
Special Report: Scientific Communication



The latter half of this century has witnessed a proliferation of scientific information as well as remarkable advances in ways of communicating that information. Both researchers and policymakers throughout the Americas need knowledge about the new technologies that are available in order for their countries to fully participate in this information revolution and reap its benefits. To address that need, the "International Seminar on the Challenges of the Information Era: Agents and Users" was held in São Paulo on 18–20 October 1994, under the sponsorship of the Pan American Health Organization and PAHO's Latin American and Caribbean Center on Health Sciences Information (BIREME). One of the round tables at the seminar focused on scientific production and quality recognition. This special report features the text of a presentation by Dr. Eugene Garfield, who explains how quantitative analysis of scientific publishing in different countries can elucidate national research policies and be useful in guiding them.

Quantitative Analysis of the Scientific Literature and its Implications for Science Policymaking in Latin America and the Caribbean²

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I have been asked to address the methodologies that I and others have developed over the years—mainly using the *Science Citation Index* database of the Institute for Scientific Information (ISI)—to

examine the productivity and impact of scientific research in individual nations and regions of the world. I will also discuss how these techniques could be used to formulate and reinforce successful

²Based on a lecture titled "Publication and National Research Policies: Quantitative Analysis of the Scientific Literature and its Implications for Science Policymaking," delivered on 19 October 1994 in São Paulo. A number of the charts used to illustrate the lecture, copies of which are available from the author, are not reproduced here because of space limitations. These include productivity, impact, and citation data for Argen-

tina, Brazil, Chile, Mexico, and Venezuela, with graphical comparisons for specialties such as molecular biology, neuroscience, pharmacology, etc.; lists of most cited Latin American authors and papers in clinical medicine; and citation analyses of tropical medicine.

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publication and research policies in developed and developing nations.

While I am perhaps best known for introducing the *Science Citation Index (SCI)* as a tool for information retrieval, I have also now become identified with the growth of interest in bibliometrics or scientometrics—quantitative studies of the scientific literature. The *SCI* has become a very valuable, if not unique, source of data for such studies. To set the record right, however, I must tell you that the *SCI* was created first as an information retrieval tool and its use as a measurement instrument came later, although this latter use often appears to be better known.

Let us survey the scientific literature of Latin America and the Caribbean, as represented in the ISI database, in an attempt to better understand the extent and nature of the output and impact of research from this part of the world.

First, it should be recognized that the *SCI* is not comprehensive in its coverage of journals published worldwide. ISI's journal coverage for the *SCI* and all other products is *selective*.

Currently, ISI indexes about 3 300 journals for the *SCI*, all peer reviewed and internationally influential. This selective coverage is not merely a matter of economics: it reflects a virtual law of nature with regard to the use of the journal literature. Just a handful of journals in any field account for the lion's share of the really important, frequently read, and frequently cited journals.

Thus, what the ISI database represents is the set of journals that constitute the internationally influential literature. It does not represent the science of any given country or region as a whole, but it does represent the portion of research that is published within and cited within the internationally elite literature. Beyond that, it generally represents the best science performed in any nation.

ISI has indexed only about a dozen science journals published in Latin America in the last two decades—a few each from Argentina, Brazil, Chile, and Mexico. While the number of journals is small, both absolutely and relative to journals from other parts of the world indexed for the *SCI*, I hasten to say that the contribution of Latin American researchers to the *SCI* is much larger than just the articles published in these few journals. We identify Latin American and Caribbean papers as those that carry an address of a Latin American or Caribbean institution, and in this way we can detect the appearance of researchers based in these countries among the select journal literature indexed by ISI.

The Latin American contribution to the internationally influential or elite literature seems to be increasing. We are currently recording about 10 000 papers by Latin American researchers in the *SCI* out of approximately 650 000 items indexed annually. That is 1.5%, which is up from a 1% world share in the 1970s. While these 10 000 papers are clearly a small portion of Latin American research output, their influence is outsized, since they appear in top journals with worldwide readership and high standards for accepting papers.

Of course, key research is communicated in regional or local journals not indexed by ISI, which serve as important, even essential, vehicles for communication for members of a local or regional community. A larger and more multidimensional picture of research in Latin America and the Caribbean could be obtained if it were based on data that included such journals. Alas, such a database does not yet exist, although I have suggested for some years that a *Latin American Science Citation Index* would be an interesting undertaking. But for the moment we'll use what we have—the *SCI*—to examine these countries' partic-

ipation in the international journal literature.

Table 1 provides a summary of the number of papers indexed by ISI from each of 31 Latin American and Caribbean nations between 1981 and 1993. All fields of science are taken into account, from biomedicine to astrophysics. This is a special dataset prepared recently at ISI called the Latin American Science Indicators on Diskette. It is a database of summary publication and citation data on papers from these 31 nations, divided by subject ac-

Table 1. Scientific publication output of Latin American and Caribbean countries, 1981–1993, in all fields of science, as represented in ISI's Latin American Science Indicators Database.

Country	No. of papers
Brazil	36 748
Argentina	25 586
Mexico	17 026
Chile	15 760
Venezuela	6 142
Colombia	1 959
Cuba	1 509
Peru	1 344
Jamaica	1 157
Costa Rica	1 098
Uruguay	980
Trinidad and Tobago	748
Panama	700
Guatemala	587
Ecuador	382
Bolivia	337
Barbados	229
Guadeloupe	225
Dominican Republic	205
West Indian Assoc. States	199
French Guiana	144
Haiti	120
Paraguay	119
Honduras	108
Guyana	99
Martinique	80
Nicaragua	78
Netherlands Antilles	77
El Salvador	56
Suriname	46
Bahamas	33

Source: ISI, Latin American Science Indicators on Diskette, 1981–1993.

ording to the field divisions used in the SCI. As the table shows, a disproportionate share of the literature is contributed by a few countries: Brazil, Argentina, Mexico, Chile, and Venezuela.

In terms of total citations, these same five countries dominate, and in the same order (Table 2). Naturally, those nations or institutions that publish a lot tend to

Table 2. Citations of scientific papers from Latin American and Caribbean countries, 1981–1993, in all fields of science, as represented in ISI's Latin American Science Indicators Database.

Country	Rank in output*	No. of citations
Brazil	1	120 482
Argentina	2	79 715
Mexico	3	69 002
Chile	4	51 159
Venezuela	5	27 332
Colombia	6	8 610
Jamaica	9	6 971
Peru	8	6 402
Panama	13	5 137
Costa Rica	10	4 997
Cuba	7	3 463
Guatemala	14	3 189
Uruguay	11	3 152
Trinidad and Tobago	12	1 920
Haiti	22	1 160
Ecuador	15	1 119
Bolivia	16	1 042
Dominican Republic	19	965
West Indian Assoc. States	20	764
Barbados	17	716
French Guiana	21	629
Guadeloupe	18	556
Martinique	26	477
Netherlands Antilles	28	381
Bahamas	31	372
Guyana	25	284
Paraguay	23	245
Honduras	24	238
El Salvador	29	201
Nicaragua	27	195
Suriname	30	111

Source: ISI, Latin American Science Indicators on Diskette, 1981–1993.

*See Table 1.

be cited proportionately. To compare the performance of different-sized research-producing entities, the total number of citations is divided by the number of papers to obtain "citation impact," a weighted measure of research influence.

Table 3 ranks Latin American and Caribbean countries (those for which at least 1 000 papers were indexed over the period) by citation impact, or citations per paper. Some much smaller countries turn up at the top of this list. When the citations per paper score of a country is set relative to the average score for the region (far right column), we obtain a measure of relative regional impact. A score of 1.00 would represent an impact equal to the regional average. However, these numbers are determined to some degree by the mix of research pursued in

each nation. Different fields of research exhibit different average rates of citation. Countries that focus on the basic biological sciences tend to show higher scores than those that concentrate on technology and applied research. It is really necessary to compare national performance field by field.

As this is a conference on health sciences information, let us now take a closer look at Latin American and Caribbean contributions to the life sciences and clinical medicine (as represented in the journals indexed for Current Contents/Life Sciences and Current Contents/Clinical Medicine). Figures 1 and 2 show the number of papers and the world share, respectively, by Latin American and Caribbean authors in the life sciences and in clinical medicine. Something of a spike can be seen in the life sciences in the mid-1980s. Also evident is steady growth in number of papers and in world share, especially in the life sciences, since 1989.

Figures 3 and 4 show Latin America and the Caribbean's citation impact in life sciences and clinical medicine, respectively, compared with that of the world, modeled in five-year windows of papers published and cited during the same five years. Note that the gap between this region and the world is smaller in clinical medicine than in the basic biological sciences, and that the gap in clinical medicine is closing in recent years.

Tables 4 and 5 illustrate the performance of individual Latin American and Caribbean countries (among those that published a significant number of papers) in these two areas. In the life sciences (Table 4), Brazil and Argentina are the big producers. Mexico produces less than half as many papers as does Argentina, but its citation total is nearly as high. Colombia, Jamaica, and Peru, while producing far fewer papers in the life sciences than the other countries, have high per-paper citation scores.

Table 3. Citation impact (citations per paper) and relative regional citation impact for Latin American and Caribbean countries, 1981–1993, in all fields of science, as represented in ISI's Latin American Science Indicators Database.

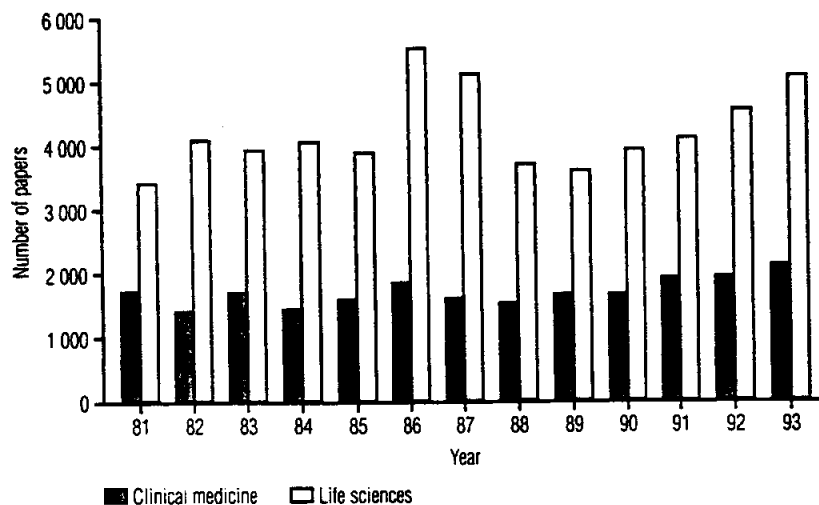
Country*	Citations/ paper	Citations/paper: regional average**
Haiti	9.67	2.76
Panama	7.34	2.10
Jamaica	6.03	1.72
Guatemala	5.43	1.55
Peru	4.76	1.36
Costa Rica	4.55	1.30
Venezuela	4.45	1.27
Colombia	4.40	1.26
Mexico	4.05	1.16
Brazil	3.28	0.94
Chile	3.25	0.93
Uruguay	3.22	0.92
Argentina	3.12	0.89
Bolivia	3.09	0.88
Ecuador	2.93	0.84
Trinidad and Tobago	2.57	0.73
Cuba	2.29	0.65

Source: ISI, Latin American Science Indicators on Diskette, 1981–1993.

*Only countries with 1 000 or more papers indexed over the period are listed.

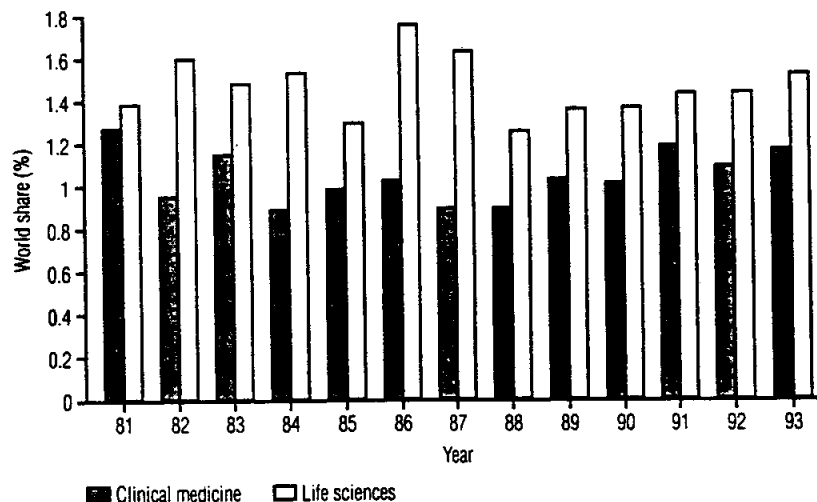
**Ratio of citations/paper for the country to citations/paper for 31 Latin American and Caribbean countries together (1.00 means impact equals regional average).

Figure 1. Number of papers produced annually by Latin American and Caribbean countries in clinical medicine and the life sciences, 1981–1993.



Source: ISI, Science Indicators Database, 1981–1993.

Figure 2. World share of papers produced annually in clinical medicine and the life sciences by Latin American and Caribbean countries, 1981–1993.



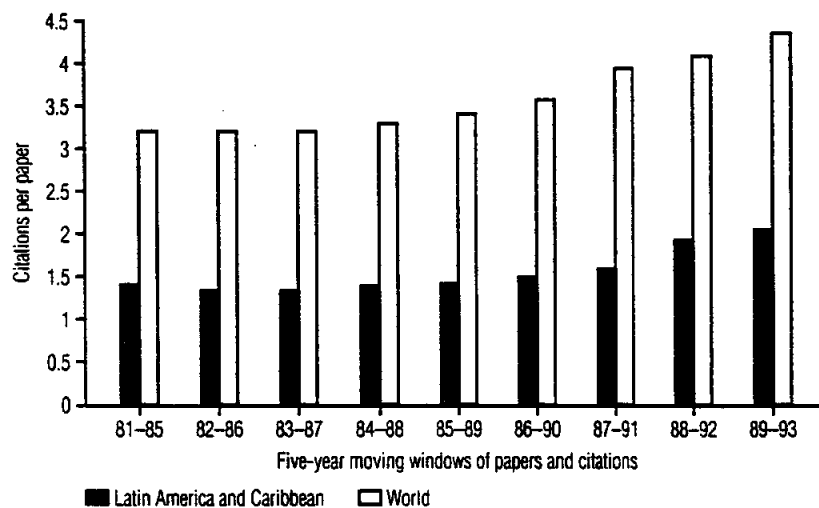
Source: ISI, Science Indicators Database, 1981–1993.

In clinical medicine (Table 5), Brazil is again on top in output, followed in order by Mexico, Chile, and Argentina. Brazil shows the highest citation impact among the large producers, but again Colombia and Peru, among the smaller producers, show high per-paper citation scores. Chile

exhibits an unusually low score in citation impact in the field of clinical medicine.

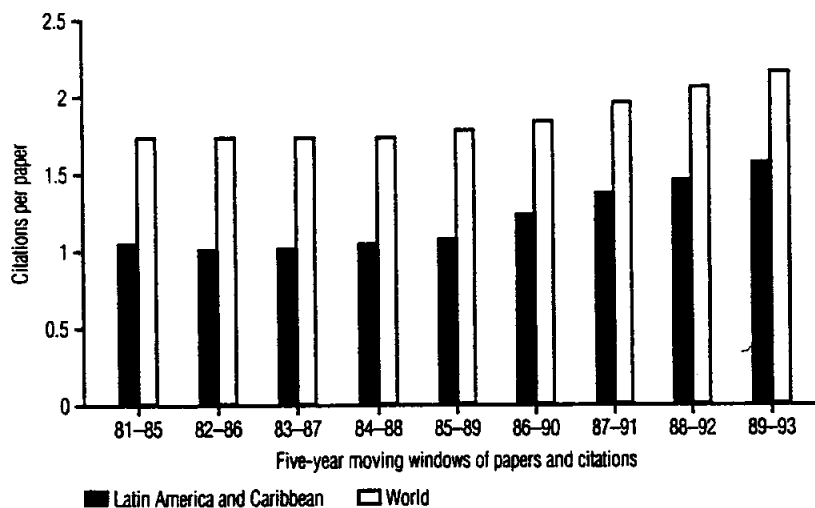
A further breakdown by major field (Table 6) reveals that each of the five largest producers shows different strengths, as judged by the relative impact score. An interesting observation from this list-

Figure 3. Citation impact (citations per paper) of Latin American and Caribbean papers in the life sciences compared to the world average impact in the life sciences, 1981–1993.



Source: ISI, Science Indicators Database, 1981–1993.

Figure 4. Citation impact (citations per paper) of Latin American and Caribbean papers in clinical medicine compared to the world average impact in clinical medicine, 1981–1993.



Source: ISI, Science Indicators Database, 1981–1993.

ing is the uniformly low relative citation impact of all five of these countries in molecular biology, a cutting-edge area of basic biological research.

These publication and citation data can be analyzed at a variety of levels. Here we have been looking at national and regional performance, but one can also

Table 4. Output, citations, and citation impact (citations per paper) of Latin American and Caribbean countries in life sciences, 1981–1993, ranked by total citations.

Rank	Country*	Papers 1981–1993	Citations to 1993	Citations per paper
1	Brazil	19 297	61 495	3.19
2	Argentina	14 086	43 316	3.08
3	Mexico	6 839	37 551	5.49
4	Chile	7 282	21 528	2.96
5	Venezuela	2 461	14 658	5.96
6	Colombia	810	5 474	6.76
7	Jamaica	592	5 102	8.62
8	Peru	633	3 995	6.31
9	Uruguay	628	2 435	3.88
10	Cuba	678	2 137	3.15

Source: ISI, Science Indicators Database, 1981–1993.

*Only countries with 500 or more papers indexed over the period are listed.

Table 5. Output, citations, and citation impact (citations per paper) of Latin American and Caribbean countries in clinical medicine, 1981–1993, ranked by total citations.

Rank	Country*	Papers 1981–1993	Citations to 1993	Citations per paper
1	Brazil	5 590	16 346	2.92
2	Mexico	4 535	12 766	2.81
3	Argentina	3 147	8 507	2.70
4	Chile	4 371	7 524	1.72
5	Venezuela	998	4 549	4.56
6	Jamaica	875	3 934	4.50
7	Colombia	486	2 868	5.90
8	Peru	412	2 641	6.41
9	Uruguay	305	1 409	4.62
10	Cuba	320	884	2.76

Source: ISI, Science Indicators Database, 1981–1993.

*Only countries with 300 or more papers indexed over the period are listed.

analyze provincial, institutional, departmental, and individual performance in terms of output and impact. Of course, publication and citation counts are only some measures of research performance and must be used carefully—especially at the level of an individual's record where the numbers may be quite small. Peer judgment is the main tool for intelligent review of an individual's research record.

The database also allowed extraction of a list of the most cited papers in clinical medicine in the period 1981–1993 that carry at least one Latin American author address. It is noteworthy that these papers also carried author addresses from other nations, and thus represent multinational collaborations. They were pub-

lished in high-impact journals: *New England Journal of Medicine*, *Journal of the American Medical Association*, *The Lancet*. If one is concerned about visibility, multinational collaboration and publication in leading international journals would seem to be a successful strategy. However, that is not a strategy for all or for every type of research. It should be noted that some highly cited papers carried exclusively Latin American author addresses.

The permutations for analysis are nearly endless—people, papers, institutions, regions, countries, fields defined in a thousand different ways. Publication and citation data can be used not just to evaluate performance but to monitor research activity and impact in a given field

Table 6. Output and relative impact statistics for the five largest producers of scientific publications among Latin American countries, 1981–1993, in clinical medicine and life science fields ranked by relative citation impact, as represented in ISI's National Science Indicators on Diskette Database.

Country	Rank	Field	Papers 1981–1993	Relative impact*
Argentina	1	Clinical medicine	1 805	0.62
	2	Neurosciences	786	0.54
	3	Pharmacology	718	0.51
	4	Immunology	363	0.39
	5	Biol. & biochem.	4 685	0.36
	6	Molecular biology	1 131	0.29
Brazil	1	Immunology	550	0.62
	2	Clinical medicine	4 028	0.53
	3	Neurosciences	773	0.51
	4	Pharmacology	870	0.46
	5	Biol. & biochem.	7 727	0.27
	6	Molecular biology	2 585	0.25
Chile	1	Immunology	82	0.76
	2	Pharmacology	395	0.51
	3	Neurosciences	307	0.49
	4	Biol. & biochem.	1 701	0.47
	5	Clinical medicine	727	0.37
	6	Molecular biology	395	0.37
Mexico	1	Immunology	207	0.70
	2	Neurosciences	792	0.57
	3	Biol. & biochem.	1 820	0.53
	4	Clinical medicine	3 404	0.49
	5	Pharmacology	511	0.48
	6	Molecular biology	884	0.45
Venezuela	1	Clinical medicine	784	0.78
	2	Pharmacology	118	0.66
	3	Neurosciences	179	0.58
	4	Immunology	149	0.58
	5	Biol. & biochem.	755	0.56
	6	Molecular biology	267	0.46

*Relative impact is ratio of citations/paper for the country to world citations/paper (1.00 means impact equals the world average).

(for example, tropical medicine) in a systematic way.

To perform these types of studies and to monitor the impact of research and not merely its output requires storing data in a way that permits both information retrieval and quantitative analysis. The advent of fast PCs with much more memory and new relational database management software has made collection of these materials fairly easy. These same tools and data should be used by science policymakers and the staff of science information centers throughout the region.

In summary, I would like to present six observations or recommendations inspired by these data, this meeting, and my past experience in studying science in Latin America.

1. Quantitative analysis of the literature can give science policymakers a unique and systematic overview of the research they administer and fund, in terms of national, institutional, and individual performance (output and impact). Inventories of highly cited papers can reveal significant discoveries made by a nation's or region's scientists.

2. Achievement in science is not democratically distributed, as citation data show. A small group of individual investigators represents an elite force that disproportionately contributes to the advance of knowledge. Recognizing and providing for this elite would seem a logical way to efficiently and systematically improve a nation's science base. Special regional interests or needs should also be recognized.

3. North-South collaborations should be fostered, as well as South-South collaborations. Numerous citation studies have demonstrated that multinationally authored papers are typically more cited than those from a single nation.

4. To more successfully communicate the results of research done in Latin America, regional journals should be started. The Europeans have shown the way in

this regard. Many national or single-association journals have done much better after being consolidated and reconfigured as *The European Journal of* ____.

5. A special effort should be made to use—and train students to use—the most advanced technology available for information retrieval, quantitative analysis of the literature, and scholarly communication (e-mail, the Internet, etc.). Technology can and is creating more and more "collaborations" every day.

6. After all relevant data are collected and digested, a decision about publication and national science policies and priorities requires individual judgment. More and better information can provide a better perspective for making decisions, but these decisions must still be made by individuals. So, by all means, choose wise editors and policymakers.



Symposium on Cutaneous Infection and Therapy

The Third International Symposium on Cutaneous Fungal, Bacterial, and Viral Infection and Therapy will be held on 14–17 September 1995 in San Francisco, California, U.S.A. The symposium will bring together leading authorities from academic, government, and commercial organizations to give presentations and lead discussions about key issues in diagnosis and management of cutaneous infections. Poster presentations are also being solicited. The deadline for submission of a poster abstract is 1 June 1995.

The most recent advances and state-of-the-art techniques in treating these infections will be reviewed, as well as the risk-benefit ratio of the new diagnostic and treatment modalities. Part of the program will be devoted to opportunistic infections in AIDS and immunocompromised patients. Since fungal, bacterial, and viral skin infections are among the most common cutaneous afflictions in HIV-infected persons, recognition of the patterns of these infections is important for correct diagnosis and improved case management.

More information, as well as registration and abstract forms, can be obtained from the Symposium Secretariat, Office of Continuing Medical Education, Room MCB-630, Box 0742, University of California, San Francisco, CA 94143-0742; telephone (415) 476-5808; fax (415) 476-0318. Reduced fees are being offered for advance registration (payment postmarked by 30 June).