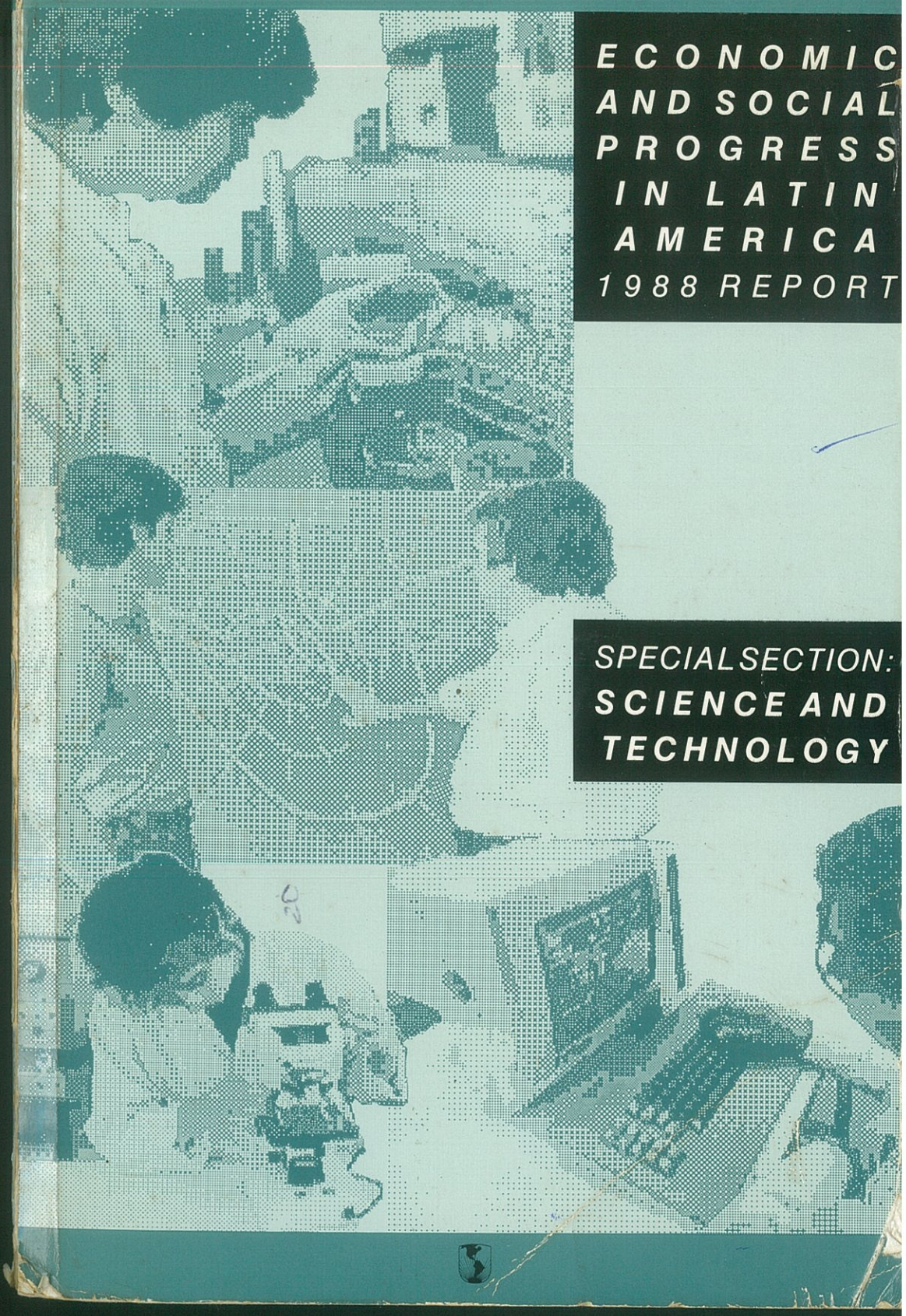
INTER-AMERICAN DEVELOPMENT BANK

ECONOMIC AND SOCIAL PROGRESS IN LATIN AMERICA

1988 REPORT

SPECIAL SECTION: SCIENCE AND TECHNOLOGY



ARREGUI
#206

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SCIENCE AND TECHNOLOGY

The special section on Science and Technology was the responsibility of Simón Teitel. Contributions were made by Ricardo J. Soifer, on information technology; by Pablo Bifani, on biotechnology, and by Patricia Arregui, on results of scientific and technological activities. Ricardo J. Soifer also collaborated on the preparatory work, including the organization of a seminar of experts, which took place at Bank headquarters in June of 1987. Several organizations contributed by either participating in that seminar or providing technical information on the subjects dealt with in the special report. We would particularly like to thank the National Science Foundation (NSF), the Office of Technology Assessment (OTA) of the United States Congress, the International Labor Organization (ILO) and UNESCO.

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CONTENTS

CHAPTER V

PART TWO

Science and Technology

CHAPTER VI

CHAPTER VII

CHAPTER VIII

CHAPTER IX

PART THREE

Country Summaries

PART FOUR

Statistical Appendix

CHAPTER IX

Comparative Indicators of the Results of Scientific and Technological Research in Latin America*

Introduction

Decision makers have long felt the need for information about the state of science and technology in their respective countries and regions and about the results of past efforts in order to evaluate their quality and efficiency. Only, although not exclusively, through a knowledge and measurement of the inputs absorbed by the scientific and technological system as well as of its outputs can a rational plan for its development be drawn up, especially in situations where there is a chronic shortage of resources like those that characterize—and certainly will continue to characterize for a long time to come—the countries of Latin America.

As is well known, the indicators conventionally used to measure the inputs of scientific and technological activity are not exempt from queries about their validity and reliability, especially as regards the compatibility of the operating definitions and the methodologies adopted and actually used to collect the necessary data in the various countries.[1] With respect to the indicators of the results of efforts in science and technology—that is, measurements of output, use, productivity, quality and impact—in addition to the criticisms of and/or reservations concerning the methodological and technical aspects of their construction,[2] there is a fairly general agreement about their conceptual limitations, especially when they are applied to underdeveloped countries.[3] The analysis and interpretation of those indicators, which include those used in this study (number of papers published in jour-

*Revised version of a paper prepared especially for this report by Patricia M. de Arregui of the Development Analysis Group (GRADE) of Lima, Peru, who is a consultant to the Inter-American Development Bank.

[1]Price 1975.

[2]Roche and Freites 1982.

[3]Moreno 1982; Velho 1985; Vessuri w/d 1987; Frame 1985; Kharbanda 1987.

nals of international circulation, number of citations of the authors of these papers in the years subsequent to their paper, patents applied for and granted, international scientific prizes awarded) require special care, therefore.

The need to design appropriate indicators is a concern of students and planners of scientific and technological development in the developing countries and has been reflected in recent years in the organization of a number of international meetings for that purpose. Many appeals have been made for the development of new indicators that will make it possible to evaluate the quality of scientific research and to pinpoint the socio-economic, political, institutional and other factors that enable research to contribute to development. New ways of estimating the returns of research, that is, of measuring its effects on: the efficiency of the productive apparatus, the growth of endogenous research capability, and improvement of the quality of life in general are clearly necessary.

Nevertheless, it is acknowledged that the design and installation of new information systems that contain more suitable indicators of the variables that really need to be measured will require long and difficult efforts. It is therefore generally agreed that, while efforts are being made to find and institutionalize new indicators that satisfy the requirements of information for evaluating and planning scientific and technological development in developing countries, the conventional indicators can be used as a first approximation (sometimes gross) to the measurement sought. The supposition is that they are useful for comparative purposes and will be even more so in the future when they are complemented by more complete data banks that target the problems of the developing countries themselves.

Whether this type of information system can be developed and institutionalized will depend on the development of a science that is better linked to the productive sector and to society in general, and can establish, jointly with them, criteria for evaluating the relevance, quantity, quality and impact of its output. In turn, in a number of cases this will require a reconsideration of the topics assigned priority in some developing countries, sometimes perhaps as a purely imitative response to the patterns observed in the industrialized countries. All this entails long-term processes. Meanwhile, however, the monitoring of the present situation with the conventional indicators, while bearing in mind the above-mentioned limitations, will be useful even as a way of exploring the validity of many generalizations and assumptions about science in the developing countries and its development.

We shall now examine the main statistics available for measuring output, distribution by subject area, impact and the quality of scientific and technological research in Latin America between 1973 and 1984. For each one of the selected indicators, which are those mentioned earlier as conventional, and the only ones for which comparable data are available, their nature, the source of the data, and the methodology used for preparing the findings presented are described. In some cases the characteristics of the situation at the end of the period are compared with those present at its

start, in others the trends visible in the data series are described. In all cases, whenever sufficient information is available, the state of the region as a whole is described and then compared with that of the world and that of the countries in which science and technology are more developed. Wherever possible, because of the availability of comparable data, the regional situation has been contrasted with that in other recently industrialized countries. Then the countries of the region are compared with one another, both by total scientific output and by areas of science. The interpretation of the data always attempts to take into account the conceptual and methodological limitations mentioned by those analysts that have previously worked in this field and whose studies it has been possible to review.

Scientific Publications

Number of Publications

The first measurement of scientific and technological output in Latin America that is dealt with in this study is the number of articles published by Latin American authors. A paper is considered by many to be the end product of scientific research. To report the new knowledge generated by it is equivalent to the completion of the effort made. As Vessuri[4] states: "Scientific research that is not published does not exist". The count of the articles published by research workers, therefore, represents a way of measuring their scientific output. Such a count is not a simple matter, and has usually been neglected by national agencies responsible for monitoring scientific and technological progress in the less developed countries. In Latin America in particular, the incipient systematic collection of information about inputs absorbed by the scientific and technological system has not been accompanied by a systematic analysis of data on their production or output. In addition, there are few studies on the subject.

In this study we have used the number of articles published by research workers from the region (independently or in collaboration with authors of other nationalities) in mainstream journals that have been identified and selected by the Institute of Scientific Information (ISI) of Philadelphia for its Science Citation Index (SCI). This institution selects, compiles and periodically publishes bibliographical information on all scientific fields, maintains a group of data banks on publications in science and technology, and provides various information services on scientific activity.[5] The Science Citation Index covers publications in nine areas of science: clinical medicine,

[4]Vessuri 1987.

[5]Its data bases are also processed by other specialized institutions in this field. Thus, the series on publications by Latin American authors used in this study were obtained from Computer Horizons, a firm that has the data in an appropriate format for the type of analysis we wished to make in this study.

start, in others the trends visible in the data series are described. In all cases, whenever sufficient information is available, the state of the region as a whole is described and then compared with that of the world and that of the countries in which science and technology are more developed. Wherever possible, because of the availability of comparable data, the regional situation has been contrasted with that in other recently industrialized countries. Then the countries of the region are compared with one another, both by total scientific output and by areas of science. The interpretation of the data always attempts to take into account the conceptual and methodological limitations mentioned by those analysts that have previously worked in this field and whose studies it has been possible to review.

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biomedical research, biology, chemistry, physics, earth and space sciences, engineering and technology, psychology and mathematics, and classifies them as such and then subclassifies them into 106 special fields.[6] Each paper included in the SCI is assigned to one of these areas,[7] or to one or more countries of origin.[8]

Table IX-1 presents a comparison, based on a sample of international scientific mainstream journals, of the total number of articles published between 1973 and 1984 by authors resident in Latin America and, on the other hand, by authors throughout the world.

The apparent lack of growth of Latin American publications (similar to that of world publications) is due to the fact that the sample of journals has remained constant since 1973,[9] and these publications usually have a more or less stable format and volume of contents over time. Therefore, lack of growth in regional or world scientific output cannot be inferred from these data. What can be clearly seen is that Latin America contributes very little to

[6]Publications on social sciences and arts and humanities are at present included into the Social Science Citation Index and the Arts and Humanities Citation Index, but the necessary data for making the desired international comparisons are not at present available. To obtain some measurement of output in these areas, the data available about Latin American authors or co-authors that have published in these areas are analyzed in the pertinent section of this study.

[7]It is the journal in which the paper in question has been published and not the contents of the paper itself that determines which area and subarea of science a specified paper is assigned to. When the journal is a multidisciplinary one, its articles are fractionally assigned to the subspecialties it usually includes.

[8]It is not necessarily the nationality of the authors that is recorded by country of origin of a paper, but rather the address they record in the scientific review, which usually corresponds to the place in which the institution in which the researcher normally works is located. This means that the work of many Latin American scientists and research workers, initially trained in their countries of origin but at present living in other places, is recorded as a paper of a foreign author. In addition, it tends to overestimate the output of certain countries in which international research institutes or centers are located. In cases of co-authorship by scientists that live in various places, the assignment is prorated proportionately among all the countries in which the authors reside.

[9]The SCI does add new journals to its sample each year, once they achieve a certain level of recognition and impact on the scientific community, but for various statistical analyses the journals base included must be kept constant for several years and these are the data to which it has been possible to obtain access. Accordingly, if the proportion of world publications coming from a country or region increases, it is safe to deduce that this level of activity has increased, which would not be possible with a sample base that is continuously growing since it would be impossible to know whether the increase in publications over time is due to greater activity or the mere expansion of the coverage of the SCI. Thus, although the figures do not make it possible to evaluate the absolute growth of the publications or the output of country in a given period, it does make it possible to measure the growth of output of a country or region relative to others and to the total number of countries in the world. In any event, to explore the possibility that the use of an expanded sample base would lead to changes in the conclusions of this study, data for 1981–1984, based on a larger sample of journals, included in 1981, were analyzed. Although the absolute differences in the number of publications (using the two sets of journals) are significant in some cases, they are not in relative terms: the ranking of the countries practically remains unchanged, the level of contribution to the world literature of the region as a whole remains unchanged and, only on a few occasions, the contribution of a specified country to world output or to regional output is changed (in an insignificant proportion).

Table IX-1. Number of scientific papers, from Latin America and from the world, published in journals with an international circulation, 1973–1984

Year	Latin America	World	Latin America/World (Percentage)
1973	2,700	279,570	0.97
1974	2,532	272,807	0.93
1975	2,521	274,707	0.92
1976	2,698	276,738	0.98
1977	2,684	282,720	0.95
1978	2,754	276,244	1.00
1979	2,919	277,106	1.05
1980	3,314	280,035	1.12
1981	3,307	287,761	1.15
1982	3,412	288,128	1.18
1983	3,369	291,262	1.16
1984	3,001	263,072	1.14

Source: GRADE, using data provided by Computer Horizons, Inc.

the world output and dissemination of new scientific knowledge. At the beginning of the period (1973), the region contributed a meager 0.9 percent of the world scientific output. At that time, the output of small European countries like Belgium and Czechoslovakia was larger than that of the region as a whole, and Israel, a recently industrialized country, accounted for 3,199 articles while Latin America as a whole published 2,700. In addition, if we take into account solely the developing countries, we find that Latin America contributed only 17 percent of the scientific literature, despite the fact that five out of the seven most productive countries in this group were in the region. Furthermore, only one Latin American country, Argentina, ranked among the 25 leading countries of the world producing scientific publications and stood in the last place.[10]

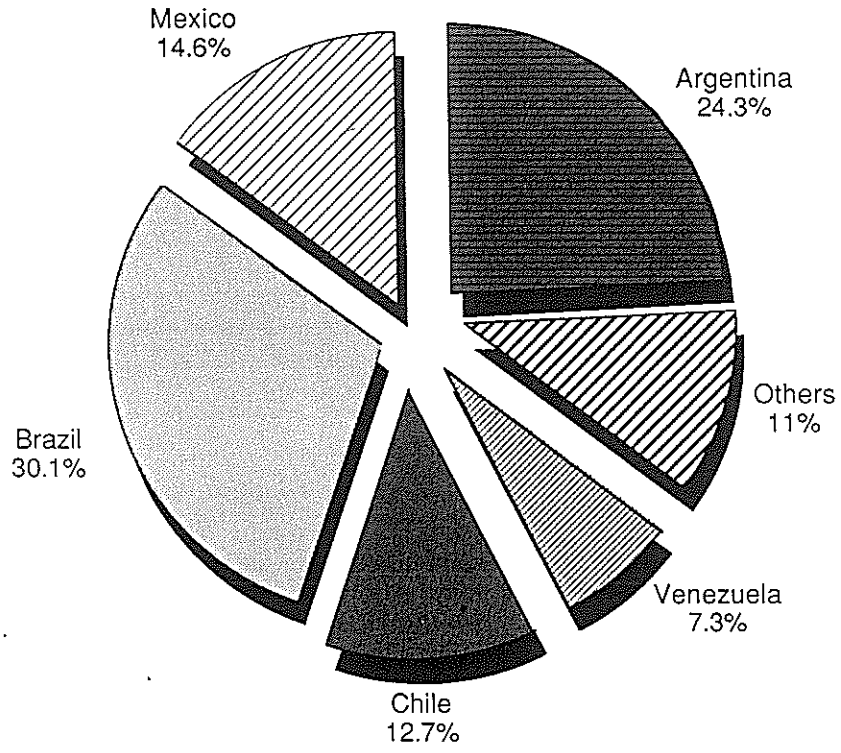
In 1984 the situation had not improved much. Although there was a slight upward trend throughout the period under review, only 1.4 percent of the world total of scientific articles published in 1984 came from Latin America. The paucity of this contribution becomes more evident if we bear in mind that in 1985 approximately 8 percent of the world population was concentrated in the region, which generated approximately 6 percent of world GDP. This 1.14 percent share is also small if we bear in mind that Latin America contains 11.5 percent of the higher education enrollment and 2.4 percent of the scientists and engineers engaged in R & D throughout the world.[11] Another way of highlighting the paucity of the results of research is the fact that in 1982, when the Latin American countries as a whole produced a total of 3,412 scientific articles,[12] the United States alone published a total of 135,953.

[10]Garfield 1983.

[11]World Bank, *World Development Report 1987* and UNESCO, *Statistical Yearbook 1986*.

[12]For the purposes of comparison with information available concerning the United States, this figure excludes publications in the field of psychology.

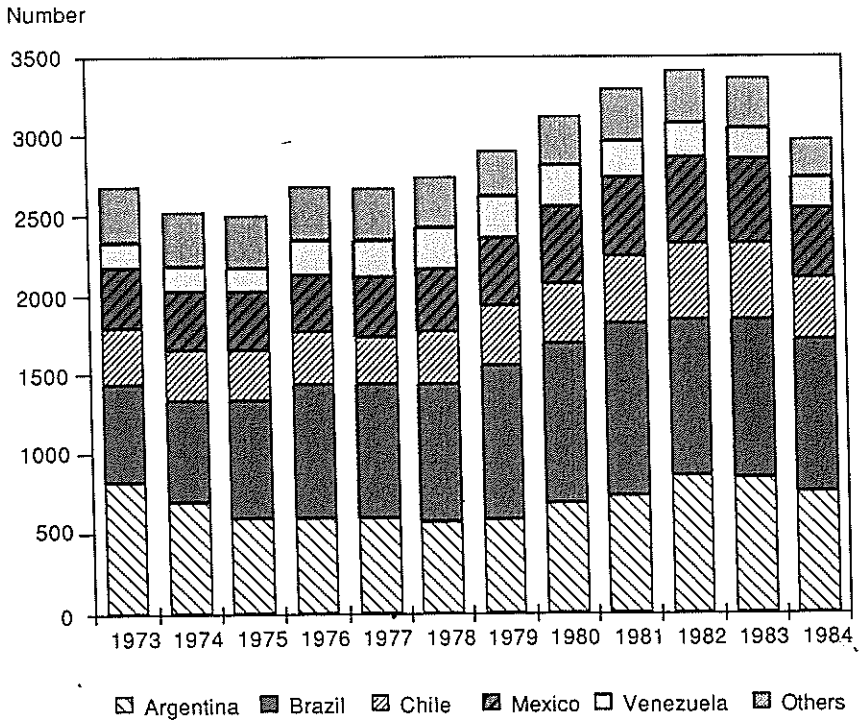
Figure IX-1. Latin America: Distribution by Country of Total Number of Scientific Papers Published in Journals with an International Circulation from 1973 to 1984



Source: Table IX-3.

Of course there are striking differences in the volume of scientific output of the different countries of the region. Figure IX-1 shows the distribution by country of the scientific publications made by Latin Americans between 1973 and 1984. The five countries with the largest output of scientific publications—Brazil, Argentina, Mexico, Chile and Venezuela—generated approximately 89 percent of the total output, while the remaining countries of Latin America together produced only 11 percent. As may be seen in Figure IX-2, except for the change in regional leadership, which passed from Argentina to Brazil in 1975, the relative contribution of the five countries with the largest number of publications did not change appreciably during the period.

Figure IX-2. Scientific Papers Published by Latin American Countries in Journals with an International Circulation, 1973-1984



Source: Table IX-3.

This assertion is confirmed by Table IX-2, which shows, ranked according to the volume of their output, the ten Latin American countries with the largest number of scientific publications in 1973 and 1984. The most noteworthy change, when we compare the two years, is the disappearance in 1984 from the list of largest producers of Peru and Costa Rica, which were replaced by Cuba and Uruguay.

Table IX-3 shows the growth in the number of publications in the different countries between 1973 and 1984. There are countries of the region whose average annual number of scientific publications in mainstream journals does not amount to ten, while in others it ranges between 20 and 50 and in the largest producers, between 200 and 1,000. In the countries with the largest number of publications (Brazil, Argentina, Mexico, Chile and Venezuela), a pattern of gradual and almost parallel growth is visible during the

Table IX-2. Latin America: Ten countries with the largest number of scientific papers published, 1973 and 1984

1973			1984		
Country	No. of Articles	Percentage of total	Country	No. of Articles	Percentage of total
Argentina	832	30.8	Brazil	953	31.7
Brazil	619	22.9	Argentina	770	25.7
Mexico	381	14.1	Mexico	435	14.5
Chile	355	13.1	Chile	386	12.8
Venezuela	161	6.0	Venezuela	197	6.6
Jamaica	70	2.6	Colombia	38	1.3
Colombia	46	1.7	Trinidad and Tobago	34	1.,1
Trinidad and Tobago	39	1.5	Cuba	33	1.1
Costa Rica	38	1.4	Jamaica	30	1.0
Peru	38	1.4	Uruguay	26	0.9
Other	121	4.5	Other	99	3.3
Regional total	2,700	100.0	Regional total	3,001	100.0

Source: The same as for Table IX-1.

Table IX-3. Latin American scientific papers published in journals with an international circulation, by country of origin, 1973-1984

Country	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Total
Argentina	832	709	611	612	614	590	597	706	747	870	855	770	8,511
Barbados	3	3	6	5	7	3	4	3	4	2	6	4	51
Bolivia	6	7	7	2	6	7	5	4	4	2	6	5	62
Brazil	619	645	739	835	844	869	975	1,004	1,088	981	994	953	10,545
Chile	355	313	316	332	296	326	378	374	418	476	478	386	4.448
Colombia	46	47	51	50	65	65	51	56	53	56	46	38	625
Costa Rica	38	24	39	40	33	31	19	41	29	33	28	22	378
Cuba	19	14	17	30	23	18	27	28	39	51	50	33	351
Dominican Republic	2	1	1	2	3	2	4	2	5	5	1	2	30
Ecuador	6	5	6	10	3	8	4	4	6	8	13	7	81
El Salvador	3	7	12	7	9	6	2	6	5	0	2	0	59
Guatemala	18	29	38	19	21	10	20	19	24	17	9	8	232
Guyana	8	3	2	2	6	1	2	4	9	5	10	6	59
Haiti	0	1	4	1	1	1	0	1	2	1	4	2	19
Honduras	5	9	3	5	8	6	3	5	2	2	2	2	53
Jamaica	70	68	44	56	56	66	56	47	56	45	34	30	627
Mexico	381	370	374	362	370	392	413	476	489	541	527	435	5,131
Nicaragua	4	1	1	2	3	1	0	0	1	0	0	0	15
Panama	13	9	10	7	4	3	7	8	15	9	13	14	114
Paraguay	3	2	2	2	6	0	5	2	1	1	1	2	29
Peru	38	34	37	41	28	30	26	33	27	29	23	21	366
Suriname	0	0	1	3	4	3	4	1	2	1	2	2	24
Trinidad and Tobago	39	43	25	37	17	37	24	22	27	29	33	34	367
Uruguay	29	27	29	19	27	16	26	14	20	26	28	26	286
Venezuela	161	159	144	214	229	263	265	268	229	220	202	197	2,549
Latin America	2,700	2,532	2,521	2,698	2,684	2,754	2,919	3,134	3,307	3,412	3,369	3,001	35,031
World	279,570	272,807	274,707	276,738	282,720	276,244	277,106	280,305	287,761	288,128	291,262	263,072	3,350,421

[1] Totals may not add up because of rounding.
Source: The same as for Table IX-1.

early years of the period under review, except for the above-mentioned strong advance of Brazil and the simultaneous decline of Argentina. However, at the beginning of this decade these countries showed some lack of growth, which became a clear deterioration in 1984. This deterioration may also be seen in the output of almost all the other countries of the region. As suggested by various observers,[13] this deterioration is probably connected with the economic crisis[14] and the effects the adjustment policies adopted in the region have had on the allocation of resources for science and technology.[15]

Apart from the criticisms leveled at the coverage of the sample of journals selected as the most prestigious by the Institute of Scientific Information (ISI), in the sense that it does not adequately cover the publications of developing countries,[16] and although no information is available that makes it possible to reliably prove that, had more regional or other international publications been included in the SCI, the number of Latin American publications would not have been significantly larger relative to the world output, it is safe to conclude that the number of scientific and technological papers published in Latin America is very small.

To what can we attribute this relative low level of publications? The literature on Latin American science and, in general, on science in developing countries, refers to a variety of factors that reportedly limit the output and productivity of science and technology in these countries, including: a) the absence of a critical mass of research workers that can lead to the development of a well institutionalized scientific community with its own formal channels of information transmission such as scientific journals; b) the predominance of an oral culture, in which personal communication or the holding of seminars, workshops or congresses are the preferred forms of dissemination; c) lack of knowledge of English, the language which at present dominates the scientific world, added to the recognition that publications in local languages reach only a very small circle of research workers; d) recognition, or assumption, that the subjects investigated locally do not interest the international scientific community; e) ephemeral life, and death, of scientific journals of recognized excellence, with systems for article refereeing and standardized quality criteria; predominance of in-house university and research center journals; f) lack of pressure and/or incentives to publish.

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[13]Among others, Sagasti and Cook 1985.

[14]The correlation between the number of publications of the various countries and the per capita income is not very high or significant, but the correlation between it and GNP is.

[15]In countries with a small number of articles, the tendency of the indicator to fluctuate violently from year to year throughout the period makes it difficult to reach a firm conclusion in this regard.

[16]For 1973, Garfield (1983, p. 13) records as part of the sample 52 journals of developing countries (out of a total of approximately 2,500) included in the SCI. According to another source, in 1980 only 17 Latin American journals were included; this is barely 0.55 percent of the 3,067 publications included in that year (Roche and Freites 1982, p. 286).

Neither social prestige nor academic promotion nor the income of the vast majority of the research workers of the region depends on their productivity in terms of published articles or books.

Research workers in universities usually move from one academic level to a higher one, according to the number of years of service rendered to the institution, rather than according to their merit. Furthermore, the explosion of demand for, and the relatively open access to, higher education offered in a number of countries of the region have led to an increase in the teaching and administrative loads of the professors, who have very little time for research. As regards income, it is well known that in Latin American universities, where most of the research workers (or those who call themselves research workers) are concentrated, the salary levels are usually low. The increase in enrollment, which has not always been paralleled by increments in the levels of financing of higher education, has also caused a deterioration in the situation of research workers/teachers. In addition, even today many scientific research workers in Latin America are physicians, who must also continue their therapeutic activity because they depend on it for a large part of their income; Latin American research workers in other fields of science likewise have to earn their living outside research.

Subject Distribution of Scientific Publications

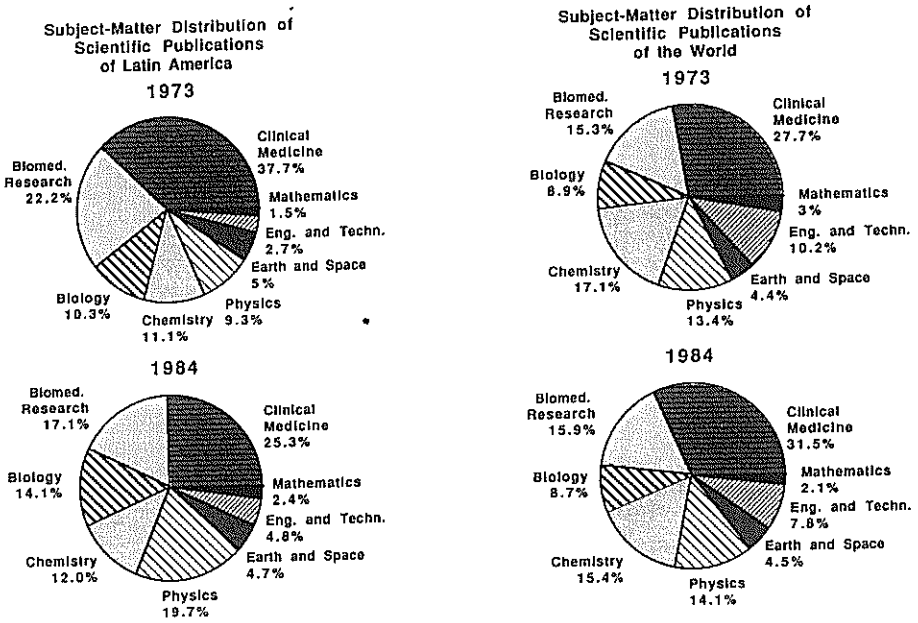
Also of interest is the distribution by subject area of the scientific publications of Latin America and its comparison with that of other countries. Table IX-4 presents the annual changes in that distribution between 1973 and 1984. It clearly shows: a) the relative decline in the areas of clinical medicine and biomedical research, b) the relative lack of growth of chemistry, mathematics and earth and space sciences, c) a slight increase in engineering and technology, and d) the expansion of the shares of physics and biology.

The heavy concentration on life sciences, especially those directly relating to human health, has been a characteristic of the research efforts of the underdeveloped countries, as has the scanty emphasis on chemistry, physics and engineering. This thematic structure, especially the strong emphasis on life sciences and the neglect of the physical sciences, has been referred to as the "peripheral complex" of Latin American scientists. Other critics wonder whether this distribution is not a reflection of a lack of linkage between the objectives of scientific and technological research and social needs.[17] The foregoing data clearly show, as does Figure IX-3, that Latin American scientific publications continue to be concentrated in the life sciences. However, a trend towards a closer approximation to the world distribution of the papers published in mainstream journals is apparent.

For its part, Figure IX-4 compares the structure by subject area of the publications of Latin America, the world, and the United States of America

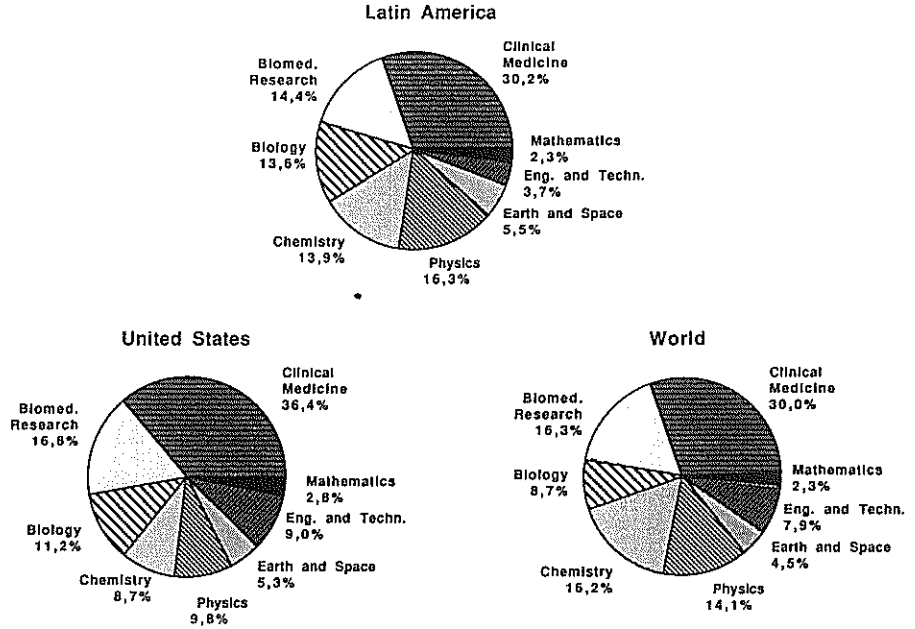
[17]Frame 1977.

Figure IX-3. Distribution by Subject Matter of Scientific Papers Published by Latin America and the World in 1973 and 1984



Source: GRADE, based on data supplied by Computer Horizons, Inc.

Figure IX-4. Subject-Matter Distribution of Scientific Papers Published by Latin America, the United States and the World in 1982



Source: GRADE, based on data supplied by Computer Horizons, Inc.

Table IX-4. Subject-matter distribution of the Latin American scientific papers published by areas of science, 1973-1984
(Percentages)

Year	Clinical medicine	Biomedical research	Biology	Chemistry	Physics	Earth and space sciences	Engineering and technology	Psychology	Mathematics
1973	37.47	22.07	10.23	11.03	9.26	5.00	2.72	0.68	1.53
1974	36.27	19.84	12.37	9.96	10.21	5.07	3.14	0.89	2.25
1975	34.25	20.24	11.94	10.80	12.11	4.69	2.86	0.96	2.16
1976	32.80	17.82	12.83	11.25	12.84	4.75	4.30	0.72	2.69
1977	31.12	21.50	12.34	10.25	12.75	4.71	3.52	1.18	2.63
1978	33.08	19.69	12.38	10.14	13.54	4.27	3.95	0.42	2.53
1979	30.82	18.84	12.74	11.20	14.45	4.98	4.09	0.56	2.32
1980	31.51	16.85	13.48	11.14	14.29	5.25	4.13	0.86	2.50
1981	29.71	16.60	12.88	13.62	16.02	5.05	3.71	0.47	1.94
1982	30.10	14.33	13.57	13.86	16.21	5.46	3.70	0.50	2.26
1983	30.11	15.64	12.62	12.82	16.26	5.02	5.10	0.54	1.88
1984	25.10	17.03	14.04	11.94	19.58	4.70	4.57	0.61	2.42

Source: The same as for Table IX-1.

in 1982. It shows the close correspondence between the world distribution and that of Latin America, while the medical sciences constitute a larger part of the total scientific publications of the United States. In turn, the basic sciences represent a larger share of the publications of the world and of Latin America than they did in the United States at that time, which is surprising. Finally, the Latin American concentration in the field of biology, which exceeds the corresponding share both of the world and of the United States, is noteworthy.

Whether or not the distribution of the publications reflects a gearing of scientific research to the needs or problems perceived as more important or urgent in the region is a matter of discussion. Few query the fact that, as Frame[18] states, the regional priorities should by and large be focused on satisfying health needs, including the feeding of the population and the requirements of an accelerated industrialization process. From this standpoint, the level of concentration on clinical medicine and biomedical research would appear to be reasonable. Nevertheless, still to be examined are the contents of that research in order to ascertain whether the subtopics studied correspond to the most pressing problems in Latin America, rather than to those fashionable in the industrialized countries. With respect to the scientific output that can contribute to the solution of food problems, the data disaggregated by subareas in the field of biology, which correspond to the subjects of agriculture, food, and livestock, indicate a low concentration on these topics. For example, in 1984, in the five countries with the largest number of publications in the region, only a total of 51 articles on these subjects were published[19]; and whereas research on biology doubled its annual output between 1973 and 1984, the number of articles on the abovementioned subtopics remained the same. Finally, as for the needs of the industrialization process, the limited expansion in the number of publications on chemistry and engineering and technology, which can be considered key areas for this type of development, is noteworthy. Although the concentration on these topics is not very much less than that of the rest of the world, it could be argued that it is insufficient for the "giant leap forward" required in the region.

Impact Measurements

Authorship of a large number of scientific publications does not necessarily mean that they are having a major impact on the conditions studied by that research, or on the scientific community working in the areas concerned. To establish a comparison of the impact of the Latin American publications,

[18]Frame.

[19]Again, it is difficult to generalize on the basis of the data available: the international mainstream journals may very possibly not be selected by Latin American scientists for disseminating the findings of this type of research, since they are not the most appropriate channels for it.

Table IX-5. Latin American countries with the largest number of citations to their scientific papers published in 1980[a]

Country	No. of citations
Brazil	2,544
Argentina	1,943
Mexico	1,668
Chile	1,116
Venezuela	493
Colombia	133
Jamaica	127
Guatemala	63
Peru	56
Cuba	48
Trinidad and Tobago	44
Costa Rica	41
Panama	33
Uruguay	19
Honduras	16
Ecuador	13
Suriname	11
El Salvador	11
Latin America	8,409
World total	1,398,506

[a] Citations appearing in international literature up to 1984.
Source: The same as for Table IX-1.

the statistics on citations of scientific articles published in mainstream journals by Latin American research workers will be examined in this Section. The indicators used are: a) the number of citations, from the date of their publication till 1984, to articles originating in each country of the region that were published in two different years: 1973 and 1980; b) the average citations to each paper; and c) the relative citation index, which links the previous average to the world average of citations. The citations have been drawn from the same sample of journals in which the publications appeared, which had remained constant over the period under review.

These output indicators were designed to measure the quality of the output of scientific research in different ways. As happens with other indicators of the output of scientific research, whether they really measure what they claim to measure is a matter of dispute. There are social, institutional and political factors that affect what is published in mainstream journals and even more so, who cites whom.[20] The existence of those factors and of networks of deeply rooted academic relationships makes it impossible to take the citations as a direct measure of output quality. Rather, this may be an approximate measurement of the impact of a specified paper through the transmission of new knowledge to the scientific community that reads that paper, and may take that information into account in its own studies. Through its effect on the scientific community it may also have an indirect impact on decision makers.

[20] Vessuri w/d, p. 7.

Of almost 1.4 million citations made in the world literature up to 1984 from scientific and technological publications issued in 1980, only about 8,400 were references to articles by Latin American authors. Similarly, only 15,720 of a total of approximately 2.6 million citations made up to 1984 to articles published in 1973, represented articles by authors of the region. For both base years (1973 and 1980) these figures show the same percentage of total world citations: a very scanty 0.60 percent.

As was to be expected, given the existing variety in the volume of its scientific publications and in the level of scientific and technological development, the number of citations to publications of authors from each one of the Latin American countries varies widely. Table IX-5 shows that for publications in 1980 it ranged from 0 to 2,544 total citations. While the five countries with the largest number of references account for 92.3 percent of the total regional publications, the number of citations received by most of the countries is very limited.

Table IX-6 contains: a) the number of citations to Latin American publications in the two base years, b) the number of citations to publications of the entire world in each scientific area, and c) the shares of the region in each total. A comparison of the findings for 1973 and 1980 shows that, whereas the impact of the medical areas declined, that of all the other areas increased, although, sometimes, very very slightly. In relative terms, the areas of the Latin American sciences most favored by the references to publications in 1973 were clinical medicine, biomedical research, and the earth sciences and, in 1980, the earth sciences, biology, and psychology in that order.

In order to control for the difference in the volume of publications made by the different countries (which could be introducing a bias into the findings of the number of citations indicator as an impact measurement), the average number of citations to the articles published by a country in a given year and in each area of science has been calculated. Table IX-7 shows first that on average Latin American publications in 1973 received 37 percent fewer citations than the average number of world publications, while in 1980 these publications received 46 percent fewer citations than those of the entire world. Second, in two areas of science (engineering and technology, and psychology) the Latin American average of citations for publications in 1973 was above the world average. In addition, several countries show higher average total citations than the world average for publications made in 1973, as well as higher citation averages than the world averages in various areas of science. The areas in which this was so for more than one country were: the earth and space sciences, engineering and technology, psychology and mathematics. As for articles published in 1980, the publications of Latin American authors received an average of 2.7 citations up to 1984, whereas each paper published throughout the entire world in that same year received, in the same period, an average of almost 5 citations. No Latin America country had an average of citations for its total scientific publications equal to the world average, although Mexico was the country that most closely approached this value. The same table also shows that in certain scientific

Table IX-6. Citations to papers from Latin America and the world published in 1973 and in 1980, by scientific area[1]

Science	World		Latin America		Latin America/World %	
	1973	1980	1973	1980	1973	1980
Clinical medicine	816,887	429,690	5,759	2,409	0.71	0.56
Biomedical research	666,687	361,897	4,673	1,845	0.70	0.51
Biology	154,118	79,024	999	714	0.65	0.90
Chemistry	364,365	189,529	1,382	915	0.38	0.48
Physics	332,125	200,151	1,411	1,382	0.42	0.69
Earth and space sciences	128,228	74,558	911	834	0.71	1.12
Engineering and technology	79,590	44,138	227	165	0.29	0.37
Psychology	40,055	9,174	241	81	0.60	0.88
Mathematics	25,838	10,345	116	63	0.45	0.61
Total	2,607,894	1,398,507	15,720	8,409	0.60	0.60

[1] Citations appearing up to 1984. Source: The same as for Table IX-1.

Table IX-7. Citations to papers from ten Latin American countries and the world, published in 1973 and 1980, by scientific area[1]

Country[2]	Clinical medicine		Biomedical research		Biology		Chemistry		Physics		Earth and space sciences		Engineering and technology		Psychology		Mathematics		Total	
	1973	1980	1973	1980	1973	1980	1973	1980	1973	1980	1973	1980	1973	1980	1973	1980	1973	1980	1973	1980
Argentina	7.87	2.57	8.09	4.06	2.52	1.88	3.82	2.60	6.94	2.98	4.40	2.26	5.43	1.63	2.00	4.43	3.71	0.41	6.75	2.75
Brazil	5.18	3.13	5.66	2.67	3.35	1.74	7.18	3.03	6.30	2.99	3.05	1.92	1.82	1.12	18.44	3.13	1.50	0.89	5.20	2.53
Mexico	5.10	2.47	10.55	6.83	3.49	2.89	4.76	2.58	4.00	4.34	5.13	6.86	6.31	1.70	19.76	3.37	7.55	0.64	6.05	3.50
Chile	3.28	1.25	9.21	4.79	6.15	2.55	4.83	3.29	3.34	2.31	10.81	11.71	1.60	0.81	0.39	0.41	0.03	0.34	5.06	2.98
Venezuela	6.95	3.31	8.06	1.23	2.87	1.43	3.02	1.52	2.67	2.23	6.00	2.00	0.54	0.78	23.00	1.94	7.86	1.95	5.73	1.84
Jamaica	8.13	2.78	18.75	4.04	7.85	2.24	1.74	0.81	7.24	21.00	17.19	2.23	0.00	2.73	0.00	21.00	0.00	0.10	10.45	2.70
Colombia	5.14	3.70	1.39	4.22	3.77	0.85	4.48	0.00	1.55	2.27	6.68	2.00	2.00	0.00	0.00	0.00	0.00	0.00	3.95	2.36
Trinidad and Tobago	2.00	21.33	11.30	0.00	3.98	0.37	3.35	0.00	1.75	0.00	4.19	4.00	0.13	0.55	13.00	0.00	0.07	0.50	3.39	2.00
Costa Rica	13.37	3.38	12.50	1.70	1.42	1.43	9.00	1.20	7.34	2.09	9.00	5.59	1.08	2.33	9.00	0.78	4.10	2.13	3.85	2.09
Peru	7.00	1.49	4.24	1.97	1.59	1.50	1.00	0.15	4.00	0.80	5.57	12.30	0.00	2.03	0.00	9.00	0.00	0.02	4.07	1.71
Latin America	5.69	2.43	7.84	3.49	3.62	1.69	4.64	2.62	5.65	3.09	6.75	5.07	3.09	1.28	13.17	3.01	2.81	0.81	5.82	2.68
World	10.84	5.14	15.99	8.01	6.36	3.23	7.85	4.19	9.10	5.32	10.71	6.03	2.85	1.97	5.55	3.61	3.14	1.48	9.30	4.99

[1] Average number of citations appearing up to 1984. [2] Order of countries according to the number of scientific papers published in 1973. (See Table IX-2)
Source: The same as for Table IX-1.

areas the papers of some countries of the region can have a somewhat larger impact than the world average. However, when we examine these cases in greater detail, we find that most of them are areas in which less than two articles by authors of the country concerned have been published, which makes it an imperative citation for any comparative study, or any study on the subject in that country. Mexico and Chile in the earth and space sciences may be exceptions, perhaps attributable to the seismic conditions of their soils (no information on the content of the articles published is available for confirming this supposition). Other possible exceptions are publications in mathematics by Venezuelan authors and in psychology by Argentine authors.

Another way of presenting the same data is shown in Table IX-8, which contains the relative citations indices, by areas of science, for the most important countries of the region in terms of scientific publications. This index compares the average citations to the publications made by authors from one country, in a scientific area or subarea, with the average number of references to all the papers in that area or subarea published throughout the world in the same year. If the value of the index[21] is 1.0, it indicates that the publications of that country are cited equally as frequently as the world average; a lesser value means that the publications have a smaller impact, and a higher value, a greater impact. This is only another way of examining the same data analyzed in the foregoing paragraphs and, consequently, it leads to similar conclusions: a) the level of impact of Latin American scientific publications is somewhat below the world average; b) at the aggregate level, for all the scientific areas and for Latin America as a whole, there appears to have been a relative deterioration between 1973 and 1980,[22] and c) there are few exceptions to the two foregoing statements: only in a few countries does the impact of their publications in certain areas of science exceed the world average.

Finally, Table IX-9 presents a comparison of the Latin American indices with those of the United States for 1973 publications (the only year for which comparable data are available). It clearly shows the greater impact of the United States publications in almost all areas of the sciences.

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[21]The formula for calculating this index is as follows:

$$\frac{\text{Citations country/publications country}}{\text{Citations world/publications world}}$$

[22]There is another possible explanation for the differences between the citations of papers published in 1973 and 1980, namely that the process of dissemination and recognition of Latin American publications takes time and, therefore, an improvement in these indices can be expected as time goes on. A simple way of testing this hypothesis would be to again calculate, in 1991, the impact of the articles published in 1980 and to see whether it is similar to that of the 1973 publications in 1984.

Table IX-8. Ratio of citations to papers from ten Latin American countries published in 1973 and 1980 to those from the world, by scientific area[1]

Country[2]	Clinical medicine		Biomedical research		Biology		Chemistry		Physics		Earth and space sciences		Engineering and technology		Psychology		Mathematics		Total	
	1973	1980	1973	1980	1973	1980	1973	1980	1973	1980	1973	1980	1973	1980	1973	1980	1973	1980	1973	1980
Argentina	0.73	0.50	0.51	0.51	0.40	0.58	0.49	0.62	0.76	0.56	0.41	0.37	1.90	0.83	0.36	1.23	1.18	0.28	0.73	0.55
Brazil	0.48	0.61	0.35	0.33	0.53	0.54	0.91	0.72	0.69	0.56	0.28	0.32	0.64	0.57	3.33	0.87	0.48	0.60	0.56	0.51
Mexico	0.47	0.50	0.66	0.90	0.55	0.90	0.61	0.60	0.44	0.80	0.48	1.10	2.21	0.90	3.56	0.90	2.41	0.40	0.65	0.70
Chile	0.30	0.24	0.58	0.60	0.97	0.79	0.62	0.79	0.37	0.43	1.01	1.94	0.56	0.41	0.07	0.11	0.01	0.23	0.54	0.60
Venezuela	0.64	0.60	0.50	0.20	0.45	0.40	0.38	0.40	0.29	0.40	0.56	0.30	0.19	0.40	4.15	0.50	2.50	1.30	0.62	0.37
Jamaica	0.75	0.50	1.17	0.50	1.23	0.70	0.22	0.20	0.80	3.90	1.60	0.40	0.00	1.40	0.00	5.80	0.00	0.10	1.12	0.54
Colombia	0.47	0.72	0.09	0.53	0.59	0.26	0.57	0.00	0.17	0.43	0.62	0.33	0.70	0.00	0.00	0.00	0.00	0.00	0.42	0.47
Trinidad and Tobago	0.18	4.20	0.71	0.00	0.63	0.10	0.43	0.00	0.19	0.00	0.39	0.70	0.05	0.30	1.34	0.00	0.02	0.30	0.36	0.40
Costa Rica	1.23	0.66	0.78	0.21	0.22	0.44	1.15	0.29	0.81	0.39	0.84	0.93	0.38	1.19	1.62	0.22	1.31	1.44	0.41	0.42
Peru	0.65	0.30	0.27	0.30	0.25	0.50	0.13	0.00	0.44	0.20	0.52	2.00	0.00	1.00	0.00	2.50	0.00	0.00	0.44	0.34
Latin America	0.52	0.47	0.49	0.44	0.57	0.52	0.59	0.63	0.62	0.58	0.63	0.95	1.08	0.65	2.37	0.83	0.90	0.55	0.62	0.54

[1] The percentages have been calculated from the average of citations appearing up to 1984. A factor of 1 means that the average of the country is equal to the world average; figures higher than 1 indicate a relatively greater impact while those lower than 1, the contrary.
[2] Order of countries according to the number of papers published in 1973. (See Table IX-2)
Source: Data from Table IX-7.

Table IX-9. Coefficients of citations to papers from Latin America and the United States, published in 1973, by scientific area[1]

Scientific area	World citations Latin America	World citations United States
Clinical medicine	0.52	1.36
Biomedical research	0.49	1.42
Biology	0.57	1.08
Chemistry	0.59	1.66
Physics	0.62	1.53
Earth and space sciences	0.63	1.38
Engineering and technology	1.08	1.28
Psychology	2.37	n.a.
Mathematics	0.90	1.24
Total	0.62	1.40

n.a.: Not available.
[1] The coefficients have been calculated from the average citations appearing up to 1984. A coefficient of 1 means that the average of the country is equal to the world average; values higher than 1 indicate a greater relative impact while those lower than 1, the contrary.
Source: For Latin America Table IX-8 and for the United States, National Science Board, *Science Indicators. The 1985 Report*, Washington, D.C. 1985.

The Social Sciences and the Humanities

So far, we have examined the state and the trends of output and impact of research in the basic and natural sciences and engineering. To approach the measurement of output in the social sciences, the arts and humanities, another indicator is available, namely, the number of scientific authors that published each year in the journals and books covered by the Current Contents and other bibliographical publications included in the Current Bibliographic Directory of the Arts and Sciences, also published by the Institute of Scientific Information of Philadelphia, United States. In this case, the annual publications base is somewhat larger than that incorporated in the SCI and, unlike it, increases annually. In this case, the figures for the sciences are therefore rather different from those examined earlier when the findings based on the number of publications indicator were presented. When we are dealing with articles by several authors (although the data used only record the residence of the first and second authors), authorship is not prorated among the countries represented as it is in the SCI. Finally, Table IX-10 presents data for the period 1984–1986.[23]

The figures confirm that the share of Latin American and Caribbean authors in world scientific output is very small, and is equivalent to approximately 1.6 percent of the total for the three years. But the small size of this share is more striking in the social sciences/arts and humanities. The number of authors and co-authors in these fields (annual average of 0.87 percent of the world total) is 13 times smaller than that of authors who published in the natural sciences and engineering throughout the three years under re-

[23] Similar data for earlier years include only the first authors and do not differentiate between the natural and the social sciences, which is why they are not included in this report.

Table IX-10. Papers and books of Latin American authors by country of origin and world total, 1984–1986[1]

Country	1984		1985		1986	
	Social sciences, arts and humanities	Science and technology	Social sciences, arts and humanities	Science and technology	Social sciences, arts and humanities	Science and technology
Argentina	141	3,569	121	3,106	136	5,037
Barbados	11	21	8	25	15	39
Bolivia	3	14	3	28	5	17
Brazil	333	4,655	335	4,620	550	6,632
Chile	121	2,105	123	1,495	155	2,119
Colombia	28	173	23	153	32	232
Costa Rica	31	184	21	161	29	166
Cuba	13	337	17	274	7	274
Dominican Republic	2	20	n.a.	11	1	21
Ecuador	1	26	n.a.	20	6	28
El Salvador	1	11	3	5	1	8
Guatemala	22	59	5	38	9	81
Guyana	1	10	5	5	4	9
Haiti	3	14	2	6	n.a.	9
Honduras	15	21	2	3	4	15
Jamaica	43	171	55	171	36	194
Mexico	168	1,726	149	1,795	268	2,707
Nicaragua	5	2	7	7	6	11
Panama	3	48	5	40	7	33
Paraguay	n.a.	12	1	7	n.a.	11
Peru	26	96	35	85	45	129
Suriname	n.a.	2	n.a.	1	n.a.	1
Trinidad and Tobago	19	91	12	102	33	86
Uruguay	4	119	12	82	11	79
Venezuela	48	692	45	673	44	796
Latin America	1,047	14,281	1,001	13,035	1,409	18,823
World Total	129,375	811,351	123,499	844,260	143,739	1,019,076
Latin America as percentage of world	0.81	1.76	0.81	1.54	0.98	1.85

n.a.: Not available.
[1] Includes both the first and the second authors of journal papers and authors of books.
Source: Institute for Scientific Information (ISI); "Current Bibliographic Directory of the Arts & Sciences" (Summaries) *Social Sciences/Arts and Humanities; 1984, 1985, 1986.* ISI, "Current Bibliographic Directory of the Arts & Sciences" (Summaries) *Science and Technology 1984, 1985, 1986.*

view.[24] In contrast, for world output, the number of authors in the social sciences and humanities represented approximately one seventh of that of authors in the natural sciences and engineering. The smaller relative concentration of Latin American research in social sciences and humanities, which follows from the findings of this indicator, is somewhat surprising since research in the natural sciences and engineering usually requires more financing, equipment and facilities, etc., which are normally in short supply in Latin America, in addition to usually having longer periods of maturation. On the other hand, it could be argued that research workers in the social sciences are more devoted to studying local problems and are primarily interested in their findings being known in their own countries (or region), which is why they would preferably publish in national or regional journals.

A comparison of the findings for the various countries of the region shows that, as in the case of the number of publications and citations indicators, Brazil, Argentina and Mexico are the countries that account for the largest number of authors and co-authors that publish both in the natural sciences and in the social sciences. Brazil has the largest number of authors and co-authors in the two areas, Argentina ranks second in science and technology, and Mexico ranks likewise in the social sciences. In the last year recorded (1986) the region increased its share in world output, although still insignificantly, especially if we bear in mind that, in contrast to the 1.7 percent of total authors and co-authors, the region has 2.42 percent of the scientists and engineers devoted to R & D throughout the world. In the case of the social sciences and humanities the 40 percent increase in the number of authors recorded between 1985 and 1986 appears promising, as does the greater relative share in world output; it rose from 0.81 percent to 0.98 percent of the total number of authors and co-authors in these fields of knowledge.

Patents

For the results of research and technological development, the most frequently used indicator is patents. Almost all the countries of the world have laws on intellectual property, the main purpose of which is to encourage invention and, through it, economic development. A patent is a right granted to inventors (or to persons to whom they transfer it) which prevents others from producing, using or selling a patented product, or using a patented method or procedures during a prescribed period. The assumption is that the inventor will have priority in manufacturing what he invented (without having initially to compete with other producers) or in selling his right to others and will benefit economically from it. For an innovation to be pat-

[24] The city of Philadelphia, United States, alone, with a population of just over one and a half million persons, shows a total of 1,539 authors in the social sciences for 1986 (Institute of Scientific Information 1986).

Table IX-11. Invention patents applied for and granted in Latin America, United States and the World, 1981–1984

Country or region	1981		1982		1983		1984	
	Applied for	Granted	Applied for	Granted	Applied for	Granted	Applied for	Granted
Latin America	18,745	18,633	21,559	20,281	19,895	14,611	19,664	12,128
United States[1]	106,413	65,770	109,625	57,889	103,703	56,862	111,284	67,201
World	800,885	417,469	809,741	413,764	824,428	406,939	859,980	422,496
				Percentages				
Latin America/United States	17.62	28.33	19.67	35.03	19.18	25.70	17.67	18.05
Latin America/World	2.34	4.46	2.66	4.90	2.41	3.59	2.29	2.87
United States/World	13.29	15.75	13.54	13.99	12.58	13.97	12.94	15.91

[1] It is not known whether the United States is registering any other form of intellectual property record (invention certificate or utility models) like those included in the figures for some countries of Latin America and of the world.
Source: World Intellectual Property Organization.

ented, it must satisfy certain requirements of novelty and inventive merit, which are evaluated by the national offices that determine whether or not the right should be granted.

For a number of reasons, especially in recent decades, the data of the annual increase in the number of patents applied for and granted does not appropriately reflect the level of inventive activity or its results. Many inventors are believed to opt not to patent their inventions[25] because of which the recorded figures underestimate real inventive output. Furthermore, and in contrast, many patents are applied for simultaneously in several countries so that the total number overestimates the real volume of inventions. Frequently, what those who patent intend is to obtain protection in international merchandise trade rather than being rewarded or stimulated as inventors. Often, there is no intention of producing the product or of using the patented process. Some studies show that, especially in developing countries, only a very small part of the patents are ever exploited, i.e. utilized by the productive sector to manufacture the product or use the patented process.[26] Although the number of patents registered can hardly measure changes in the inventive level of the country, such data can, in comparative terms and when disaggregated by nationality of the applicant, reflect the degree of technological dependence of a country and can measure, through the technological flows between them, the level of economic integration of specified countries —in this case, those of Latin America. They can also be used, although this type of analysis will not be made in this study, to identify the industrial sectors in which greater incentives to invention are being given in different countries.

Data on patents applied for and granted in each one of the countries of Latin America between 1976 and 1984 are available, as are those for their distribution between residents and non-residents (and non-residents are further broken down into residents of other Latin American countries and residents of other regions). These data are published by the World Intellectual Property Organization (WIPO) in Geneva, which collects them from the national agencies responsible for recording them in each of the countries of the world.

Table IX-11 compares the total number of patents applied for and granted annually between 1981 and 1984[27] in 24 countries of the region with

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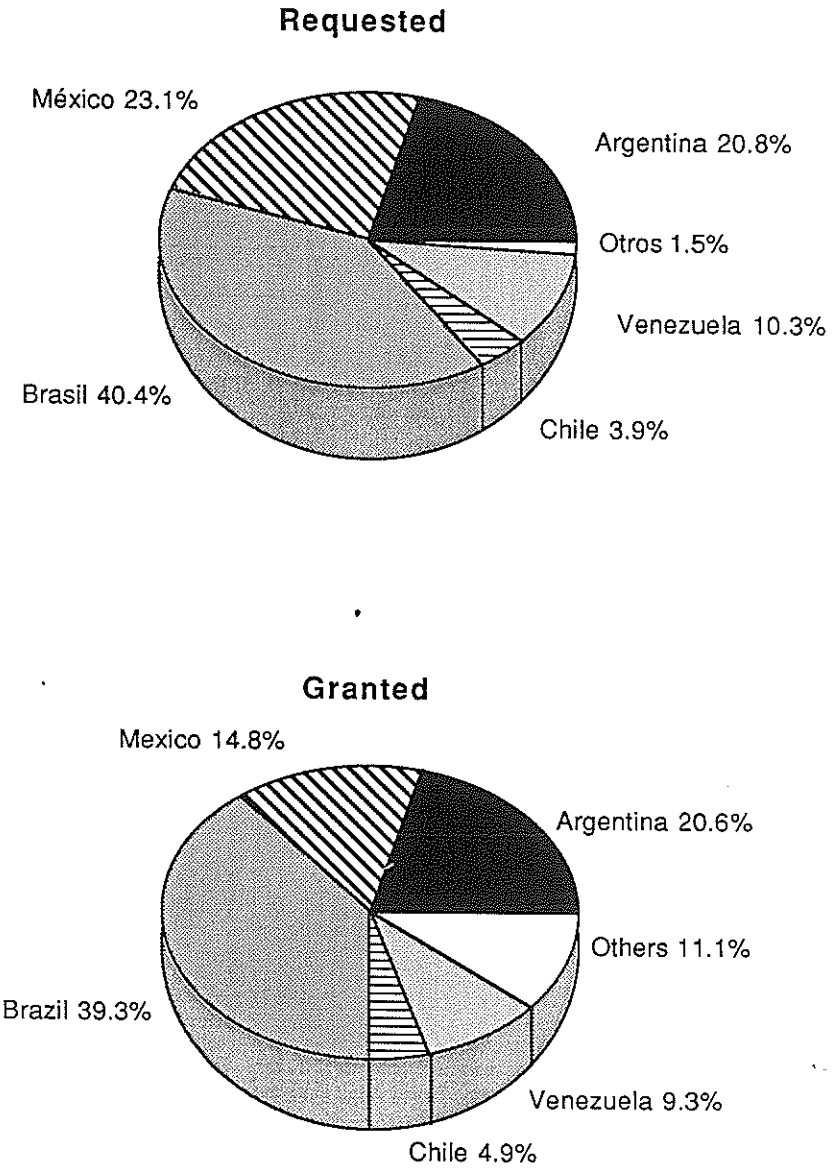
[25]This could be so for a variety of reasons, for example inventors who: a) are unaware of the commercial value of the innovation, b) fear the bureaucratic requirements the patenting process entails, c) give greater value to technological leadership than to protection, d) believe more in secrecy than in patents, e) know that their inventions are difficult to copy or, on the contrary, f) know that other producers will copy them in any event since there are no ways of exercising control over and collecting fees for their use, etc.

[26]This is particularly true of patents registered in a country by foreigners. A survey made by the United Nations in three developing countries reveals that less than 10 percent of the products and processes patented were ever exploited. (UNCTAD 1975).

[27]The data for earlier years are not analyzed because information from many countries is lacking.

Figure IX-5. Latin America: Distribution by Country of Total Number of Patents Requested and Patents Granted, 1978-1984



Source: World Intellectual Property Organization

corresponding figures for the United States and the world, obtained from the above-mentioned source. Between 1981 and 1984 the number of patents applied for in the Latin American countries averaged 2.4 percent of the world figure while the number of patents granted was about 4 percent of the world total. These figures contrast with the share in the world total of patents registered in the United States, which for the period averaged 13.1 and 14.9 percent of the applications and grants, respectively. The total number of patents applied for in Latin American countries does not amount to a fifth of those applied for in the United States, while the grants reach only one third of the United States total.

As in the case of scientific publications, applications and grants of patents are heavily concentrated in a few countries of the region, as shown in Figure IX-5. The five countries with the largest number of patents: Brazil, Argentina, Mexico, Venezuela and Chile, received 98.5 percent of the applications submitted and issued 88.9 percent of the patents granted between 1978 and 1984 in Latin America and the Caribbean, whereas the remaining 19 countries for which figures are available, were together responsible for the remaining 1.5 and 11.1 percent, respectively. However, not even the countries of the region most active in the area of patents achieved levels close to those of the world's industrial powers.[28]

An analysis of the annual changes in, and the distribution by country of, patents granted in Latin America (see Figure IX-6), highlights the downward trend of the grant of patents in recent years, as well as the marked predominance of grants to foreigners, which represent 85.6 percent of the total awards. Very few of the patents are granted to residents of other Latin American countries while the share awarded to residents of a particular country has not varied much throughout the period.

It has been noted that in Latin America patents that will never be exploited are granted to foreigners (or even to residents of a country, who in actual fact are branches of transnational corporations).[29] For example, of a sample of 4,872 patents granted in Peru between 1960 and 1970, in the main industrial sectors, the exploitation of only 54, that is, 1.1 percent, has been reported. These patents are taken out solely to protect or monopolize the flow of imports of the countries that grant them[30] and actually entail costs that are harmful to the country concerned, both in the short term, in terms of the foreign exchange that must be assigned to the import of the products or the procedure patented, as well as in the long term since they take away incentives to innovation and local technological development and, conse-

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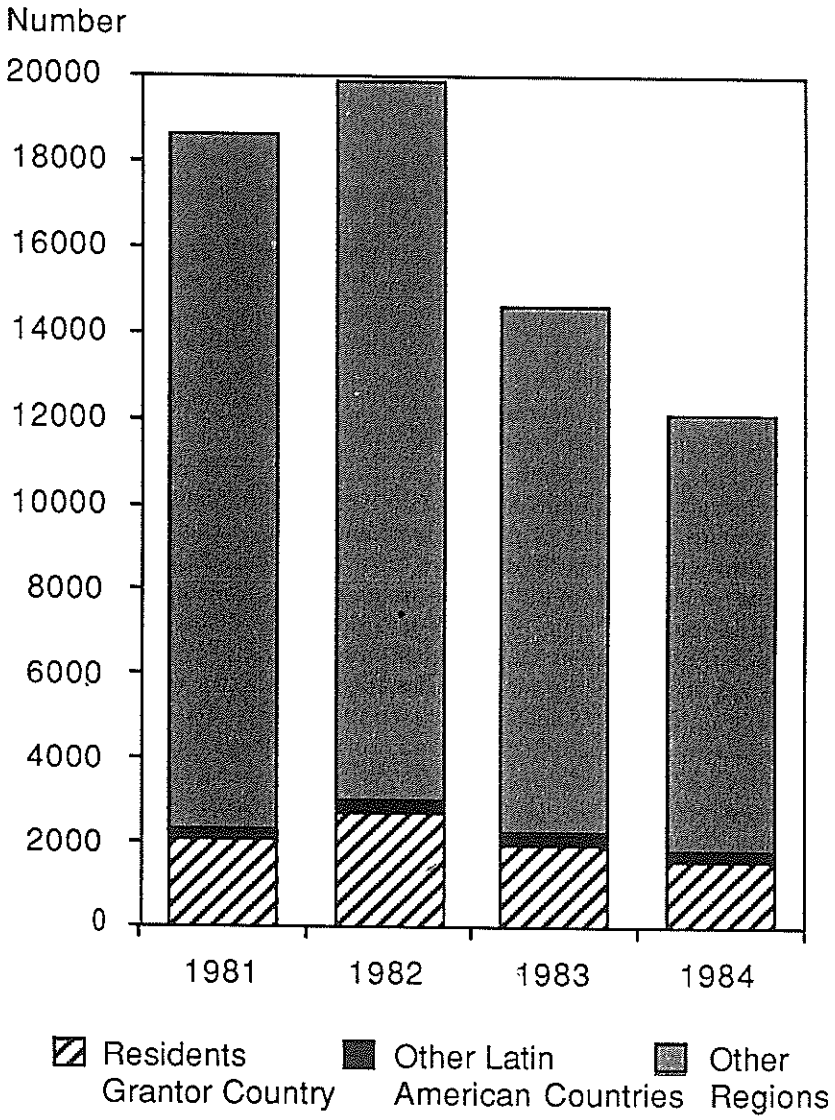
[28]For example, in 1984 Brazil granted 4,887 patents to applicants from Brazil and from the rest of the world, whereas in the same year, Japanese inventors alone obtained 11,110 patents from the United States Patent Office (NISTADS 1986).

[29]". . . the degree of utilization of the patents in general, and the utilization of patents belonging to foreigners in particular, is extremely low and barely exceeds 5 to 10 percent of the total" (UNCTAD 1975, p. 43).

[30]UNCTAD 1975.

Figure IX-6. Patents Granted in Latin America to Residents of Grantor Country, of Other Latin American Countries, and of Other Regions, 1981-1984



Source: World Intellectual Property Organization

quently, lead to the non-utilization of national scientific and technological capacity.

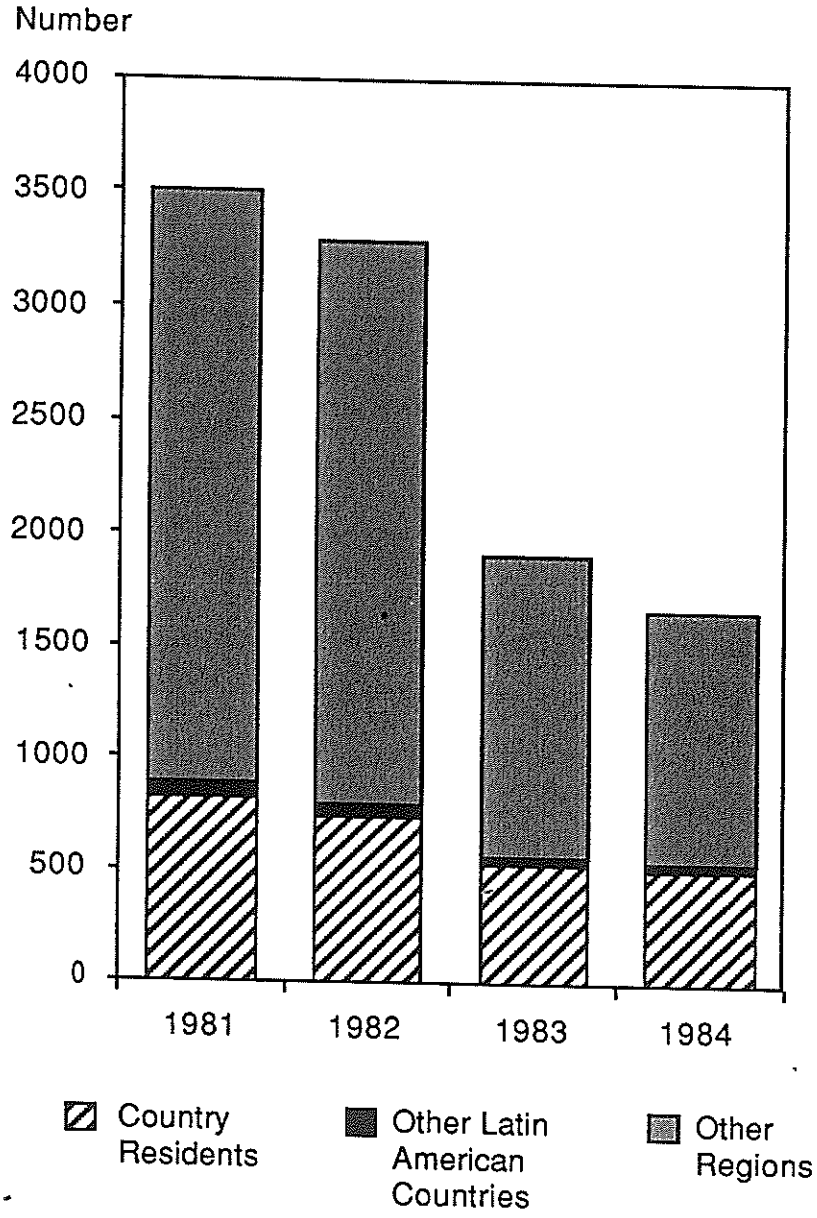
Figures IX-7 to IX-10 illustrate the differences in this regard among some of the countries of the region. Although the percentage of grants to foreigners in most of them more than exceeds the patents granted to residents, the cases of Argentina and Cuba are exceptional because of a rather large proportion of patents granted to their own residents. Mention may also be made of Ecuador, a country in which the proportion of patents granted to residents of other countries of the region is significantly larger than that of the other countries of Latin America. Finally, Chile represents the case of the country in which almost all patents are granted to residents of countries outside the region.

Figure IX-11 shows the distribution of the patents applied for and granted by Latin American and Caribbean countries to residents of other countries of the region. As we have already seen, the total number of these patents is very small and their share of total patents applied for and granted is insignificant. However, the national distribution of that group of patents gives rise to certain questions that require greater study if they are to be answered: Why is it, for example, that Panama is one of the countries that applies for most patents within the region? Why is it that Brazil, one of the most promising markets for products that could be invented in Latin America, is so little sought after by applicants for patents? What is it in their respective science and technology policies that determines the levels of patenting shown by the different countries of the region? etc.

International Scientific Prizes

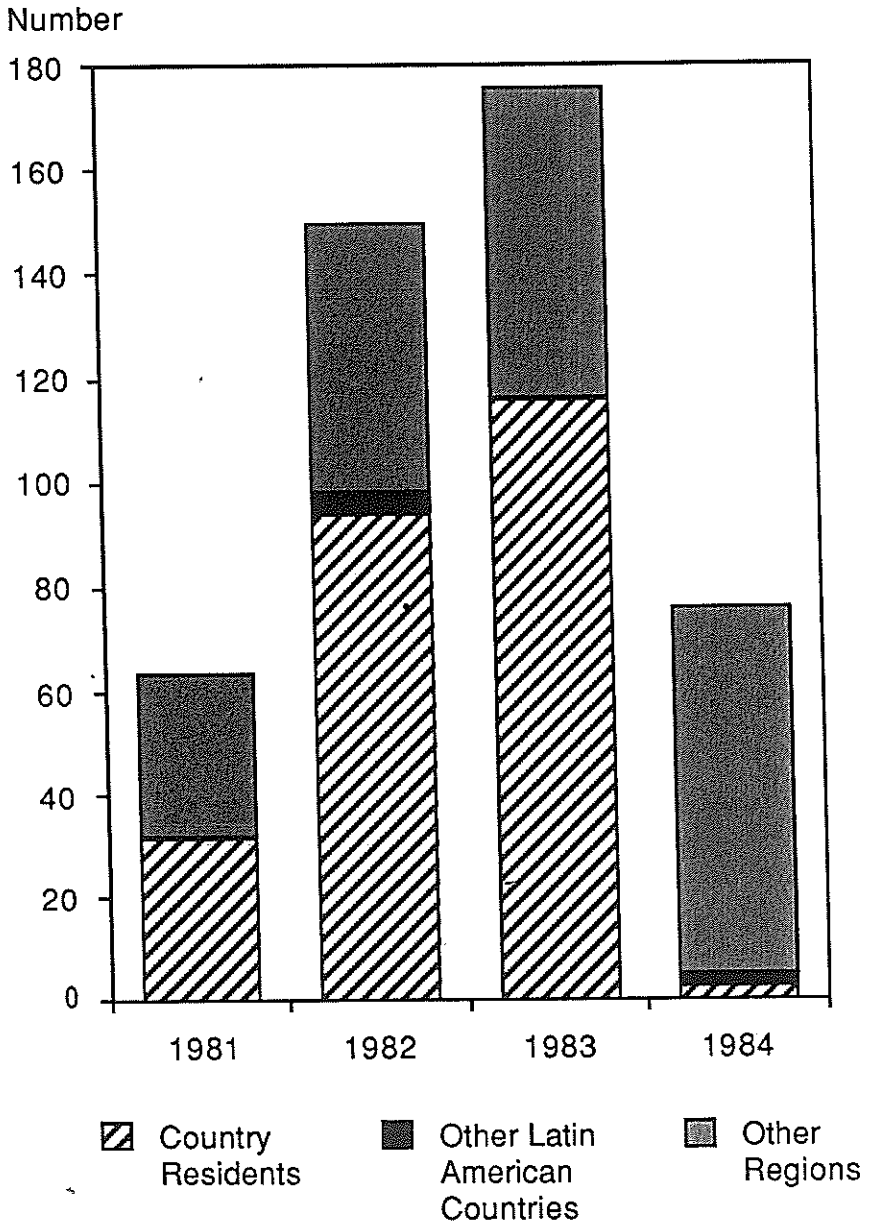
The number of citations to the scientific publications of a country is a token of the recognition the international scientific community grants to the output of its investigators. However, as mentioned earlier, a count of citations as a measure of the quality of the output of research can be biased by a variety of factors and must be considered more a measurement of impact, especially on the international scientific community. To measure the quality of the output of a scientific undertaking is a major methodological problem. Merely to define what is understood by quality or excellence in agreed or acceptable terms, in different countries and in different social, economic and cultural environments, is a serious problem per se, since in any event such a definition depends on the objectives sought by the scientific and technological system at a given time. Since the output of scientific research is knowledge, and knowledge is rather intangible, how to measure the quality of the output of research may be the subject of extensive discussion and result in wide disagreements. No attempt will be made here to define the terms of such a discussion and much less to attempt to settle it. Rather, an effort will be made to use a new way of evaluating the results of the efforts made by scientific investigators on the basis of the explicit recognition of the quality of a study as indicated by the award of prizes or academic recognition at the

Figure IX-7. Patents Granted in Argentina to Residents of Argentina, of Other Latin American Countries, and of Other Regions, 1981-1984



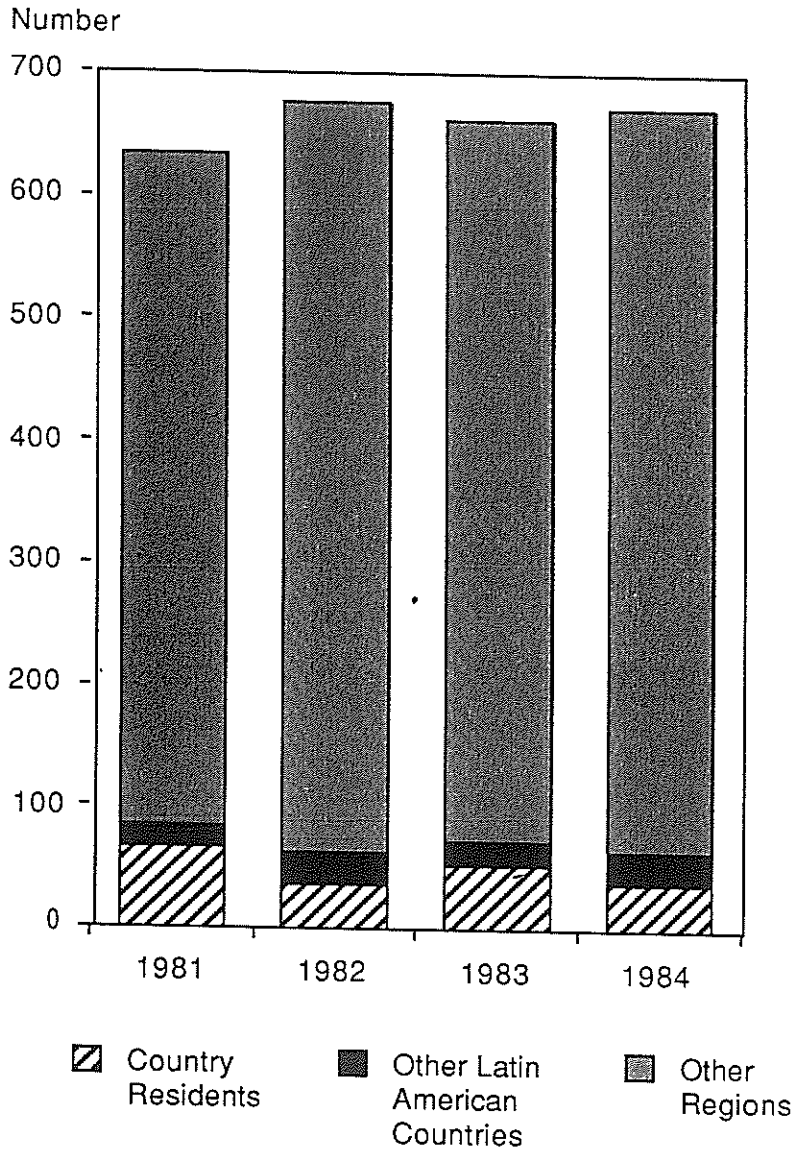
Source: World Intellectual Property Organization

Figure IX-8. Patents Granted in Cuba to Residents of Cuba, of Other Latin American Countries, and of Other Regions, 1981-1984



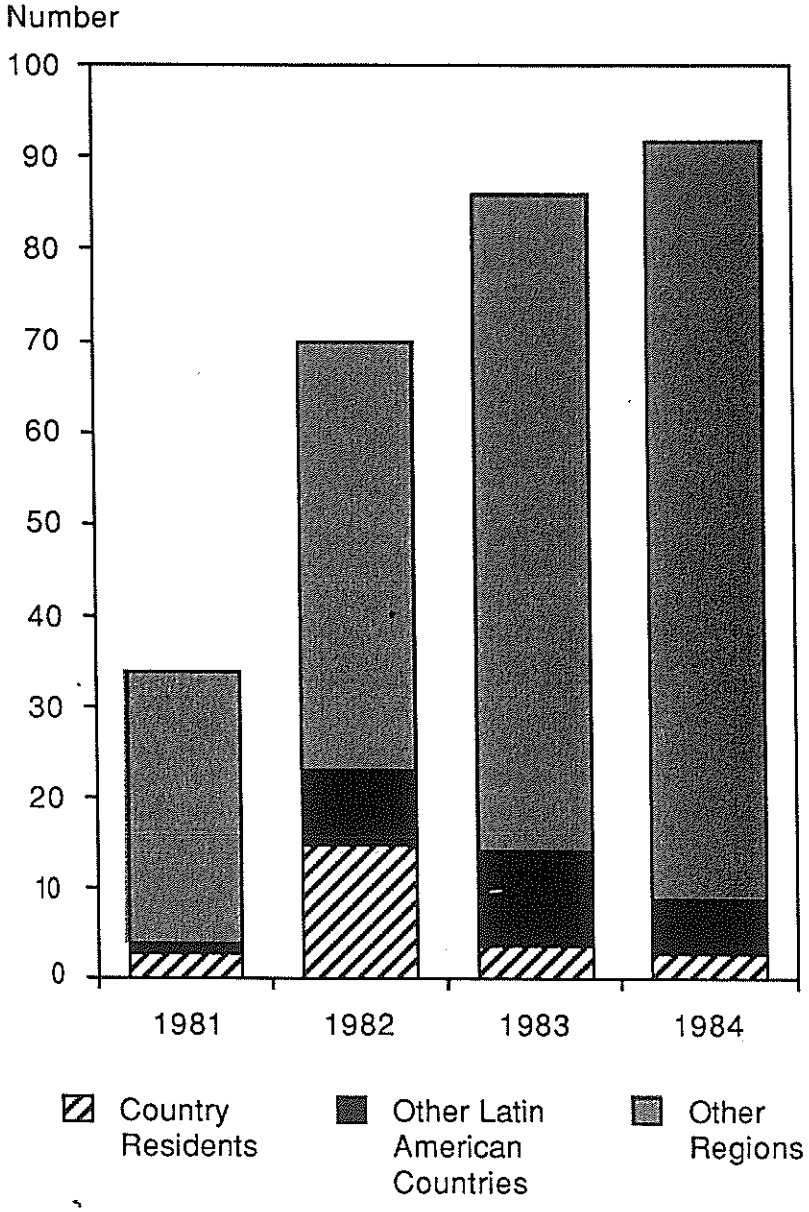
Source: World Intellectual Property Organization

Figure IX-9. Patents Granted in Chile to Residents of Chile, of Other Latin American Countries, and of Other Regions, 1981-1984



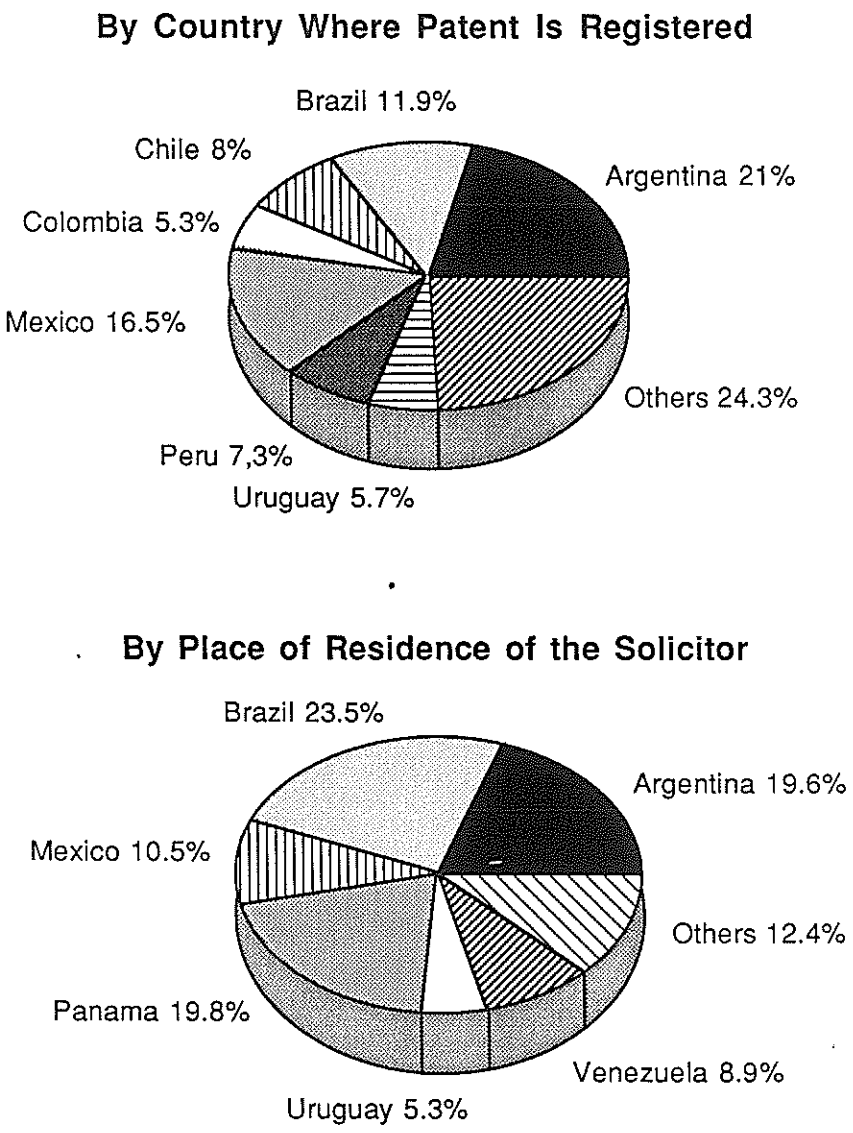
Source: World Intellectual Property Organization

Figure IX-10. Patents Granted in Ecuador to Residents of Ecuador, of Other Latin American Countries, and of Other Regions, 1981-1984



Source: World Intellectual Property Organization.

Figure IX-11
Distribution of Patents Requested by Latin Americans in Latin America (Cumulative Total, 1981-1985)



Source: World Intellectual Property Organization (WIPO)

international level. We shall therefore focus only on the prizes and, of these, on the Nobel prizes since it was not possible to obtain sufficiently detailed and comparable information concerning other international prizes and other scientific honors such as appointments to scientific academies and other prestigious associations at the international level.

The most prestigious scientific prize at the world level is the Nobel prize, which since 1901 has been awarded in the areas of chemistry, physics and medicine. Up to 1984, the studies of 321 research workers throughout the world had been recognized: 104 in physics, 97 in chemistry and 120 in medicine (see Table IX-12). Scientists of developed countries account for almost all the prizes in the three fields, and are headed by scientists from the United States, which accounts for more than one third of the total prizewinners. As already noted in the case of other indicators, a few countries account for a large part of the prizes. Thus, in physics, the United States accounts for just over one third of the prizewinners, and together with the United Kingdom and Germany, is responsible for 66.3 percent of the total number of prizewinners. In chemistry, the first three countries (United States, Germany and the United Kingdom) are responsible for 72.1 percent of the total number of prizewinners and in this case the proportions are equally divided among the first three countries. Finally, in medicine, the same three countries account for 68.4 percent of the prizewinners.

The developing countries accounted for three prizewinners in physics (all from Asian countries: Pakistan, India and China); one prizewinner in chemistry and two in medicine; only six prizewinners in all, that is less than 2 percent of the total number. Three prizewinners in chemistry and medicine belong to Latin America and all are of Argentine nationality. Two of them were awarded their prizes for medical research studies; Dr. Bernardo Houssay[31] in 1947, and in 1948, Dr. Cesar Milstein,[32] who works in the Molecular Biology Laboratory of the British Medical Research Council in Cambridge. The other prize winner, this time in the field of chemistry, was Dr. Luis Federico Leloir in 1970.

Since 1969, the Nobel Memorial Prize in economics has also been awarded, and up to 1984, 22 research workers received it. Of the prize winners up to that date, 12 or 54.5 percent, were United States citizens and the remainder represented other industrialized countries with the exception of one prizewinner from a developing country. He was Sir Arthur Lewis, born in Saint Lucia, British West Indies, who shared it in 1979 with Theodore W. Schultz, of the United States.

There are no prizes of comparable prestige in other social sciences, and since data on publications in this field are reported in certain cases together

[31]Subsequently, the Organization of American States created a regional scientific prize bearing his name.

[32]Milstein received the prize for the development of the monoclonal antibody technique, together with the German scientist Georges J. F. Kohler.

Table IX-12. Nationality of scientists who were awarded Nobel Prizes, 1901–1984

Country or group of countries	Physics		Chemistry		Medicine	
	Number	Percentage	Number	Percentage	Number	Percentage
United States	38	36.5	24	24.7	56	46.7
United Kingdom	17	16.3	22	22.7	17	14.2
Germany	14	13.5	24	24.7	9	7.5
France	7	6.7	5	5.1	7	5.8
Other industrialized countries	25	24.0	21	21.6	29	24.2
Developing countries	3	2.9	1	1.0	2	1.7
Latin America[1]	(0)	(0.0)	(1)	(1.0)	(2)	(1.7)
Total[2]	104	100.0	97	100.0	120	100.0

[1] The Latin American data are part of those for the developing countries.
[2] The total corresponds to the number of scientists awarded the prize and not to the number of times the prize was awarded.
Source: GRADE.

with those on the humanities and the arts (Table IX-10), we refer below to the Nobel prize for literature as an indicator. Only 4 (5.1 percent) of a total of 78 winners of the Nobel prize for literature between 1901 and 1984, come from Latin America. They were: Gabriela Mistral (1945) and Pablo Neruda (1971), both from Chile; Miguel Angel Asturias (1967) from Guatemala; and Gabriel Garcia Marquez (1982) from Colombia. However, the performance of Latin America and the Caribbean is slightly better in this case, especially compared with other developing country areas.

Final Comments

Although it is recognized that the measurement of the output of scientific research and, to a lesser extent, of technological research involves serious problems, the use of various indicators shows that the output of Latin America have been relatively insignificant both if compared with that of the industrialized countries and with what was to be expected, given the population and gross product of the region. Furthermore, the results obtained do not reflect the number of scientists and engineers engaged in R & D in Latin America. It is not much of a consolation that the results of other developing regions are no better.

Within the region, the output of scientific and technological activity is concentrated in a few countries. They are: Argentina, Brazil, Chile, Mexico and Venezuela. Although towards the end of the period under review they together represented just over 70 percent of the population, and 80 percent of the GDP of the region, they were responsible for almost 90 percent of the scientific publications. The poor performance of some countries that were outranked in various indicators by rather small countries, is noteworthy. Noteworthy also is the improvement in the performance of Brazil, which in 1975 outranked Argentina in the number of scientific publications and from then on became the regional leader.

From the point of view of subject matter, the scientific publications of the region emphasize the medical sciences and biology; however, there is a trend towards a decline in the share of the medical sciences.

The percentage of citations of Latin American authors in the international scientific literature, a measure of their possible impact, is rather low and has fluctuated around 0.6 of the world total. The countries with the largest number of citations are those that have the largest number of publications and are responsible for more than 90 percent of the regional total. The areas of Latin American science with the largest number of references to studies that were published in 1973 are: clinical medicine, biomedical research and the earth sciences; and in 1980: the earth sciences, biology and psychology.

Again, in the social sciences and humanities the region shows a level of publications below that expected and even more so than in the natural sciences, which is surprising.

The number of patents applied for and granted in Latin America is a

small proportion of the world total. Between 1981 and 1984 it represented 2.4 percent of the applications and 4 percent of the grants. The same five countries that accounted for the largest number of scientific publications accounted for 98 percent of the patent applications and 89 percent of the patent grants between 1978 and 1984. Although patents do not adequately represent the level of technological innovation, the high proportion of patents granted to nonresidents in Latin America is noteworthy: 80 percent of the total in the period 1978–1984. This phenomenon, which is a world phenomenon, appears to be aggravated in the region. Furthermore, the Latin American market does not appear to be very important from the point of view of patents sought in it by inventors of the countries of the region.

The proportion of Nobel prizes received by Latin America is rather low but represents 50 percent of the total awarded to citizens of developing countries between 1901 and 1984. The three prizes awarded to Latin America were obtained by Argentine scientists.

It is to be expected that the counting, comparison and analysis of the results of applying various output indicators, which is practically begun here for some indicators, will continue in the region for the purpose of improving existing indicators and expanding their coverage and refining measurement. In addition, studies designed to generate new and better output indicators for scientific and technological activity should be undertaken. They will not only be of use in the better planning and follow-up of science and technology projects, but will also contribute to a better linkage with policy formulation activities and the planning of economic and social investments, which should be assigned priority in the region.

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