic journals is not over 1.0 for any of these countries (same number of citations as articles), but this does not mean that every article was cited. The citation percentage is 67% for Guatemala (12 out of 18 articles cited), 65% for Colombia, about 50% for Brazil and Mexico, 43% for Argentina, 42% for Peru, 40% for Chile, and 22% for Venezuela.

Some authors have calculated that the number of published articles listed in the SCI should be multiplied by two for Venezuela and by a factor of two to four for Brazil to produce a more realistic estimate of the number of articles originating in these countries, both in mainstream science and in nonmainstream or local science. In other words, all articles that appeared in national or regional journals, classified as journals of excellence by referees in the various disciplines, would be considered. In 1973, the SCI included only 17 Latin American journals, representing 0.55% of the total, and the *Social Science Citation Index* included only seven Latin American journals, or 0.16% of the total.

A more recent study (Krauskopf et al. 1986) analyzed mainstream scientific output in Latin American and Caribbean countries, taking SCI information as the base. According to this analysis, the number of articles, broken down by field of specialization for each country covered in this study, was as shown in Table 82.

In 1981, the SCI listed 7 230 articles from Latin America, equivalent in that year to 1.3% of the world total of internationally listed publications. Of the Latin American articles listed, 27.6% originated in Brazil, 23% in Argentina, 17.3% in Mexico, and 16.2% in Chile. In other words, these four countries accounted for 84.1% of Latin American mainstream publication. Biology was the most prolific field, with 33.3% of the total, followed by medicine with 29.1%. Chemistry and physics were much further behind, each accounting for about 10% of the articles. In short, Latin American scientific production is highly concentrated in life sciences, with low output in fields linked to industry.

It is also worth noting, as Krauskopf et al. (1986) mention, that production in agricultural sciences is very low. In absolute terms, it is highest in Brazil, but represents only 3% of Brazil's total output while, in Cuba, it represents about 38%. This major effort by Cuba in the field of agricultural research is followed, in decreasing order by Peru, Costa Rica, and Colombia. Again, it should be kept in mind that what is being measured is only the number of articles published in scientific journals listed by the SCI in 1981; this index omitted major Latin American agricultural journals and, therefore, a significant number of articles published in this field in Spanish and Portuguese (Velho 1985).

According to data published in the Current Bibliographical Directory for 1981 to 1983, distribution of scientific authors among the Latin American countries selected for this study was as shown in Table 83. The average number of mainstream scientific authors per year for 1981–1983 was 2 233 for Brazil, 1 511 in Argentina, and 1 121 in Mexico. There were 914 in Chile and 431 in Venezuela.

Table 82. Number of scientific publications by country and field of specialization, 1981.

Field	Argentina	Brazil	Chile	Colombia	Costa Rica	Cuba	Ecuador	Guate-mala	Mexico	Peru	Venezuela
Mathematics	10	47	2	2	0	11	0	0	25	1	13
Physics	142	304	10	1	8	26	0	0	130	0	52
Chemistry	223	191	2	2	3	72	0	1	154	2	72
Biology	447	689	23	26	16	647	6	7	282	19	158
Earth sciences	7	58	0	0	0	2	0	0	7	0	8
Astronomy	19	28	0	0	1	56	0	0	12	0	1
Engineering	66	85	3	0	2	10	2	1	46	1	23
Medicine	681	385	18	12	31	307	2	27	456	12	75
Agricultural sciences	24	60	13	11	44	17	2	7	24	15	8
Social sciences	30	98	16	11	10	19	0	0	75	11	15
Legal sciences	1	6	0	0	0	0	0	0	2	0	0
Humanities	5	10	0	0	0	2	0	0	28	3	0
Other	5	38	2	0	1	5	0	0	10	7	13
Total	1 660	1 999	89	65	116	1 174	12	43	1 251	71	438

Source: Krauskopf et al. (1986).

Table 83. Number of scientific authors[a] by country, 1981–1983.

Country	1981	1982	1983
Argentina	1 335	1 529	1 669
Brazil	1 925	2 394	2 376
Chile	927	1 083	732
Colombia	85	112	133
Costa Rica	60	97	79
Cuba	106	113	142
Ecuador	13	16	32
Guatemala	40	48	34
Mexico	1 215	1 089	1 060
Peru	75	95	84
Venezuela	390	439	464

Source: Current Bibliographical Directory.
[a] Includes authors of books and joint articles.

Comparisons of scientific productivity are generally arrived at by establishing certain coefficients, such as the number of publications divided by the total population, the number of authors per capita, one or the other of these per million dollars of GDP, etc. Table 84 gives figues for scientific production of Latin American and selected countries from other regions, measured as articles per million people for 1980. As Roche and Freites (1982) comment with regard to this comparison, the mechanism used as the basis for calculation may prove to be quite arbitrary in this case. There are countries in Latin America with large populations that are illiterate or too young, or that have been marginalized and, therefore, make this type of comparison less valid. As Moura Castro (1985: 74) says, it is inevitable that countries with large populations, such as Brazil, will suffer in this kind of comparison: a phenomenon that also affects the USA, the USSR (91 articles per million people), and Japan.

It would be better to compare the input and output of scientific research directly to gain an idea, however rough, of average scientific productivity in each country. It is obvious that the apparent productivity of the more developed countries will then be adversely affected, because large numbers of their scientists and engineers working on R&D are involved in experimental development activities and often do not publish mainstream articles. Table 85 shows average scientific productivity calculated as the number of articles (listed by the SCI) published in each country in proportion to the number of its scientists and engineers working on R&D based on the Unesco statistics quoted earlier in this study.

Table 84. Scientific productivity measured as articles per million people for a selected group of countries, 1980.

Country	Articles per million people
Israel	892
USA	742
Canada	692
Sweden	513
France	343
West Germany	331
Japan	161
Spain	74
Portugal	18.3
Chile	64.4
Argentina	38.6
Costa Rica	38.1
Venezuela	26.8
Brazil	13.1
Mexico	11.3
Cuba	7.8
Peru	4.5
Guatemala	3.4
Colombia	2.6
Dominican Republic	1.2
Ecuador	1.0

Source: Roche and Freites (1982).

Based on these and similar statistics, Roche and Freites (1982: 286) conclude that there is a group of "more productive" countries in the region, including Argentina, Brazil, Chile, Costa Rica, Mexico, and Venezuela. Using data from the SCI, Blickenstaff and Moravcsik (1982) have calculated that, from 1971 to 1976, the highest per capita productivity in mainstream science in Latin America took place in Argentina, Chile, and Venezuela; the countries whose contribution grew most over the period in question were Mexico, Brazil, and Costa Rica. A similar discussion can be found in the article by Krauskopf et al. (1986), where it is shown that, in terms of scientific authors from the five most productive countries in the region, growth patterns differed over the period 1978–1982. According to this calculation, extended back into the last decade, only Argentina seems to have had steady growth from 1967 to 1982, while Brazil and Mexico experienced a relative

Table 85. Scientific productivity measured as articles per scientist or engineer engaged in R&D for a selected group of countries, 1980.

Country	Articles per individual in R&D
Canada	0.66
USA	0.29
Great Britain	0.29
France	0.27
Israel	0.24
Spain	0.15
Venezuela	0.19 (1977)
Argentina	0.13
Mexico	0.08 (1974)
Chile	0.07 (1975)
Brazil	0.06 (1978)
Guatemala	0.05 (1978)
Cuba	0.01 (1979)

Source: Roche and Freites (1982).

decline, despite the increase in absolute numbers of their scientific authors.

To complete the exploration of this theme is to return to the topic of individual productivity. The best way to calculate this for each country would be based on both mainstream and nonmainstream publications of recognized seriousness and excellence. Per capita productivity for researchers and institutions could be established based on this count and comparisons could be made at the national and international levels. This data would also enable study of a single institution, the creation of a critical mass within it, and its progressive integration into the international network (see the interesting article by Lomnitz (unpublished) in which she develops this viewpoint).[4]

Moura Castro (1985) calculated that, in Brazil, average per capita productivity is 0.87 articles per year. In Venezuela, Roche and Freites (1982) calculated per capita productivity in three institutions, where it ranged from 1.3 to 0.5 articles (in Brazil, it ranged from 2.96 to less than 0.1). A similar calculation for other institutions or groups of scientists shows that the Nobel prize winners studied by Zuckerman in 1977 had a per capita productivity of 5.9

[4] Lomnitz, L. Publications and referencing patterns in a Mexican research institute. (preliminary version, 1986)

articles per year, while the scientists listed in *American Men of Science* had a productivity of 1.9. Similar studies show productivities of 3.8 and 0.6 in 1988 at the Jodrell Bank and Cambridge Laboratories, respectively. It was 1.3 at the Max Planck Institute in 1980 and 2.6 for a group of researchers at different institutions in India in 1971 (Roche and Freites 1982: 284).

A similar study would have to be carried out for individual Latin American countries, based on sufficient information on the number of researchers, on whether they work full-time or part-time, and on the number of articles they publish at home and abroad in journals considered to be scientific. It would also be necessary to distinguish between fields of specialization and types of institution, because what little information there is indicates that there are marked differences from one field to another: international journals play a role in the exact sciences, for example, that is completely different from their function in social sciences; and different institutions, depending on their degree of specialization, the work schedules of their members, their size, scientific tradition, incentives or type of financing, etc., generate different productivity patterns.

7

Scientific Communities and the Research Career

A vast amount has been written about the groups of specialists that are nowadays called "scientific communities" and also about the scope, limits, and potential distortions this term can introduce, giving the impression that these groups are purely intellectual in nature and develop with no connection to external or "trans-epistemic" factors (Bourdieu 1975; Knorr-Certina 1981). Although I will not attempt to comment on this debate here, it does shed some light on this aspect of the Latin American scientific world. I will attempt to show how the disciplines, as knowledge enterprises, actually function in the countries of Latin America and how their main activity, research, is organized.

The relationship between the sciences and the public sector in Latin American countries is examined, focusing on the creation of science and technology research councils, on development plans for science and technology, and on forms of public funding for research. Following this is a general discussion of training for researchers and specialists in scientific development and the patterns that shape the careers of these professionals. Finally, the opinions of the researchers themselves about their fields and their work, and about the institutional framework required for the development of research are briefly discussed.

The Public Sector and Research

The conclusion is inescapable that the public sector has played the major role, in almost all Latin American countries, in launching, developing, and institutionalizing science. In practice, governments and public agencies have financed the bulk of the current research infrastructure, subsidized the training of researchers, awarded a large number of grants for their further training abroad, and are providing the funding needed to carry out research projects. Regardless of the size of the science and technology system in any of these countries, or of their political orientation or their prevailing economic model, in all of them, over the last three decades, the government has created and supported most of their institutionalized science and technology activities; this phenomenon can also be observed in most developed countries (Machlup 1962).

The private sector, on the other hand, has generally played a lesser role. Based on available information, its financial contribution appears to be modest, as does its contribution to the institutional development of R&D activities, especially at the level of the firm. Private initiatives in the education sector are a different matter, especially at the university level. However, even in this field, there appear to be few private institutions that, without government support, would have been able to play a leading role in research or research training, although there are a few instances of significant contributions.

However, the contribution made by international cooperation in its many forms has been decisive: technical support and consulting, training for researchers, exchanges of professionals, contribution of resources, dissemination of organizational models and scientific paradigms, etc.

Building institutions from above

Modern development of R&D activities requires an institutional system that combines skilled people, resources, jobs, specialized communications media, links between a diversity of institutions, forms of contact between the people working in the field and the public and private sectors, etc. In many Latin American countries, this complex and sometimes vast institutional system has arisen through the efforts, usually unplanned, of the scientific community itself, but it is principally a creation of segments of the government technocracy.

In most countries of the region, the creation of science and technology research councils represents a particularly important moment in the creation of institutions "from above." These councils are the expression of a consensus among government agencies, technocratic circles, and leading groups in the scientific community on the need to strengthen the role played by the public sector in developing S&T activities. The example of the drive of the United States, during and immediately after World War II, to promote R&D activities as part of a national development plan has undoubtedly had an influence. In particular, the 1945 report by Vannevar Bush, proposing the creation of a National Science Foundation, pointed out an easy route for the incorporation of R&D activities into the national agenda. Unesco, followed by the Scientific Affairs Department of the OAS, undertook an extensive campaign in Latin America to disseminate this model for organizing and supporting the sciences with the participation of the public sector. With the creation of science and technology research councils, like the National Commission for Scientific and Technological Research (CONICYT) in Chile (Amadeo 1978; Texera 1983) the public sector was already playing a dynamic role in the development and institutional organization of science and technology, which has continued to the present.

While the councils were being established, training was stepped up for small core groups of scientists and engineers who gradually specialized in managing S&T activities and who later had a decisive influence on the creation of new support institutions, the channeling of more resources into R&D activities, and the establishment of science and technology services, which became increasingly necessary as the institutional structure became more complex.

Two approaches to science and technology, which soon came to have a decisive influence on the administration of these activities in most countries in the region, began to develop simultaneously. On one hand, the "systems approach" applied to the development of scientific and technological activity (Amadeo 1978) had a practical impact on the building of institutional systems and support functions in this field; on the other, the concomitant "planning approach" acquired wide currency (Sagasti 1977; for a case analysis, see Peluccio Ferreira, unpublished)[5] and almost all the countries formulated scientific and technological plans and programs.

[5] Peluccio Ferreira, J. Ciencia e tecnología nos países em desenvolvimento: a experiencia do Brasil. (preliminary version, 1983).

Developing plans and programs

In almost all the countries of the region, S&T programs have been defined and approved for periods of 2 or more years and serve as a framework for the definition of more specific programs and lines of action (see the base studies which contain descriptions of the plans, programs, and goals). As a recent study by the Board of the Cartagena Agreement shows (Junta del Acuerdo de Cartagena, unpublished),[6] the overall objectives of these plans are generally quite similar. For the countries included in that study — Bolivia, Colombia, Ecuador, Peru, and Venezuela — these "main" objectives were

- Building up the national scientific and technological infrastructure;
- Linking scientific and technological capability to the solution of the nation's major problems;
- Fostering research in priority areas;
- Supporting the creation of endogenous technological capability;
- Increasing dissemination and publicizing of science and technology activities;
- Rationalizing, modernizing, and integrating the public bodies that contribute to the country's scientific and technological development; and
- Making optimum use of the international cooperation mechanisms available in this field of activity.

The document goes on to give a detailed analysis of the ways in which these objectives converge, grouping them around three central concerns:

- Creation of a national S&T response capability in terms of strengthening the infrastructure, training human resources, upgrading national capability for technological negotiation, increasing the production sector's capability for technological innovation, and disseminating scientific and technological culture to the general public.
- Application of the results of S&T activities to the production sectors and to solving social problems by disseminating and using the results of R&D and strengthening the liaison mecha-

[6] Junta del Acuerdo de Cartagena. Objetivos globales y sectoriales de política científica y tecnológica en la subregión andina y líneas de convergencia. (C.CT/IV/dt 3, 1986)

nisms between scientific and technological activities and the production sector.

- Promotion of regional integration of S&T and more efficient technical cooperation at the subregional level.

It is interesting to note how the planning approach has led to the formulation of a few goals that can be applied in countries that are dissimilar and at different stages in S&T development. Moreover, as the Cartagena Agreement Board document shows, the member countries also arrive at similar definitions of more specific objectives in priority areas. These areas, emphasized to varying degrees by the countries that are parties to the Agreement, are agriculture, basic sciences, biotechnology, computer science, education, energy, fisheries, food and nutrition, forestry, health, housing and urban planning, manufacturing, mining and metallurgy, and natural resources and the environment.

On this level, the objectives are much more precise. For example, goals for the agricultural sector include the need to foster research on genetic inputs and germ plasm, sanitation problems, equipment, biocides, chemical therapeutic products, immunization, and antigens. In basic science, the goal is to boost national capability in terms of equipment and equipment maintenance, personnel training, and the creation of scientific communities.

In short, this strategy of building institutions from above has led to the adoption of a planning approach that, on one hand, clarifies and presents coherent public objectives that are coordinated with broader national development objectives and, on the other, provides a post hoc justification of the myriad of dissimilar, almost uncoordinated, day-by-day initiatives that eventually result in construction of an institutional apparatus for S&T. What begins as a way of legitimizing public intervention in the field and justifying the investment of public resources in its development becomes a need to react to the variety of initiatives that shape this complex institutional system, which usually emerges as a weakly linked, disjointed structure, requiring new efforts at integration and coordination. In other words, public intervention has the effect of decreasing the need for public intervention over time; it triggers a feedback process that has led many people to criticize its involvement in S&T, while failing to notice that the field could not have developed or attained its current size in any of the countries of the region *without* such intervention.

The systems approach

Intellectual fashion alone cannot explain the adoption of the systems analysis approach in S&T, which has proved so powerfully attractive and has penetrated so deeply in a variety of disciplines and areas of activity. More likely, this approach has developed as a complement to the planning approach and has won acceptance as the best way of approaching analysis and action in this sector.

Especially in the larger, more developed countries, like Brazil, Mexico, and Argentina, but also in countries whose R&D sector is medium-sized, it has become normal to approach R&D as a system of various internal elements with lines of interaction between them and many functions that either complement and reinforce one another or overlap. In practice, the "system" is perhaps a different thing. A concrete illustration is the scientific and technological development system in Brazil. The following description relys heavily on the work of Peluccio Ferreira (unpublished, see footnote 5) (for a more detailed analysis that refers specifically to the training of human resources for R&D activities, see de Souza Paula and Assad Ríos, unpublished; de Souza Paula et al., unpublished).[7,8]

Peluccio Ferreira (unpublished, see footnote 5) postulates two characteristics of the current system that differentiate it from its previous stages of development. The first is strong government intervention with the deliberate aim of establishing a national system for S&T development; this intervention began with the creation of the Conselho Nacional de Pesquisas (CNPq, national research council) in 1951, grew with the formation of the Fundo Nacional de Desarrollo Tecnológico (FUNTEC, national fund for technological development), and culminated in the establishment of the Strategic Development Program (SDP), which defines the basic guidelines for national S&T policy and outlines the overall shape of the system. The second characteristic is the development of the various plans in the wake of the SDP, to the point where they flow into the Basic Science and Technology Development Plans, which set global and sectoral goals.

In structural terms, the system resulting from this combination of intervention from above and the planning and systems approaches can be described as a set of federal and state public institutions and agencies, combined with financial mechanisms that are linked to the expansion and operation of the system and the achievement of its goals. The system includes universities, institutions, and other scientific and technological research agen-

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[7] de Souza Paula, M.C., Assad Ríos, A.L. Formaçao de recursos humanos para pesquisa no Brasil. (preliminary version, 1987)

[8] de Souza Paula, M.C., Assad Ríos, A.L., della Senta, T. Política de formaçao de recursos humanos para pesquisa: o caso do Brasil. (preliminary version, 1988)

cies, which provide the kinds of service required in this field, and also agencies and financial mechanisms for development and coordination.

The strategic objectives of the system are

- To organize and operate an infrastructure for training researchers and conducting research in the various fields of science and its applications. This includes technological services, such as scientific and technical information, testing, quality control, preparation of technical standards, etc.
- To articulate and support the system in relation to the production sector in all its branches of activity, giving special priority to private national enterprise, whose active role in R&D is one of the key principles of S&T policy and is a condition for reducing dependency on external technological sources.
- To channel and monitor flow of external technology to facilitate learning processes and the incorporation of technology by domestic companies and to strengthen cooperation between developed and developing countries.
- To formulate proposals and studies that harmonize science and technology policy with other government policies.

Four basic functions are identified in the operation of the system as a whole: programing, coordination, and financing; development; implementation; and relations with other countries (transfer of technology, cooperation, and bilateral and multilateral exchanges).

Programing, coordination, and financing. The central agency at this level in Brazil is the CNPq which, since 1974, has come under the Planning Secretariat of the Office of the President of the Republic. The CNPq has a consultative body, the Science and Technology Council, which is divided into working committees of specialists. Representatives of public agencies involved in S&T policy and representatives of the scientific community sit on this council, which plays an important role in preparing Basic Science and Technology Development Plan projects. The CNPq cooperates in preparing federal S&T budgets by providing support to the Budget and Finance Office of the Planning Secretariat, but it has also retained some of the key functions of its earlier role, for example:

- *Development:* awarding scholarships to graduate students abroad and within the country, and grants to support scientists and small teams — recently, the CNPq also assumed responsibility for financing and coordinating some larger scale programs, such as the semi-arid tropics program.

- *Project implementation:* through any of the six research institutes that form part of its own structure (pure and applied mathematics, national observatory, space research, Amazon research, scientific and technological information, and the Brazilian Physics Research Centre) — science and technology research councils in other countries are also responsible for implementing projects through their own institutes and research centres (e.g., CONICET in Argentina).

The ministries that belong to the Science and Technology Council are assumed to have their own individual S&T sections. The state governments have also created agencies to support R&D activities in their own regions. In total, there are five programing and coordinating agencies that act in a wider field:

- The National Graduate Program Council, chaired by the Minister of Education and Culture;
- The Secretariat for Industrial Technology (Ministry of Industry and Trade);
- The Brazilian Agricultural Research Corporation (EMBRAPA), which carries out research in its own field;
- The Armed Forces General Staff (EMFA), which programs and coordinates the research activities of the defence ministries; and
- The Ministry of Foreign Relations (Scientific, Technical and Technological Cooperation Department).

Development. The most important agencies, mechanisms, and policy bodies contributing to the development of science and technology in Brazil are

- Financiadora de Estudios e Proyectos (FINEP, studies and projects funding agency), a corporation which, like the CNPq, comes under the supervision of the Planning Secretariat of the Office of the President. It administers the National Scientific and Technological Development Fund (FNDCT). FINEP finances a variety of activities in the field of S&T, from projects and programs, including graduate programs, to investments in equipment. It may offer support to universities, public and private corporations, and other agencies that carry out R&D.
- Coordination of Development of Highly Qualified Personnel (CAPES), an agency of the Ministry of Education which, like the CNPq, operates with advisory committees of specialists and makes funding available for projects, programs, and scholarships.
- Fundo Nacional de Desarrollo Tecnológico (FUNTEC/BNDE, national fund for technological development), which has

recently been supporting mainly the projects of private sector companies, i.e., activities in the area of experimental development and technological innovation.

- State banks, a number of whom have special funds for research support.
- Secretariat for Industrial Technology, which has several research institutes and manages the National Technology Fund (FUNAT), a funding source which operates in a similar fashion to FINEP, but exclusively in the field of technological research.
- State-owned companies operating in industrial and infrastructural sectors that are dynamic in terms of technological progress; such companies make arrangements with private enterprise to facilitate research and applied production technology.
- The Market Reserve, a nonfinancial mechanism that seeks to boost the use of existing R&D capacity within the country and has been used in the aeronautics industry and the microcomputer sector.
- Tax incentives.

Implementation. Four types of institutions are responsible for implementation: universities and independent scientific institutes; technological research institutes; technological service institutes; and state-owned companies.

Foreign relations. The Ministry of Foreign Relations acts as the coordinating institution for the conclusion of agreements involving the transfer of technology in conjunction with agencies, such as the Planning Secretariat and the CNPq. The National Industrial Property Institute plays a role in transfers of technology and maintains the register of patents.

As the case of Brazil demonstrates, S&T "systems" have arrived at significant, complex stages of development in some countries in the region. However, there is insufficient information to classify all Latin American systems by size, amount of resources managed each year, internal structure, fields of activity, role played by the government, and market mechanisms. Nor has the way in which these systems operate as a whole been evaluated, although efforts have been made to gather basic information for this kind of study in some countries (e.g., see James 1981; Moura Castro 1985 — the articles by Eliezer Tal on S&T systems in Colombia, Panama, and Peru in *Science and Public Policy*, April 1984, February 1985, and October 1985 are also interesting).

In Argentina, CONICET acts through a variety of programs, including

- Subsidies for research and development projects in public and nonprofit private institutions;
- Grants for training and development of young researchers both inside and outside the country;
- Support for mature researchers through the medium of the Research Career; and
- Support for research institutions, comprising six regional centres and 116 institutes, that come exclusively under CONICET.

In 1985, 1 124 research and development projects were supported, 48% exact and natural sciences, 11% in engineering and architecture, 22% in medicine, 10% in agricultural sciences, 7% in social sciences, 2% in the humanities, and the rest in other fields. Within the country that year, 2 500 grants were awarded to both young researchers starting their careers and mature researchers for professional development and for advanced training.

The Research Career is a national research support system in which the most skilled researchers in each field (elected by their peers) receive long-term support; their work is evaluated regularly to determine whether such support should continue. According to the Argentine base study, there are 2 500 researchers in the Career program at various levels from assistant to senior researcher.

Argentina also has national and sectoral plans and programs for the development of S&T that define priority research areas: food technology, endemic diseases, housing, electronics, petrochemicals, renewable natural resources, biotechnology, genetic engineering, etc. Special programs provide additional funding and make for better coordination between the participating organizations. In addition to the priority areas, there are major priority sectors defined in terms of national development goals: food, capital goods, electronics, energy, petroleum and petrochemicals, health and pharmacology, and basic social sectors, such as housing and education.

In other countries, such as Chile, for example, increasing emphasis is being placed on distributing research resources through mechanisms based on individual competition, involving the use of juries of peers and action by the staff of CONICYT. In Brazil, the greatest emphasis is placed on the "systems" aspect of national S&T. This is also the case in Mexico where a system, composed of several subsystems — research, research–production links, research–education links, dissemination, standards and planning, and coordination — is described in the base study.

In all the countries, the training of researchers is based on a structure that combines internal effort through national graduate programs and grants for students with external effort, i.e., sending students abroad with or without local grants, exchanging professors to enhance the level of domestic graduate programs, and securing academic assistance from abroad under specific agreements. In some cases, there are programs to train young researchers, inside and outside the Research Career system, generally through grants for training or working on research as such. In general, the largest domestic role in this area is played by universities and institutions that offer graduate degrees, together with the agencies that fund these programs for students who wish to train as researchers.

With regard to funding for research, there are many sources, channels, and operating mechanisms that reflect a strong government presence, occasionally combined with a competitive stimulus through market mechanisms. Funding may be channeled to institutions, programs, projects, or individuals. It may be based on political decisions, bureaucratic negotiation, judgement of peer groups, or combinations of the foregoing elements. Several countries (e.g., Argentina and Mexico) have grant systems for trained researchers that, in their most highly organized form, become research career systems.

Creating the Research Career

The S&T systems described in the preceding section were created through an impetus from above, but they have also required development, from below, of communities of specialists who are professionally responsible for advancing knowledge in a discipline or specialization and who negotiate with external agencies (not in the scientific field itself) to promote its institutionalization and development.

A quick review of the literature on the creation of these communities shows that the processes are extremely complex. If the period following the Second World War is examined, some of the typically Latin American features of their development can be identified. (This is discussed in many of the works cited throughout this book, including Schwartzman 1978, 1979, 1981; Lomnitz 1979; Díaz et al. 1983; Vessuri 1984a,b; Brunner 1985; Sagasti et al. 1985; Courard 1986, 1987.)

In the beginning, science in most Latin American countries was restricted to a few core groups frequently made up of foreign researchers and their circles of local disciples. Because these groups were not usually in contact with one another, there were no dynamic factors to promote their expansion and consolidation. Such factors appear, still indirectly, only after 1950, when demand for professionals in the countries of the region grew as a result of increased social mobility and the political mobilization of the emerging middle class. This demand involved pressure to create new universities and public institutions of higher education and generated market forces favouring university education.

Despite this pressure, the new institutional apparatus that emerged gave rise, at the outset, to very little sustained scientific effort. This was accompanied by low demand for technological innovation due to the pattern of industrialization adopted by most of the countries in the region, which made them dependent on imported technology or allowed domestic firms to operate under strong protection without having to face international competition.

Nevertheless, strong growth in the higher education sector required academics with professional qualifications, thus providing a recruitment base for potential scientists. In addition, and more importantly, the need to organize an academic profession within the university system led some countries to demand advanced university degrees as the legal requirement for entry; this provided the main impetus for the development of graduate teaching, as was seen in Chapter 4.

The need to attach a research base to graduate programs, continually illustrated by the ideas and practice of international agencies and research support foundations, and by young academics trained abroad, opened up an environment in which science could finally install itself in Latin American universities. Where graduate programs were not created during this period or where demand for research training was weak, external influences and the demands of core groups of highly trained academics served to create the necessary environment, although, of course, on a smaller scale.

These efforts in building science were given drive and direction from above, as was seen in the previous section. This led to a convergence of the dynamic forces of the university and scientific worlds, the labour market, the resources of the public sector, and international support that resulted in the appearance of communities of specialists, professionally engaged in producing and communicating knowledge in a given discipline or specialization.

Amid these converging processes, creation of national research support councils and funding and development agencies was to play a central role, conferring public legitimacy on the activities of scientists and justifying them to society in terms of their usefulness for national development. National and sectoral S&T plans and programs also played a key role here.

Most members of these nascent communities probably saw the process in another way. For them, it involved the progressive opening up of a profession environment around the function of producing and communicating specialized knowledge. Subsequent stages included development of a line of inquiry, the important elements of which were publication, securing recognition and visibility, and forming ties with communities of peers inside and outside the country. Only on this basis was it possible to be relatively successful in obtaining renewed or increased funding to maintain continuity in research, to advance within the formal research career, and, more importantly, to be recognized within the subtle hierarchies of the "invisible colleges" that provide their members with access to new developments in a field, contact with leaders in a specialization, seminars and congresses of colleagues, prestige, and resources.

The fact that science was rapidly becoming a complex enterprise, in which resources came through a variety of increasingly bureaucratized channels, forced many researchers to become agents for procuring their own funds, presenting projects or competing for favours and access to decision-making circles. As Schwartzman (1978) notes, besides doing their own work, many prominent scientists were also involved in the many committees and groups that play a role in discussing and determining research support policies and programs, with a sacrifice of time and energy that could be significant.

Because most research is carried out in universities (although they do not necessarily receive all the resources spent on S&T), scientists are also involved in the problems typical of university institutions. These vary in nature from country to country and from one period to another, but are generally the result of a chronic lack of resources, struggles for power and rank within the university, turnovers in administrative staff, vulnerability to governments and party politics, and weak links to the nonacademic world, especially the production sector. Despite this, the typical Latin American researcher continues to perceive himself, and is perceived by society, as a university professor — an academic, a professional in a field — who works in a university department or institute, longing to be left in peace, wanting more resources, a lighter teaching load, and trying not to become involved in administrative affairs or university politics.

There is much less information available on researchers working outside universities, either in industry or in the public sector in nonacademic agencies. In the more developed countries, most R&D expenditures are channeled into experimental development, but in Latin America the case is different. Quite often, the money spent on R&D outside universities ends up supporting activities that are very similar to those of academics, or it is used by people who model themselves on university researchers. In terms of budgetary allocations, the second Brazilian Science and Technology Development Plan of 1975 can be considered an exception, because it set aside 25.6% of total resources for scientific development and training of personnel and graduates, while 20% went to industrial technology, 14.8% to applied agricultural research, 13.9% to infrastructure technology (energy, transport, and communications), 7% to atomic energy, 6.9% to technology for social and regional development, and 3.5% to other technologies. It would be interesting to make an evaluation, after the budgetary period was over, of how much was actually spent and what it was spent on.

In Latin America, public and private enterprises, especially the latter, seem to show little interest in experimental development activities. There are good reasons for this, as some authors have noted. Generally it is cheaper to license or import technologies that are well established abroad than to attempt to develop them locally. Foreign technology has already been developed and evaluated and is, therefore, reliable. The policy of most Latin American countries is aimed at encouraging the inflow of capital, companies, and technologies. This pattern, as Schwartzman (1978) concludes with respect to Brazil, not only facilitates imports of processes and equipment, but has also become essential for survival in the market. Domestic technological capacity must often be built up in opposition to market calculations, which indicate that, over the short term, it is cheaper to import technologies than to produce and develop them locally.

In this context of weakness in technological research in the production sector, researchers appear to face additional problems. One is lack of contact with their peers working in universities who are frequently engaged in developing lines of inquiry that are theoretical or not so directly applicable. The lack of contact, as a study on chemists in Venezuelan industry shows (Licha 1983: 251), has the same structural base as mentioned above. Since industry is not engaged in innovative research, which would require theoretical support and interaction among different professionals, but in adapting processes and products to local conditions or in competing in the market, ties between industry and the university do not materialize.

Moreover, researchers engaged in applied research are subject to an ambiguous definition of their roles and an ambiguous relationship with their peers. Because recognition in the scientific community is based on publication, applied researchers are often forced to publish instead of using their knowledge for purposes that are better tailored to the needs of the production sector or to those of the users of the information produced.

Industrial researchers often complain about their university training because they consider it highly theoretical and insufficient for real working requirements. As the study on the Venezuelan chemists working in industry shows (Licha 1983: 254),

> [They live] in almost total isolation from their milieu and engage in solving minor problems arising in their area of work, while also having to work closely with the head office on the larger problems posed by systematic and progressive technical training.

The Opinion of the Scientific Community

There is no comprehensive comparative study of Latin American countries that would permit a close examination of the opinions of the scientists themselves with regard to their work. Therefore, sources for this discussion are limited to the few available studies such as Sagasti et al. (1985), on four scientific communities in Peru, and passing references in the study by Freites and Roche (1983) on Venezuela.

In Venezuela, close to 70% of researchers agreed that the government should provide strong guidance for science and technology and that these activities should be planned by the State. On the other hand, when these scientists were consulted about what mechanisms should be used to ensure government guidance for research, only 9% mentioned planning, while over 40% were satisfied with existing mechanisms. This was confirmed by the positive perception the Venezuelan scientists had of CONICIT. More than half agreed that it was necessary to define priority areas, and those who objected to this frequently did so because they found such definitions to be overly general or because they believed that certain areas are often omitted. A third of those who favoured close ties between the government and research activities did so because the government sets the country's goals; nearly 30% because the government funds research; and close to a quarter of those interviewed believed that such ties make government management in the field of S&T more rational.

A high proportion of the Peruvian scientists interviewed by Sagasti et al. (1985) thought that the state of science in that country was unsatisfactory. Among the most positive group, economists, only 20% said that their discipline was in good shape. They generally believed that the government had no science and technology policy. A quarter of those interviewed believed that the main obstacle to the development of Peruvian science was lack of interest among politicians. This impression was particularly strong among mathematicians and seismologists, less so among biologists and economists. However, only 15% of the Peruvian researchers surveyed believed that it was a priority to inform senior government decision-makers about the results of their research. Those who were least interested in doing so were the mathematicians and seismologists. Only 6% of the scientists surveyed were working for the government and only 3.7% of researchers were funded by the government. Half declared themselves satisfied with the norms governing the administration of R&D activities.

Despite their poor evaluation of Peruvian science, the researchers surveyed generally had a high opinion of their own work. Most believed that their contribution had been important both nationally and internationally, and over half considered themselves pioneers in their fields. This is a good example of the sharp difference that may exist between people's perception of the general situation in their field and their evaluation of the worth of their own contribution within that context. Only 5% of the Peruvian researchers were in favour of practical activities; 55% preferred pure research or basic research. However, 50% believed that the purpose of science is to apply knowledge for practical purposes; 40% thought that the purpose of science is to develop knowledge itself.

8

The Current Context

As has become apparent in the course of this study, Latin America's inclusion in the world framework of major production and creativity is tenuous. Weak and dependent are the terms most usually employed, especially when speaking in strictly economic terms. As Table 86 shows, at the beginning of the 1980s the region held 8% of the world's population, but its contribution to total GDP, manufactures, capital goods, and highly trained personnel lagged well behind developed countries. The higher the value added by society as a whole to the output of increasingly complex goods and to knowledge, which is progressively systematized as such goods are produced, the lower the relative contribution of the Latin American region. Looking at development in terms of participation in (and incorporation into) the modern dynamics of production and creation, shows that, in the more advanced central countries, the relative weight of population compared to other indicators of the generation of products —knowledge and technology—and to the national stock of highly specialized human resources, is exactly the reverse of the situation in Latin America.

Not only is Latin America's position tenuous, but the gap that has developed between the region and the most dynamic poles in the system of so-called market economies is vast. It calls to mind Braudel's (1985: 103–104) observation on the role of the "centres" in the world economy during recent centuries:

> It is there that the sun of history makes the colours shine brightest; there that we find high prices, high salaries, bank-

Table 86. Economic and technological position (% of world total in the early 1980s).

	Latin America	USA	Japan	West Germany
Population	8.0	5.0	2.5	1.3
Gross domestic product	7.0	27.0	9.4	5.8
Manufactures	6.0	18.0	11.7	9.4
Capital goods	3.0	14.7	11.1	9.6
Engineers and scientists	2.4	17.4	12.8	3.4
Spending on R&D	1.8	30.1	10.2	6.7
Scientific authors	1.3	42.6	4.9	5.4

Source: ECLAC, based on information from UNIDO, Unesco, National Science Foundation, and the Current Bibliographic Directory.

> ing, "real" commodities, efficient industry and capitalist agriculture; there that long trade routes start and finish, that we find precious metals, solid currencies and credit instruments. All advanced modern economic activity focuses on this nucleus.... Advanced technologies are also found there, as a rule, together with the basic science that accompanies them. The "freedoms" reside there, though they are neither wholly myth nor wholly real.

Underdeveloped Development

Is anything new being said by emphasizing the peripheral and subordinate position of the region, especially while beginning to consider the increasingly elaborate parameters of the modern world? Not necessarily; but something that must be rediscovered each time is new contexts to identify the nature of this subordination, the changes it undergoes, its shifts and the new problems it poses, above all in the area of formulating plans, preparing strategy, and adopting policies.

The Latin American situation with regard to scientific and technical capability and the weight it carries in the world is radically different today from what it was in 1960, and even from what it was at the beginning of the 1970s. The key problems have changed; today's needs are different, just as the strategy and policy challenges have changed. The debate on this matter that went on in the 1960s (see Chapter 1), for example, has little to do with the current situation. Then, the problems were those of a region that was virtually empty from the standpoint of S&T development, with only a few exceptions. It was a world where such things were nonexistent, rather than simply scarce. Qualified human resources, postsecondary students, graduate program structures, and a minimum institutional framework for R&D activities were all absent. Governments were unconcerned with this field as can be seen from the absence of agencies and instruments to promote, coordinate, and plan S&T.

This picture has changed considerably over the last two decades. Today qualified personnel are relatively abundant, although an appreciable number have been migrating (escaping) to the more attractive countries of the North. There is unemployment among professionals and scientists and a number of them have been unable to find jobs that are appropriate to their qualifications. Considerable numbers of students are enrolled in graduate courses. There are thousands of graduate courses throughout the region and a multitude of institutions of various types engaged in R&D; in most countries, the government plays a crucial role in financing and promoting them. Innumerable large and small communities of specialized scientists have arisen and are in more or less constant contact with their reference communities at the international level.

Considering only the brief period between 1970 and 1980, it is apparent how quickly and dramatically S&T activities in Latin America changed (Sagasti et al. 1984). The number of engineers and scientists in the region working on R&D rose as a proportion of the world total from 1.5 to 2.4%, while spending in this field increased over the same period from 0.8 to 1.8% of the world total. This means that the number of scientists and engineers rose from 38 000 to 91 000, increasing the ratio per million people from 136 to 253. Spending on R&D rose from 498 million to 3.8 billion USD, increasing from 0.30% of the Latin American GNP to 0.49% (see Table 67).

In the area of education, this period of expansion meant multiplication and diversification of institutions of higher education, increased university enrolment, gradual professionalization of teaching staff, expansion of programs, more places in graduate courses, and an increase in the number of university graduates. This significant effort must be examined within the context of world trends in the field of S&T.

The average number of scientists and engineers per million people for the whole world was five times that of Latin America in 1970, but only 3.3 times higher in 1980; the region improved its position within the category of developing countries, rising from 1.68 times the average for this category in 1970 to 2,02 times in 1980. In 1970, world R&D spending was 125 times that of Latin America; in 1980, it was 55 times higher. Compared to developed countries, however, Latin American spending has decreased: in 1970, developed countries spent about 2.9 times more than Latin America and about 3.3 times more in 1980. With respect to the number of scientific authors with internationally listed articles, Latin American barely improved in the world context. Toward the end of the 1960s, Latin America's share of the world total was 0.77%; by 1980, it had risen to 1.27% (Sagasti et al. 1983: 60–65).

In short, over the last three decades Latin America has made a significant effort to develop its scientific and technical capability — an effort that was intensified from 1970 to 1980. The result has been an increase in the ratio of scientists and engineers to the total population, increased spending on R&D (both in absolute terms and in terms of the regional GNP), a relative improvement in the position of the region compared to other developing countries, and a slight upward movement of relevant indicators within the world framework.

This expansion has led to a situation that is completely different from that of the 1960s. The challenge is no longer to institute a science and technology system, but rather to plan growth strategies for it. There are sufficient institutional bases, better defined actors with more finely tuned interests, and a variety of options. Questions of quality, yield, efficiency, and evaluation are being raised repeatedly, and the complexity of the systems presents new challenges with regard to the articulation and interaction of components, institutions, and individuals.

The Heterogeneity of Science and Technology

It is clear that heterogeneity is the most striking feature of the new R&D community. At least four interconnected "planes of heterogeneity" can be distinguished that are important for the future development of S&T activities in the region and for the formulation and application of human resource policies in this field:

- Heterogeneity in the intraregional distribution of capability and resources;
- Heterogeneity of national institutions;
- Heterogeneity of disciplinary areas and types of research; and
- Heterogeneity in the way in which scientific activities are organized.

To identify the new problems in contemporary S&T in Latin

America, to arrive at possible development alternatives, and to prepare an agenda of necessary policies (including policy for training of human resources for R&D), it is essential to define the nature and dimensions of these different kinds of heterogeneity. This task goes beyond the limited scope of this book; only a few reference points will be mentioned here.

Intraregional differences

Latin American development in recent decades has led to increasing differentiation among countries, to the point where any talk about Latin America as a whole has become suspect and often conceals more than it reveals about regional realities. The region has grown on the basis of changing relations between its component countries, and that heterogeneity is its most characteristic feature. Per capita GDP grew faster between 1950 and 1980 in some countries than in others (Table 87).

This has led to significant changes in the regional distribution of GDP. In 1950, Mexico and Brazil together accouted for 41.9% of the regional GDP and the Southern Cone countries (Argentina, Chile, and Uruguay) controlled 31.7%; by 1980 the Mexico's and Brazil's share had increased to 60.3% while the Southern Cone's had decreased to 15.9%. The change was even more dramatic with regard to manufacturing. Taking the same two groups of countries, in 1950 their shares of GDP from manufacturing were 43.2 and 37.2%, respectively; in 1980, they were 64.9 and 16.9%.

Although the Latin American picture at the beginning of the 1980s bears scant resemblance to that of the 1950s (as can be seen

Table 87. Growth of per capita GDP from 1950 to 1980 in Latin America.

Country	Growth index
Brazil	Over 300
Mexico	260–300
Costa Rica, Dominican Republic, Ecuador, Panama	230–260
Colombia	201
Paraguay	199
Venezuela	185
Guatemala	175
Peru	169
Argentina, Chile, Uruguay	150–160
El Salvador	151
Bolivia, Haiti, Honduras	Below 150

on such different planes as urbanization, degree of industrialization, job creation in modern urban markets, reduction in the agricultural EAP, etc. — Martner 1986: 18–46), the nature, pace, and impact of the changes have varied greatly in the different countries of the region, deepening intraregional differences and making national situations still more heterogeneous.

In the field of scientific and technological development, Latin American countries have become differentiated as well, reflecting a combination of factors, such as the dynamism of their respective economies, their initial degree of modernization and the pace of modernization over the period, educational policies and investments, strategies for institutional development, spending on R&D, and the type and degree of interaction with S&T on an international level.

To classify and compare the countries, Sagasti and others have combined criteria of size and geography, distinguishing between the "large countries" (Argentina, Brazil, and Mexico), the "Andes countries" (Bolivia, Chile, Colombia, Ecuador, Peru, and Venezuela), the "other South American countries" (Uruguay and Paraguay) and the "Central American" and "Caribbean countries" (Sagasti et al. 1984). Other typologies could probably be constructed, based on quantitative or qualitative criteria that would be more specific to S&T activities: number of scientists and engineers per million people, number of articles and scientific authors listed internationally, "density" of research areas (number of researchers, projects, and institutions working in an area and their productivity, combined with the number of graduate programs in each of them), spending on S&T, and distribution of projects by sector of activity. Regardless of how the countries are classified, it seems clear that the national situations are quite different and that it is impossible to speak of the region as a whole.

There are obvious differences in the "size" of the systems and their complexity, for example, in Brazil, Mexico, Argentina, Venezuela, Cuba, and Chile on one hand (with the first three forming a separate subcategory), and in Costa Rica, Ecuador, Guatemala, and the Dominican Republic on the other with intermediate situations observable in Colombia and Peru. However, to analyze these differences more precisely, the other "planes of heterogeneity" must be included.

Institutional differences at the national level

R&D activities are not found exclusively in a single type of institution. On the contrary, in each country, and especially in the group that has developed more complex systems, a clear differentiation has occurred between sectors of activity, i.e., the university, the public corporation, the private production sector, and private research and development institutions. Even within each sector, there is an intense dynamic process of internal differentiation, with the result that, in each country, just a few universities conduct most of the research activities, and among public R&D enterprises, some work exclusively on R&D while others are production and service enterprises with departments or sections engaged in R&D. The differentiation goes even further when including international or regional institutions that carry out R&D, R&D departments in the subsidiaries of multinational companies, and joint ventures that combine the resources and efforts of national agencies and international companies.

The traditional assumption that S&T activities in Latin America are highly concentrated in the universities provides only a partial and misleading picture. For example, considering distribution of total spending on education in about 1983, by sector (see Table 71), of the countries under study, only Mexico and Costa Rica spent as much as a half on higher education. Spending on higher education was 20% or less in Argentina, Brazil, Colombia, Cuba, and Guatemala. In most of these countries in about 1980, many scientists and engineers working on R&D were in the higher education sector, but in no country were all of them to be found there, as is generally believed. In Argentina, Brazil, Cuba, Ecuador, Mexico, and Peru, the higher education sector accounted for up to half; in Colombia, Costa Rica, Chile, and Venezuela, the figure ranges from 50 to 75% of total personnel working on R&D. It is also possible that there is a trend toward a decline in the number of researchers working exclusively in the universities.

In short, superimposed on intraregional differences, there is increasing internal differentiation in national S&T systems, which are evolving in the direction of greater specialization, diversification, and heterogeneity.

Diversity in fields and types of research

The phenomenon discused in the preceding section is partly related to the dynamics of the scientific disciplines themselves, which are being drawn irresistibly toward specialization and subspecialization; it is also linked to growing distinctions between the different types of research, however they are named.

A global approach to R&D activities in the region overlooks these more subtle, but intense, forms of differentiation that occur at the operational heart of scientific and technological activities. The fields of natural or exact sciences, for example, are very different from social sciences. Their ideals of explanation are distinct, their paradigmatic nature is different, and they use different kinds of instruments to arrive at their conclusions and validate them. As most studies of science show, the different disciplines, even those in the same large group, possess different cognitive and technical structures, which give rise to different research practices and to different subcultures, each with its own traditions, heroes, specialized literature, academic societies, and circle of contacts. It would make little sense to use the same policy for the development of biology, mathematics, sociology, and linguistics. How can a common yardstick be used to measure the output of all of them and the productivity of the researchers involved, without introducing major distortions?

The situation becomes even more complex when going beyond a discussion of scientific research alone, and talking about R&D. This area encompasses research procedures ranging from the most abstract analysis in some field of theory to the most concrete trial and error method, where the motivation may be a desire for pure knowledge or the wish to obtain a commercial advantage. Simply referring to a dichotomy between pure and applied research or between science and technology is undoubtedly a convenient device, but it leads nowhere. It would be better to follow Ziman (1986: chapter 12), who suggests that modern R&D activities form a continuous spectrum in which, as a minimum, the following types of research can be distinguished:

- Basic research, aimed at knowledge within a framework that is regulated by a research paradigm or program, with no utilitarian considerations of any kind;
- Strategic research, still aimed at knowledge, but taking current or planned technologies into account. Even though this kind of research is not aimed directly at solving practical problems, it should eventually accomplish this;
- Targeted research, which includes activities that come much closer to reality or current problems. It has a clearly utilitarian motive and is expected to produce usable results within a foreseeable time;
- Technological development, covering the whole gamut of technical improvement, component design and testing, prototype testing, etc., that are necessary for a new product or process to be produced and used. Immediate utility is the prime concern.

Engineers and technicians engage in this activity, and so, to an increasing extent, do scientists from a variety of disciplines.

To regard these research activities as forming part of a continuous spectrum has the advantage of blurring the distinctions between one activity and another. It permits an understanding of the rise of R&D institutions and agencies that may cover the entire range of activities or handle a special combination of them to fulfill their mandate. It also leads to the belief that, in the current stage of development of S&T systems in Latin America, or at least in the most advanced countries, all these kinds of research are probably present. Each of them requires a specific type of personnel and has different operating and funding requirements. Even in the social sciences, a model similar to the "continuous spectrum of relevance" has emerged and ranges from basic research (the principles governing the reproduction of student populations, for example) through strategic research (the effect of different teaching methods on education) and targeted research (detailed study of the impact of the availability of textbooks on academic performance in a given target group), to action research, which blends into development activity (such as organizing community groups or adult education as a tool for tackling situations of social domination or exclusion).

Current knowledge about S&T in Latin America does not give a precise picture of the specific ways in which different types of research operate, or even of the various types of research that are going on in different disciplines and fields of specialization. Little is known about "targeted research" and "technological development," even though, in some cases, these types of research may be the most relevant in tackling the countries' development problems — providing basic human necessities, improving the quality of life, increasing the competitiveness of domestic industries, or solving social and economic problems. This lack of information is partly due to the dominance and prestige of the "academic science" model, whose ethos and ideology are defined by its anti-utilitarianism, its independence from external contingencies, its theoretical vocation, and its refusal to be evaluated in terms of concrete social product or economic costs and benefits.

Coexistence of various kinds of scientific enterprise

There is a move, especially in the developed countries, away from "academic science" (which is the basis for the construction of the perceptual categories and concepts for representing and measuring development in the sciences) toward a model of "industrial" or "collective science" (Ravetz 1973; Ziman 1986; for Latin America, Vessuri and Díaz 1986). The essential features of this phenomenon are the predominance of "big" science, characterized by industrial production and capital-intensiveness; a blurring or weakening of the boundary between science and industry; and a related trend toward the creation of scientific collectives that are closer to a "society" than a "community."

In industrialized countries, there is a growing interpenetration of the "academic" and "industrial" types of science (to which some add a "governmental" mode). A new "collectivized" form of organizing and administering research activities blends the characteristics of the previous types (Ziman 1986). The argument for the complete independence of science and its purely academic and individualistic ethos (knowledge for its own sake) is gradually losing ground, and utilitarian motives are gaining a higher profile in scientific discussions and activities. There is a growing demand for a science that offers immediate results, be they social, economic, or military. R&D activities are gradually coming under collective control. As Vessuri and Díaz (1986: 3) point out:

> [This new type of science] implies a social organization of scientific institutions that is different from the classical patterns, a different psychosocial attitude on the part of scientists towards their professional activities, their disciplines and their colleagues, and a changed ethical position.

Science now takes place within large organizations, with a preponderance of costly apparatus and tools that are used by research teams composed of large numbers of professionals. In many cases, projects are undertaken as a result of bureaucratic decisions and are carried out within institutionally imposed limits. There is no transparency in communicating results or progress, and the individualism of the scientific–academic ethos is in general retreat. An element of "management" is being introduced into collectivized scientific activities, which must justify themselves in terms of a utilitarian evaluation of their results, whose "relevance" is judged in terms of exogenous patterns. Simultaneously, the strong pressure exerted by government and industrial financing of R&D activities, even when they are carried out within universities, imposes a new logic on the operation of this segment, which, until recently, claimed complete independence from outside influence. The scientific field is moving increasingly closer to the central power structures in society (both capitalist and socialist) and is becoming an organ of the State, the military–industrial complex, or the existing socially organized expression of the class that exercises leadership.

This multifaceted process of change in the organization and direction of science is also occurring in specific forms in Latin

America. Science is becoming increasingly collectivized, although this is not necessarily the result of its incorporation into the world of industrial production. It may rather be attributed to external demands, such as the requirement that science fulfill a social function, assume a national responsibility, and serve development objectives, or the need to justify growing public spending on R&D activities. Internal factors also play a role, such as the growth dynamics of the large scientific institutions themselves, with their costly equipment, their collective forms of work, and their inevitable management approach to research activities.

In short, science in Latin America is becoming heterogeneous on this plane as well, inasmuch as there is no longer a single "academic" model for the production of knowledge, but rather a coexistence of scientific enterprises guided by different values, subject to different restrictions, and posing various policy requirements that are not necessarily compatible or harmonious.

National Politics and S&T Policies

Considering the different planes of heterogeneity in scientific and technological development could lead to erroneous conclusions, such as the idea that, in view of the processes that are at work, the goal of all scientific policy should be maximum homogeneity and uniformity of scientific activity and its organization, or that the goal should be maximum possible relevance (primacy of utilitarian motives and criteria), leading to the collectivization of science and its growing industrialization and abandoning the precariously institutionalized traditions of academic science.

On the contrary, the purpose of this analysis of the heterogeneity of science and technology in Latin America is precisely to show that this kind of simplification no longer works. The state of S&T development in the region differs between countries, sectors of activity, disciplines and specializations, and different types of scientific enterprises, which are collectivized according to the prevailing type of control or industrialized according to the preferred production mode and the degree to which R&D activities are incorporated into the economic system.

There is no linear development model for science that, for example, leads inexorably and by stages from a core of scientists in a traditional community to a modern community and then to a collectively controlled organization, just as there is no development model that leads from pure science to science applied to industrial activities. Nor is it conceivable that every country in the region should move from a situation in which R&D is institutionalized in a few university centres to a system combining academic and government science, and then expanding into industrial science. It cannot be assumed that complex, heterogeneous systems in all fields will develop in all places, or that most of the disciplines or all the types of research on the "spectrum of relevance" will be present, with an ideal number of scientists and engineers per million inhabitants, or in relation to the GDP, etc.

It is more likely that each country will tailor its S&T development policies to its own style of development and overall goals, within the economic and political constraints that define the particular operational framework, so that policies can be formulated coherently and applied with relative success. In fact, what could be called the nonlinearity effect of S&T development and its specific degrees and types of heterogeneity is closely related to the same operational constraints and, therefore, to the economic and political cycles that generate, maintain, or modify them.

An external approach to S&T policies and their impact must be taken to analyze this point, while not disregarding the substantial role played in the development of R&D activities by internal factors peculiar to each discipline. It is clear, for example, that in any discipline, advances in theory, in formulation of research paradigms or programs, and in evolution of research methods and tools are decisive influences. From this internal viewpoint, it is possible to discuss the relative importance of the increasing internationalization of science, the predominance of certain advanced forms of international division of labour in the field of science, and the dissemination of conceptual and organizational models of scientific work from the centre to the periphery. However, this type of issue is outside the scope of this book.

From the external viewpoint, the concern is to understand how political and economic cycles affect the development of S&T activities, particularly with regard to the formulation and application of policies aimed at ensuring such development.

It is not necessarily the political regime in a country that determines the specific policies that will be followed in the R&D area. What should be examined is the relation between the political and corporate actors (businessmen, associations, the armed forces), the kinds of explicit or tacit alliances they make among themselves, the room the scientists have in which to maneuver, the direct or indirect influence of their actions on R&D funding agencies, the degree of institutionalization of the national scientific community, the role played by bureaucracies in determining policies, etc. (Moura Castro 1985: 23–26). It is clear that politics determine the

S&T policies adopted in a given country. To underrate the political conditioning of the policies applied to S&T development can often result in a failure to understand why, for example, the results of a planned action are different from those expected and are sometimes even in conflict with them. Policies always end up producing their results interactively, i.e., through a process that combines the paths followed by different actors, each of whom pursues his own objectives and acts with partial information within a frame of uncertainty determined by factors that none of them can totally control.

In this situation, it is difficult to establish definitive goals and achieve them efficiently. There is a tendency to think that basic economic conditions alone can delimit alternatives for action and ensure that policies are potentially realizable. In other words, it is generally thought that the economy, with its less-yielding trends, structural inertia, and apparently rigid delimitation of scenarios on the basis of use of available resources, could indicate what policies are possible and necessary for scientific and technological development. This subject must be dealt with by referring directly to the crisis affecting the region and its possible consequences for the development of S&T in all the Latin American countries.

The Economy and S&T Policies

> Since 1981, Latin America has been experiencing an economic crisis which is the most acute, the longest, the most multi-faceted and the most generalized it has known since the Great Depression of the thirties. (ECLAC 1985: vol. II, p. 1; also, see Sunkel, unpublished)[9]

From 1981 to 1985, per capita output dropped by 1.8% a year, while consumer prices rose by an annual average of 157% in the region. This stagflation was accompanied by high unemployment rates, deterioration in the terms of trade, and, as a consequence of high regional indebtedness, a net transfer of financial resources amounting to 26 billion USD a year from 1982 to 1986 — that is, seven times annual regional spending on S&T.

The impact of the crisis on education and R&D activities has been less clear (Unesco Statistical Yearbook, 1987; Tedesco, unpublished).[10] Taking 1980 as the base year and comparing it with the

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[9] Sunkel, O. La crisis económica de América Latina: situación actual, antecedentes y perspectivas. (preliminary version, 1987)

[10] Tedesco, J.C. El impacto de la crisis en el sector educativo: situación actual y perspectivas futuras. (discussion paper, 1987)

most recent year available (in most cases 1985), it is apparent that graduate enrolment has increased. Of 18 Latin American countries, it rose in 17 and fell in only one, Nicaragua. It rose significantly in Argentina, Chile, Colombia, Cuba, El Salvador, Honduras, Mexico, Panama, Paraguay, Peru, Uruguay, and Venezuela. In the remaining countries, graduate enrolment increased slightly or remained constant. Except in Argentina, Chile, Uruguay, and El Salvador, growth in enrolment was much higher in the 5-year period from 1975 to 1980 than in the following period. University enrolment, or the equivalent, increased from 1980 to 1985 in all countries, except, once again, Nicaragua. It rose significantly in Argentina, Colombia, Cuba, El Salvador, Honduras, Mexico, Panama, Paraguay, Uruguay, and Venezuela. Considering only the countries covered by this study, postsecondary enrolment in the crisis years remained steady or grew in the 11 for which information is available. It increased more than 20% in Argentina, Chile, Cuba, Mexico, Peru, and Venezuela.

There was not, therefore, the massive widespread drop in postsecondary enrolment that some had predicted as a result of the crisis, although the tendency in most countries was for the pace of growth to slow and, in others, to stagnate. This checked the rapid growth in higher education in the region over the last decade, a phenomenon that was to be expected, even if the crisis had not occurred.

Moreover, university (or equivalent) enrolment did not fall over the period. The trend was similar to that of overall postsecondary enrolment although with wider fluctuations. This indicates that, at least during the early years of the crisis, there was no sign on a massive scale of universities significantly reducing classroom access and so forcing demand to shift to nonuniversity institutions in the higher education system.

Information on changes in university teaching staff fails to distinguish between full-time and part-time professors and data on trends in academic salaries in the period from 1980 to 1985 are inadequate. In the 12 Latin American countries for which information is available, the number of postsecondary teachers has risen over the period, except in Guatemala where it dropped more than 25%. Focusing on universities (or equivalent), the number of professors rose in 12 and dropped in two of the 14 countries for which information is available. Significant increases occurred in Argentina, Colombia, Cuba, El Salvador, Honduras, Mexico, Panama, and Peru; these are also the countries in which university enrolment continued to show the greatest expansion over the period (with variations that do not alter the overall picture).

To isolate the direct effect that the crisis may have had on postsecondary enrolment would require a separate analysis, as the subject is extremely complex and a more refined analysis would require more data than is currently available. It is clear that, in the area of admission to higher education, the impact has not been drastic, uniform, or "catastrophic," as some had predicted or feared. On the contrary, enrolment did not drop and its growth rate decreased only slightly, probably under the influence of other factors. After 1985, as the crisis became "prolonged" and part of everyday reality, it may have begun to exercise a more clearly restraining influence on postsecondary enrolment (particularly in universities), causing it to fluctuate a little more from year to year or shifting it more markedly in the direction of stagnation or even a drop in the absolute number of students.

It can be argued that economic cycles do not act immediately and directly on the supply of, or the demand for, higher education, but rather through mediating levels and agents that are able to neutralize, or even reverse, the effects that would be expected from a purely determinist or economic viewpoint. As suggested by Tedesco (unpublished, p. 16, see footnote 10), the middle class is probably one of the foremost of these mediating agents; its losses in certain areas (income, employment, subsidies) are compensated by maintenance or even gains elsewhere, for example, in education, which tends to be guaranteed or facilitated by the State.

To explore a nondeterministic hypothesis such as this, public spending on education must be examined more closely, particularly spending on postsecondary instruction. Is it not unlikely that, with the crisis and the consequent drop in government revenues, the State would also have to reduce its spending, particularly on education and, more markedly, on the upper level of the education system, specifically the S&T system?

Available information suggests a more subtle and less clear situation. Out of 18 Latin American countries for which data exist, spending on education as a percentage of the GNP dropped in 10 between 1980 and 1985, while it increased in the other 8. It dropped dramatically in Bolivia, significantly in Costa Rica, Cuba, Ecuador, and Mexico, and moderately in Brazil. It increased significantly in Colombia, Honduras, Nicaragua, and Venezuela and moderately in Argentina. In 1985, Bolivia, Brazil, Colombia, Guatemala, Mexico, Paraguay, Peru, and Uruguay spent less than 3% of their GNP on public education. Spending on education, compared to total government spending, increased in six countries between 1980 and 1985 (including Argentina, Chile, Panama, and Venezuela), and dropped in another six (markedly in Ecuador).

Spending on postsecondary education as a proportion of the total budget for education rose in 11 out of 15 countries in the region; it fell in the other four. It dropped drastically in Bolivia, strongly in Chile, moderately in Argentina, and only slightly in the Dominican Republic. It grew explosively in Nicaragua, Costa Rica, Panama, and Cuba, but also increased in Brazil, El Salvador, Honduras, Mexico, Uruguay, and Venezuela.

The crisis has affected spending on education, and higher education in particular, in different ways in the various countries of Latin America. It is worth noting that, in some countries where postsecondary enrolment continued to grow after 1980, the resources spent on this level of the education system dropped. There may be more than one explanation for this phenomenon. Some of the increased enrolment may have occurred in the private sector of higher education, where fees are charged; some may be due to an increase in the number of students enrolling in "cheap majors"; some budget cuts may have taken the form of a decrease in academic salaries or a reduction in medium-term and long-term investments in the system, without immediately affecting enrolment. In some countries, higher education may have obtained a larger share of declining total spending on education measured as a percentage of the GNP. A detailed study of of the evolution of the economy in each country after 1980 would be necessary to pinpoint growth or drops in the GNP, year-by-year dynamics of public spending, use of the governments' noneducation budget to allocate resources to the education sector, and changes in the public and private subsectors of higher education.

Spending on R&D since 1980 in the 12 countries covered by this study is shown in Table 88. Notwithstanding the shortcomings and dissimilarities in the available information base, it can be seen that, in general, spending on S&T in the individual countries tended to fluctuate, although the net effect is not as spectacular as might be expected because of the depth of the crisis in the region since 1981. Total spending in Brazil dropped, particularly federal government spending, which has only begun to recover since 1986. There appears to be a decrease in spending in Chile, but it is difficult to measure because of the poor quality of the data. In Mexico, on the other hand, there was no drop in total spending on R&D in current dollars or as a percentage of the GNP, but the federal budget fell between 1981 and 1983 and recovered afterward. In Peru, total spending fell between 1981 and 1983; in the Dominican Republic, a decrease took place over a longer period. There was no decline in spending on R&D in Cuba. In Venezuela the data are ambiguous because spending dropped between 1980 and 1981 when expressed in dollars, but appears to increase until 1983 when

Table 88. Total spending on R&D in current dollars and as a percentage of GNP.

	USD, millions	% of GNP
Argentina		
1980	683.70[a]	0.47 (% of GDP)
Brazil[b]		
1978	1 150.03	0.61
1982	1 771.90[c]	
1984	1 231.24	0.58 (% of GDP)
Chile		
1979	65.65	0.33
1980	121.30[c]	
1982	98.45	0.41 (% of GDP)
1984	83.00[d]	
Colombia		
1978	20.60	0.11
1982	42.97	0.15
Costa Rica		
1981	5.19	0.17
Cuba		
1978	112.27	n/a
1981	134.47[c]	
1983	196.39	0.72[e]
Dominican Republic		
1972	1.57	0.08
1981	3.80	0.31 (% of GDP)
1986	2.54[d]	
Ecuador		
1979	11.63[f]	
Guatemala		
1978	35.50	0.22

(continued)

Table 88. Concluded.

	USD million	% of GNP
Mexico[g]		
1980	371.74	0.24
1982	442.71	0.27
Peru		
1976	48.11	0.36
1980	64.23[h]	0.30 (% of GDP)
1981	69.87[d]	
1983	51.42[d]	
Venezuela[i]		
1977	201.62	0.56
1980	252.58	0.43
1981	253.80[c]	

Source: Sagasti et al. (1984); Sagasti and Cook (1985).
[a] The figure from CASTALAC II (Unesco 1985) is 808.52.
[b] The base study gives the following figures for the federal government's total budget for S&T (USD, millions): 1982, 604.4; 1983, 610.7; 1984, 374.1; 1985, 514.5; 1986, 1,262.9 (budgeted).
[c] Figure taken from CASTALAC II (Unesco 1985).
[d] Figure taken from the base study.
[e] Total social product.
[f] The figure from CASTALAC II (Unesco 1985) is 30.14.
[g] The base study shows that federal spending on S&T increased from 52 million to 316 million USD between 1970 and 1980, for an average annual growth rate of 20%. Between 1981 and 1983 federal spending on S&T dropped at an average rate of 30% a year, to about 230 million USD in 1983, but increased to about 350 million USD in 1984 and 1985.
[h] The figure from CASTALAC II (Unesco 1985) is 119.69 and includes spending on S&T services.
[i] The base study reports spending on S&T (in millions of Venezuelan bolivars) and as % GNP as follows: 1978, 601.60 (0.353); 1979, 633.99 (0.305); 1980, 851.28 (0.335); 1981, 1004.60 (0.352); 1982, 1151.82 (0.395); 1983, 1196.50 (0.412); 1984, 1361.64 (0.391); 1985, 1411.72.

expressed in domestic currency and as a percentage of the GNP, with a dip in the following year.

These observations appear to confirm the idea that, although economic cycles constitute an operational framework for S&T policies, they do not automatically determine the behaviour of public spending, much less spending by the group of government, public, and private agents involved in R&D activities. In the broader field of training human resources for research, the effects of the economic crisis appear to operate in a contradictory manner, generating pressure for a drop in government spending on education that did not necessarily lead to a drop of the same magnitude in the money received by universities and other institutions of higher education. In the long run, however, it would appear that a prolonged economic crisis will, in the end, have an impact on higher education and the training of researchers, because study opportunities are fewer, research activities are cut back or reduced, professors' salaries decline and force them to take on more work commitments outside the university or leave the country, and opportunities and means to take graduate courses in the country or abroad are reduced.

General economic conditions, like general political conditions, create an operatioal framework and a set of possibilities within which the actors, the institutions, and the policies function. However, such conditions can never completely determine the results of their operations, and the latter cannot develop consistently over the long term in a direction contrary to, or outside of, the reality defined by the economy.

Issues in Shaping S&T Policies

The preceding discussion sets the backdrop for considering policies for training human resources for S&T research in the region. There are two levels on which S&T policies can be discussed in terms of the planes of differentiation and heterogeneity referred to earlier: a macro level, which is highly aggregated (regional and national levels), and a micro level, on which policies are eventually implemented and produce their impact.

The macro level is the domain of "major policy" and, therefore, there is a considerable risk of overgeneralizing or oversimplifying. The greatest risk in this case is to assume that situations are relatively homogeneous. Because of the regional approach taken in this book, only a few generalizations are possible, generalizations that may be useful as a framework for discussing the formulation, design, and implementation of research training policies.

The first is related to the role of the government in developing S&T in the region. Based on empirical evidence, R&D is maintained and developed through government support. Even in the most advanced capitalist countries, the government plays a decisive role. In the OECD countries, about half of the resources spent on R&D come from the public sector. The proportion is higher in less developed countries, such as Greece and Portugal, and lower in such countries as Switzerland and Japan, where private funding is dominant (ECLAC/UNIDO 1985: 13). Therefore, to affirm that government support for sciences is particularly important in developing countries whose private industries spend a minimal amount on R&D cannot come as a surprise to anyone. In these countries, only the government can make the investments required by collectivized science, support long-term scientific programs whose results are a gamble, and stand up to the challenge of supporting and upgrading basic research, strategic research, and research for national development goals, particularly improvements in living conditions for the poorest sectors. As Ziman (1986: 192) concludes:

> Although the relative balance between public and private financing for research and development may swing to one side or the other depending on the political and economic theories of the party in power, it appears that there is no way of returning to a world in which science does not depend on public funds for its existence.

Second, regardless of the evolution of the university sector in the different countries in the region, no matter what its importance in carrying out R&D projects, and what amount of funding it may receive, it will have to play a key role in developing S&T. The problems of Latin American universities are also problems that affect R&D activities. Their cumbersome institutional structures, their explosive growth, their incomplete professionalization, their bureaucratic procedures, their tendency to be fragmented, their refusal to allow their performance to be publicly evaluated, their frequently old-fashioned forms of government, their chronic lack of resources for equipping themselves with the necessary technical and scientific infrastructure, their bias toward producing academics are all problems that must be carefully considered when S&T development policies are being planned. The universities cannot realistically be left aside when discussing the future of R&D activities in the region; but also, their problems, limitations, and deficiencies cannot be disregarded

Finally, available information clearly indicates that the S&T system could not function in any Latin American country under a "single central command"; its various segments (academic, quasi-academic, governmental, and industrial) operate with relative independence, under different restrictions and according to different logics and rhythms. This observation acquires even greater importance when considering the levels of heterogeneity in S&T development in these countries. On the other hand, to acknowledge the radical differences among S&T systems in the region does not mean that this basic finding cannot be the starting point in looking for opportunities for combined programing, coordination, and implementation that may be broadened and used to advantage. Specifically, if governments are called upon to assume responsibility for managing the S&T system — through financing, control, sponsorship, the creation of incentives — then rationalizing this intervention and making it efficient will become an issue of particular urgency.

Training for Research and Development: an Agenda

A discussion on the subject of training human resources for research must include the following topics:

Developing endogenous training capacity

Several countries in the region have made significant progress in building up endogenous institutional capacity for training scientists and engineers for R&D. As our analysis shows (see Chapter 4), the structure of graduate programs that has development over the last two and a half decades partly fulfills this function, creating an unprecedented situation in the region. This structure is no longer dependent on foreign countries for training its high-level scientific and technical teams, although a many graduate programs are oriented toward training university teachers or toward other objectives and are not in the business of training for R&D.

It is important to discuss the organization, operation, and degree of development of doctoral programs in the region. These programs are expected to play a key role in training human resources for S&T. To do so, they must be firmly established in institutions where research is carried on continuously and standards are high; the professors must be researchers; the students must study full-time in their programs; and the programs must be linked to the appropriate international scientific community. These kinds of programs must, moreover, be subject to regular evaluation as a guarantee of their academic soundness and performance, and as a means of establishing realistic criteria by which to judge similar programs.

Complementary efforts at regional and subregional levels

The current situation, unlike that of the 60s, makes it possible and realistic to think about ways to complement, at the regional and subregional levels, the efforts and initiatives directed at training human resources for R&D. The pronounced intraregional differences in the field of S&T and in the institutionalization of doctoral programs, make it possible to conceive of schemes for cross-fertilization: countries that are relatively less developed can benefit from the progress made by their neighbours in this field. Something along these lines has been happening in recent years, but the number of Latin American scholarship students who go to a second country in the region to train as researchers is small — probably due to the lack of adequate scholarship programs and to the prestige still accorded to higher academic degrees from leading universities in northern countries.

What seems to be important in this context is support for regional initiatives aimed at developing graduate programs, such as that of UNDP for several countries in the field of biology, and the role that can be played by certain regional organizations that offer doctoral programs on their own or in combination with well-established national universities. There have been other initiatives, such as PISPAL, which for almost 10 years coordinated support from international and foreign agencies of different types with the efforts of Latin American academic institutions to promote the development of social research on population. Through it, a significant core of Latin American researchers was trained on-the-job rather than through formal courses. There are also some interesting complementary ventures that have been organized among countries in the region to facilitate the exchange of researchers. Other initiatives in this field include the recently created "Researchers Exchange Network for Latin American and Caribbean Development" (RIDALC), which is supported by UNDP in six or seven countries through their respective science and technology research councils.

Different kinds of training for researchers

Academic training for a doctorate is not the only possibility for research training. Although a doctorate is essential in certain disciplines, it can sometimes be replaced or supplemented by nonconventional forms of training, especially in disciplines that do not require strict socialization in a paradigm governing scientific activity in a specialized field.

The emerging academic professionalism in the region requires higher academic degrees as a condition of employment in university positions and in research. However, it is possible to conceive of additional types of training for researchers that make use of "tutored participation" in research activities, such as has been seen in social science disciplines in some Latin American countries over the last decade. It has also been suggested that an important part of the real training received by scientists or engineers working on technological development takes place within the firm. Therefore, the question of the actual links between universities and the production sector must be raised, as must the way in which they can interact to provide innovative learning experiences.

In general, it seems necessary to take advantage of all the varied forms or means of training, which should be promoted and systematically evaluated, although it is acknowledged that the most common type of training for researchers, in all disciplines has come to be defined strictly in academic terms and has, consequently, been monopolized by programs leading to higher academic degrees.

Training researchers abroad

In Latin America, training of researchers abroad has generally been viewed with some suspicion, notwithstanding the fact that a significant number of the scientific elite in each country have studied abroad and hold degrees from universities of recognized international prestige. In reality, that attitude appears to be increasingly outdated, not only because of the growing internationalism of science, but also because the North exercises almost complete control over scientific standards, theories, and schools, and the most highly valued degrees on the S&T market. The old idea that training abroad would inevitably go hand-in-hand with some degree of alienation, or at least make young returning researchers incapable of dealing with the problems of their own countries, should be reviewed and tested through empirical studies.

In fact, the desire, expressed in many parts of the region, to develop an endogenous capability to train researchers has less to do with an alleged nationalism than with economic considerations related to increasing the number of scientists and engineers who must be trained. The effective dissemination of standards and theories can also now be achieved within Latin America, at least up to a certain point and without serious time lags. Maintaining open channels for training scientists abroad seems likely to continue as a policy in all countries in the region insofar as it is economically possible, and demand for this type of training will likely continue. The problem now is whether the supply of trained scientists will decrease as a result of prohibitive tuition fees for foreign students in northern countries and reduced grants from nonnational sources.

Along this line, the most interesting question for discussion is not whether training of researchers outside their country of origin is alienating, but how it should be channeled and made compatible with each country's criteria for scientific and technological development, either in terms of opening up new areas for research, overcoming significant national gaps, or supporting centres of excellence.

Ongoing training for researchers

Remembering that researchers' training does not end when they obtain their doctorate, conduct their first research project, or publish their first article, these observations acquire additional force. Training is an ongoing process, especially for scientific researchers. It has become almost a condition of survival, at least in the field of academic science, to have access to continuing training opportunities in the form of sabbatical leave, postdoctoral grants, visits to foreign universities, and attending academic seminars and workshops. Ongoing training for researchers is completely internationalized and is one of the characteristics of the modern scientific community. The degree of internationalism in the careers of researchers tends to be used increasingly as an indicator of the extent to which they are recognized and, therefore, of their standing in their particular discipline.

This aspect of the internationalization of training researchers, accompanied by concern over the location of their early training, must be considered. Failure to do so would seriously distort the discussion and could obscure the most recent phenomena that have come into play as a result of this process of internationalization.

Heterogeneity of scientific enterprises and demands for training

Training for researchers in R&D can no longer be thought of in terms of demand from the academic science subsector. Moving along the "spectrum of relevancy" from basic research to technological development, one increasingly finds training requirements other than those met by graduate training in universities; they requirements display differing degrees of internationalization. It is possible that the "nationalistic" argument for training is more relevant at the practical end of the spectrum, where research is goal-directed or has to do with development of technological processes and products in a context determined by conditions in each country. In this case, the quality and "relevance" of training will increasingly depend on the development of endogenous capacity to train human resources at the graduate level and, in the case of engineers, at the undergraduate level. However, this strengthening of endogenous capacity is dependent on the degree of communication between universities, the government, and industry, which has been described as tenuous and sporadic in the countries of the region. This lack of communication likely also affects the training processes, especially for senior staff who are expected to carry out goal-oriented research or technological development.

Any proposal to create "endogenous core groups to boost technology," such as has come from agencies like ECLAC, implies that production must become more creative, but, as observed at the beginning of this chapter, the absence of such creativity is one of the most striking features of the region in the context of the world economy. Growth alone, as demonstrated by Latin American development between 1950 and 1980, does not automatically ensure that creativity will also increase. As an ECLAC (1985: vol. 3, p. 72) study states:

> Creativity is a complex process in which a broad range of agents and motives play a role: large industrial plants linked to small and medium-sized plants, technology institutes, basic science institutes, the bodies that train qualified personnel at the different levels, the mass media and the ministries and central agencies that define policies and standards....

In the long run, the nature of the ties between all these bodies define the conditions for creativity in production and determine the conditions for training researchers engaged in the R&D activities that are relevant to national development. Development models that depend on impetus from the developed countries or are limited to exporting natural resources do not provide the ground for fruitful communication among the different bodies in question. In such cases, training for engineers and scientists will certainly be insufficient, even if the curriculum is "modern" and well-structured.

An additional point in this context is that of training for middle-level technicians. Although their decisive role in technological processes (and even in much basic research activity in large laboratories) has frequently been acknowledged, the same amount of effort has not been invested in designing training programs for them. The growing possibilities for training these technicians in nonuniversity institutes of higher education has undoubtedly pushed discussion of the subject into the background; the study and discussion of university matters tends to take priority over examination of these less "prestigious" fields.

Should the training of researchers be planned?

Planning for highly trained human resources took place throughout the region in the 1960s, bringing great illusions in its wake and, in general, producing few results. However, the idea has never completely disappeared, even when it was hoped that the market would automatically solve the problem by efficiently assigning resources and channeling the supply of places available in universities on the basis of trends in employment for professionals and technicians. If planning was difficult and often off target, the market, on the other hand, was continually flooded to the point where the massive increases in university enrolment took place "behind the back" of and even "against" the market.

It is difficult to calculate the long-term commercial advantage, or even social advantage, of training for researchers. Individuals are being trained for activities that are largely controlled by governments and whose results are generally unpredictable; this is especially noticeable away from the utilitarian end of the research spectrum. Given that governments provide the main support for these training functions, it seems evident that training should be guided by clearly established objectives that are accepted by the various agents in national science and technology systems and the bodies that represent society politically.

There is, of course, no question that training for researchers could be planned to the last detail. If this was attempted, "management" would not exist; rather, ther would be absolute control that would surely extinguish opportunities to develop S&T and train human resources for R&D activities. What is important, especially in countries with few or limited resources, is that direction be provided for the activities and sectors that are in the long-term national interest and that cannot be coordinated by other bodies — as in the case of training human resources for S&T.

Government intervention can take different forms, and these will generally function better if they involve the scientific community and representatives of the other bodies that must be linked together within the S&T system. The aspects that can be programmed are also varied, ranging from rigorous planning of openings for students and their assignment to various jobs to indicative programing, implemented through the provision of incentives and subsidies for creating areas of excellence in training, developing approved graduate programs, sending young researchers abroad for short periods, training researchers in the more backward fields of science or in the less-developed regions of the country, etc.

Information for policy formulation

It has been made sufficiently clear in this evaluation of the state of human resources training for S&T in Latin America that there is a general lack of information of sufficiently good quality for relatively simple and urgent planning. In some cases, there is not even the minimum information necessary to permit discussion of policy options and reduce uncertainty and the possibility of error in subsequent action.

It is, therefore, necessary to identify adequate indicators for diagnosis, policy formulation, programing, and evaluation of training for human resources for research. There is also a need for each country to produce adequate data bases covering fairly long periods of time, which can be compared at the regional level. They must include a set of conventional data as well as information collected expressly with a view to improving the quality of research training policies.

Within this set of needs, international cooperation could provide assistance in the following ways: undertaking the necessary minimum tasks; providing continuity to such activities in countries where such continuity is lacking; and contributing to the design of a regional system for obtaining and using information that will facilitate intraregional cooperation in this field. If this minimum infrastructure is not available, many other initiatives will be left up in the air or will be undertaken blindly, with a resulting waste of resources.

Training for S&T administrators

It is also essential to develop professional ability to manage R&D institutions, programs, and projects. Thus far, efforts to train management personnel have been inadequate and training programs have not always responded to the actual needs of the countries or to a clear concept of what each requires. On many occasions, the researchers themselves have had to become entrepreneurs of science or administrators of R&D activities, at an excessively high cost in time and errors. This situation is not receiving the attention it merits.

Once again, here is a demand that could be handled regionally and would benefit from international cooperation and assistance. Instead of thinking in terms of long and costly training programs, what is probably required is innovative learning experiences, through short workshops or seminars combined with periods of practical training. Instruction in specific subjects could be supplemented with participation (real or simulated) in R&D administrative activities, related to laboratories, university institutes, S&T planning agencies, and similar bodies. The establishment and development of such "experiences" make it necessary to have adequate information, as well as a variety of case studies to make it possible to ground these learning processes in analysis that will be empirical and not solely directed toward the discussion of texts.

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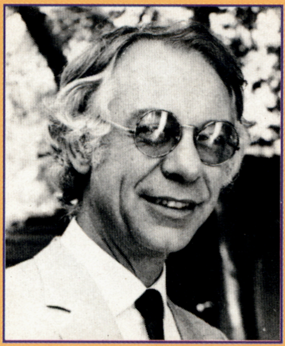

José Joaquín Brunner is a researcher with the Latin American Faculty of Social Sciences (FLACSO), which he directed from 1981 to 1988. He is also the President of the Council on Higher Education of the Chilean Ministry of Education. He has been a visiting professor at many Latin American universities and a consultant for Unesco and for international organizations concerned with scientific research. In 1988, he was a visiting researcher in Canada. His most recent books include *Universidad y Sociedad en América Latina* (1985), *Inquisición, Mercado y Filantropía: Ciencias Sociales y Autoritarismo en Argentina, Brasil, Chile y Uruguay* (with Alicia Barrios, 1987), *Un Espejo Trizado: Ensayos sobre Cultura y Políticas Culturales* (1988), and *Educación Superior en América Latina: Cambios y Desafíos* (1990).