

# Biological sciences in Chile and South America, 1981-1991: A citationist perspective. Output data and specialty area impact trends

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*The purpose of this report is to examine the biological sciences in Chile and South America in bibliographic terms -the number of papers each nation published from 1981-1991 and the number of citations to them in the international research literature. The database consists of 34,600 biological science papers from Argentina, Brazil, Chile, and Venezuela in the 1981-1991 Science Citation Index® files of the Institute for Scientific Information®. Twelve specialty areas were selected to represent the biological sciences of special interest to Chile: animal sciences, biochemistry/biophysics, environmental sciences, experimental biology/medicine, immunology, microbiology/cell biology, molecular biology/genetics, neurosciences, pharmacology, physiology, plant sciences, and reproductive sciences. Data are reported on the number of papers in these fields, combined, by authors based in Chile and other South American nations. In addition, time-series trends in the impact (average citations per paper) of Chilean research relative to South America as a whole, overall and in each specialty, are presented and discussed.*

**Key words:** *bibliometry, Chile, citation, scientific productivity, scientometry, South America.*

## INTRODUCTION

In recent years it has become standard practice to evaluate scientific performance in quantitative, bibliometric terms (5-8). That is, the relative stature of various nations, institutions, departments, etc. is now often indicated by literature-based rankings of output (numbers of papers), impact (average citation frequency), citedness (proportion of cited and uncited papers), and so on. These bibliometric indicators are increasingly used because they are objective, quantitative, and readily obtained from the major secondary information services. They are also reliable and valid measures of impact, stature, prominence, correlating highly with subjective expert and peer assessments (1-4, 9-11). And with the availability of electronic bibliographic databases, the indicators are becoming

more widely, easily, and affordably accessible.

The purpose of this study is to present a scientometric survey of research in the biological sciences from Chile and South America.

## DATA AND METHODS

It should be stressed that the present study is not an exhaustive inventory of the entire publication output of Chile and South America. Rather, it reports on papers from the leading international research journals. Data from the Institute for Scientific Information® (ISI®) consistently show that a relatively small set of journals accounts for the majority of both papers and citations.

Figure 1 illustrates this dominance of a comparative few leading research journals. The data are based on about 4,500 journals covered in the 1989 Journal Citation Reports® (JCR®) volumes of the Science Citation Index® (SCI®). The dashed line shows that just 100 journals account for more than 20 percent of what is published. And the solid line shows that 100 journals account for more than 40 percent of what is cited. Only 600 journals account for more than half of what is published -and over 75 percent of what is cited. By indexing over 7,000 journals, ISI covers substantially more than the most significant journals of international research.

This study includes the four most-productive South American nations in terms of the number of ISI-indexed papers for the period 1981-1991. They are: Argentina, Brazil, Chile and Venezuela. Other nations—for example, Peru, Ecuador, Uruguay, and so on—produced too few papers in the database to be meaningful for analysis.

Twelve specialties are included to represent the “biological sciences”:

- animal sciences;
- biochemistry / biophysics;
- environmental sciences;

- experimental biology / medicine;
- immunology;
- microbiology / cell biology;
- molecular biology / genetics;
- neurosciences;
- pharmacology;
- physiology;
- plant sciences;
- reproductive sciences.

The above specialties were selected in consultation with Chilean scientists to reflect the areas of special national interest and involvement. They also represent some of the largest areas in the biological sciences, as indicated by ISI's data.

ISI's databases of these specialties were searched, and 34,604 papers published from 1981-1992 with at least one author address in Argentina, Brazil, Chile or Venezuela were extracted. Citation data over the same time period were obtained for these papers. Various time-series trendlines were derived for scientometric comparisons of the South American nations: the proportional output of papers for each nation; their average citation impact; their impact relative to the world average and to the South American average. For Chile alone, its impact was compared over time with the South American baseline

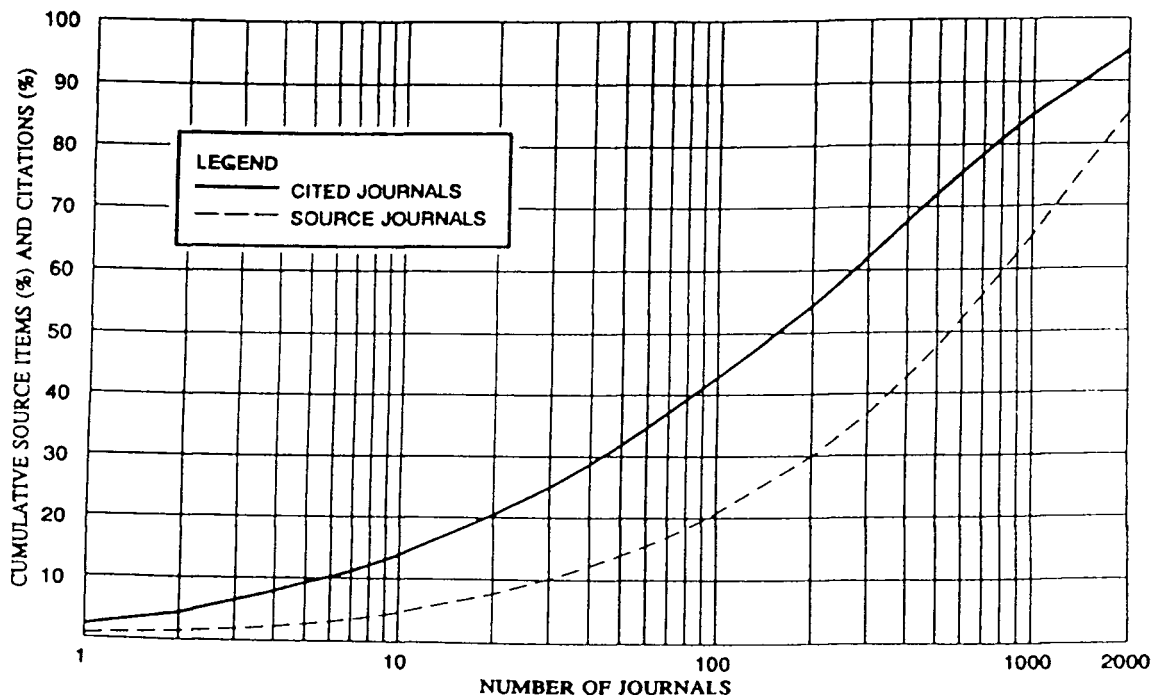


Fig 1. Distribution of published items and citations among science journals (1989 SCI).

in the 12 specialty areas noted above. The database 6,609 ISI-indexed papers from Chile was sorted to rank the most-cited papers, most-productive and highest impact institutions, and most-productive and highest impact authors.

## RESULTS

### *Output Trends*

Table I shows the proportional distribution of the South American biological sciences by each nation. For the overall 1981-1991 period (34,604 papers), Brazil (41.2%) and Argentina (33.7%) account for the largest shares, followed by Chile (19.1%) and Venezuela (6.0%). The table also shows output changes over time. The South American nations produced 2,465 papers in 1981 and 3,048 in 1991, a 24 percent increase. In comparison, the entire SCI database grew by 10 percent over this time. The growth in South American output is not necessarily due to journal coverage changes at ISI.

Twelve journals from these nations were indexed in 1981 and in 1991. The increased output probably indicates that South American researchers are indeed publishing more in the international journals.

Over this time period, Brazil significantly increased its output share -from 39.5 percent in 1981 to 54.2 percent in 1991. In contrast, the others declined -Argentina from 36.2 percent to 28.6 percent, Chile from 17.2 percent to 10.8 percent, and Venezuela from 7.1 percent to 6.5 percent of regional output.

### *Impact Trends*

Output of papers is perhaps the most widely used indicator of scientific performance. Because ISI also indexes references cited by authors in the papers they publish, another quantitative indicator is possible -*impact*, or the average number of citations per paper. Through citations, authors formally acknowledge their use of published research in their own work. The frequency of citation of a paper is thus an objective, quantitative indicator of its general utility or impact. Citation impact does not necessarily indicate impor-

tance, significance, excellence or other subjectively-defined qualities. But impact rankings often agree with subjective peer assessments of quality.

There are various ways to calculate impact. In order to obtain time-series trends, for example, impact may be calculated by using five-year periods that advance one year at a time: 1981-1985, 1982-1986, and so on through 1987-1991. That is, the number of papers published in these five-year periods are aggregated, as are the number of citations they received in the same five-year periods. Impact is then calculated by dividing total citations by total papers.

Figure 2 shows impact trends for each nation over the 11-year period. Venezuela has the highest five-year impact factors, steadily averaging about 2 citations per paper. Chile's impact was the lowest for most of the period before rising rapidly to 1.27, virtually equaling Argentina's impact of 1.32 by 1987-1991.

Another way to calculate impact is to divide citations by the number of papers that were actually cited during these five-year periods. That is, uncited papers are excluded from the calculation. Figure 3 shows cited impact trends for each nation. As previously, Venezuela is the leader for the 11-year period. But Chile's cited impact improves sharply until it equals Venezuela's in the most recent period 1987-1991.

Still another way to view the performance of these nations is to compare their impact relative to a standard baseline -for example, the world average impact factors. But this may not be an appropriate comparison because the world average is dominated by the USA, Western Europe, Scandinavia, and

TABLE I

Proportional distribution of ISI®-indexed biological sciences papers from South America, by nation

| Nation       | 1981-1991 | 1981  | 1991  |
|--------------|-----------|-------|-------|
| Brazil       | 41.2%     | 39.5% | 54.2% |
| Argentina    | 33.7%     | 36.2% | 28.6% |
| Chile        | 19.1%     | 17.2% | 10.8% |
| Venezuela    | 6.0%      | 7.1%  | 6.5%  |
| Total Papers | 34,604    | 2,465 | 3,048 |

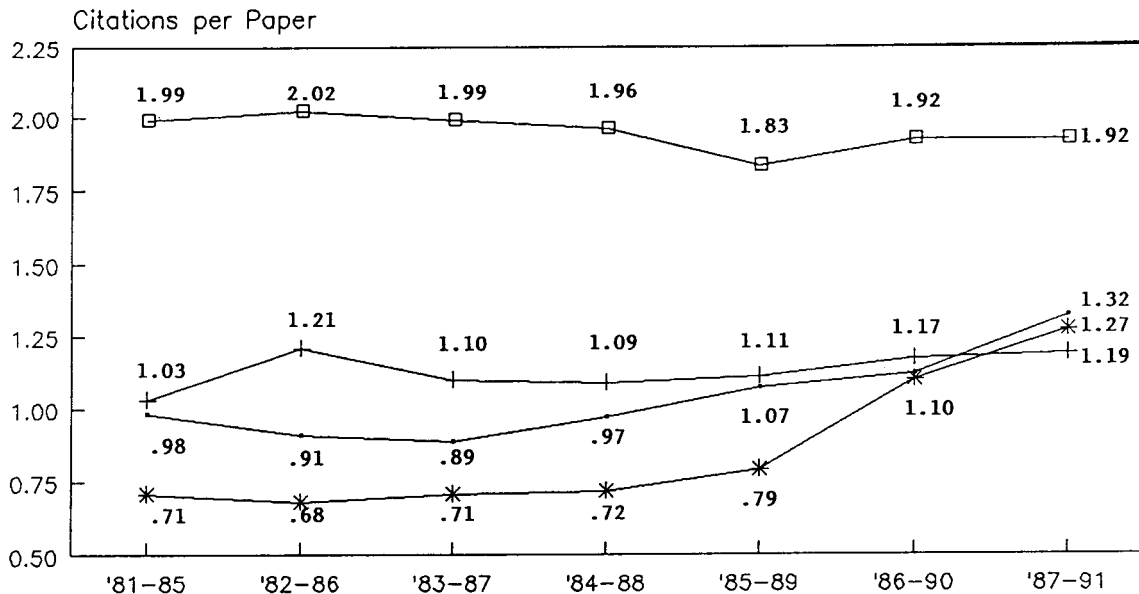


Fig 2. South American biological sciences. 5-year impact trends. ISI science indicators database. •, Argentina; +, Brazil; \*, Chile; □, Venezuela. (Copyright, 1993, ISI).

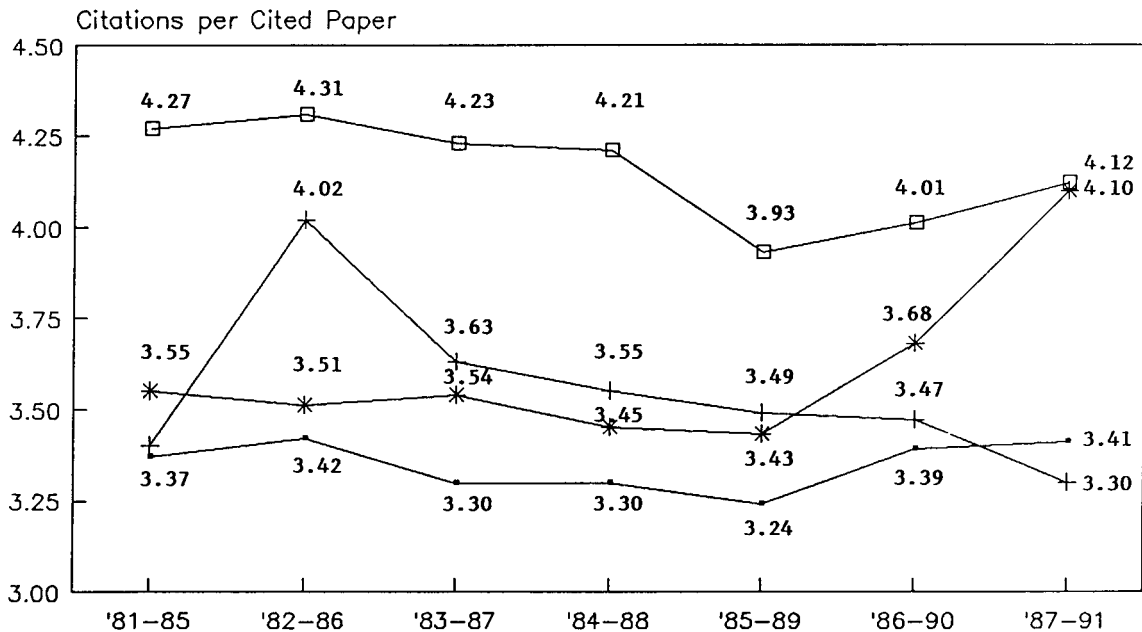


Fig 3. South American biological sciences. 5-year cited impact trends. •, Argentina; +, Brazil; \*, Chile; □, Venezuela. (Copyright, 1993, ISI).

other research “superpowers”. The scientific resources of these nations far exceed those of South America -greater research funding, laboratories equipped with the most modern and sophisticated instruments, freedom to pursue basic research unrestricted by national needs and priorities, attraction of the best and brightest graduate students from around the world, and so on.

Instead, each of the South American nations in this study is compared with the average for South America as a whole. No doubt there are many differences between South American nations as well. But they are more comparable to themselves than they are to the dominant research superpowers.

Figure 4 shows how the five-year cited impacts of Argentina, Brazil, Chile and Ve-

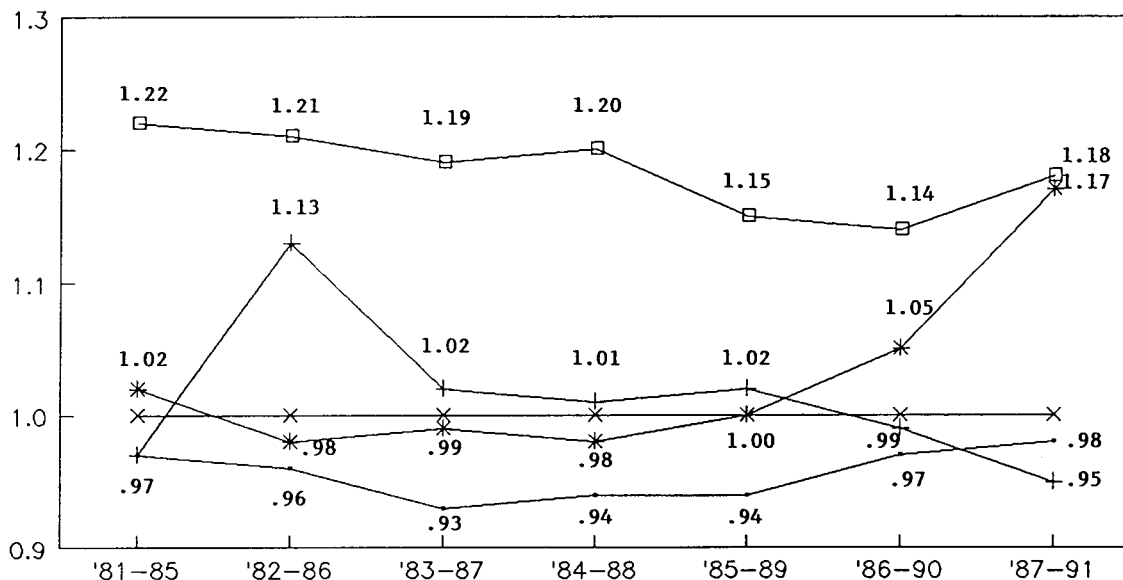


Fig 4. South American biological sciences. 5-year impact relative to South America baseline. ●, Argentina; +, Brazil; \*, Chile; □, Venezuela; x, South America. (Copyright, 1992, ISI).

nezuela compare with the average for all four combined in the biological sciences. In this graph, the South American average cited impact is defined as 1.0 in each five-year period. Venezuela's cited impact was consistently higher than the South American average by about 20 percent, but it has steadily declined. Chile's performance was fairly stable, being cited virtually as often as the South American average until the period 1985-1989. Its performance improved steadily thereafter, and Chile shared first place with Venezuela in 1987-1991. In this most recent period, Chilean biological sciences papers were cited 17 percent more often than the South American average.

SPECIALTY IMPACT TRENDS:  
CHILE vs REGIONAL AVERAGE

Having surveyed the leading South American nations in the biological sciences overall, we will now focus on the specialty level and examine Chile's cited impact relative to the region's average in the 12 specific areas identified earlier. They are discussed here in order of their proportional share of total Chilean papers in the 1981-1991 Science Citation Index database, shown in Table II.

Of the 6,609 biological sciences papers from Chile, 59 percent were in experimental

TABLE II  
Proportional distribution of ISI®-indexed biological sciences papers from Chile, by specialty areas

| Specialty                       | 1981-1991 |
|---------------------------------|-----------|
| Experimental Biology / Medicine | 58.5%     |
| Biochemistry / Biophysics       | 10.8%     |
| Pharmacology                    | 5.2%      |
| Neurosciences                   | 4.4%      |
| Environment / Ecology           | 4.2%      |
| Microbiology / Cell Biology     | 4.1%      |
| Animal Sciences                 | 3.7%      |
| Plant Sciences                  | 2.8%      |
| Physiology                      | 2.1%      |
| Reproductive Sciences           | 1.9%      |
| Molecular Biology / Genetics    | 1.3%      |
| Immunology                      | 1.1%      |

biology/medicine. This area is defined by a set of 277 journals indexed under this Current Contents heading. It is distinct from clinical medicine and includes basic biological and medical research. About 10 percent were in biophysics/biochemistry. This includes biologically-oriented chemistry rather than "pure" chemistry. The remaining specialties account for 5 percent or less of Chile's output: pharmacology (5%); neurosciences, environmental sciences, microbiology/cell biology, and animal sciences (4% each); physiology and reproductive sciences (2% each); and molecular biology/genetics and immunology (1% each).

### Experimental Biology / Medicine

The number of papers in this specialty for each five-year period is shown above the box in Figure 5. The decline in output is obvious -from 2181 papers in 1981-1985 to 1170 in 1987-1991, a 46 percent decrease. While Chilean authors have published fewer papers in this specialty, their cited impact has remained fairly constant and essentially equalled the South American baseline throughout the 11-year period. Chile's relative cited impact increased modestly by 8 percent, from 0.97 in 1981-1985 to 1.05 in 1987-1991.

In absolute terms, Chile's cited impact was 3.07 in 1981-1985 and 2.96 in 1987-1991, a decline of just 4 percent.

### Biochemistry / Biophysics

Figure 6 shows that the number of papers from Chile in biochemistry/biophysics has remained fairly constant, decreasing just 8 percent over the 11-year period. But Chile's relative cited impact in biochemistry/biophysics improved dramatically. In the period 1981-1985, its papers were cited about 20 percent less than the South American average. By 1987-1991, it exceeded the average by 13 percent. This represents a 38 percent increase.

One might ask whether the actual five-year impact for Chile remained stable while that for South America deteriorated. This is not the case. In the period 1981-1985, the cited impact of Chilean papers in this specialty was 3.44. By 1987-1991, this had increased by 39 percent to 4.77.

### Pharmacology

As seen in Figure 7, the situation is reversed in pharmacology. Chile's output of papers increased by 44 percent. But relative to the South American average, the cited impact of Chile's papers declined sharply and then recovered. It started out in 1981-1985 at 23 percent higher than the South American average and ended in 1987-1991 just 5 percent below, a 23 percent decline overall.

This is not a case where the absolute five-year cited impact of South America improved dramatically while Chile remained constant. Even in absolute terms, Chile declined -from 4.08 in 1981-1985 to 3.19 in 1987-1991, a decrease of 22 percent.

### Neurosciences

Figure 8 shows that Chile improved its performance relative to the baseline cited impact of South America in the neurosciences -from

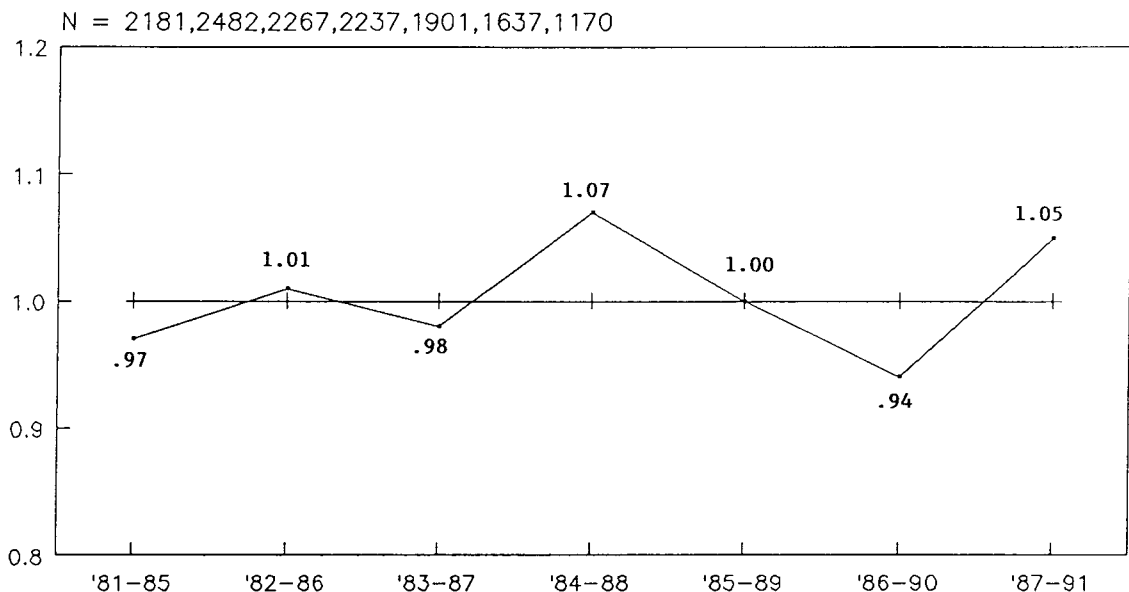


Fig 5. Experimental biology / medicine. Chile's cited impact relative to South American baseline. Numbers of papers in this specialty for each five-year period shown above the box. ISI science indicators database. ●, Chile; +, South America. (Copyright, 1993, ISI).

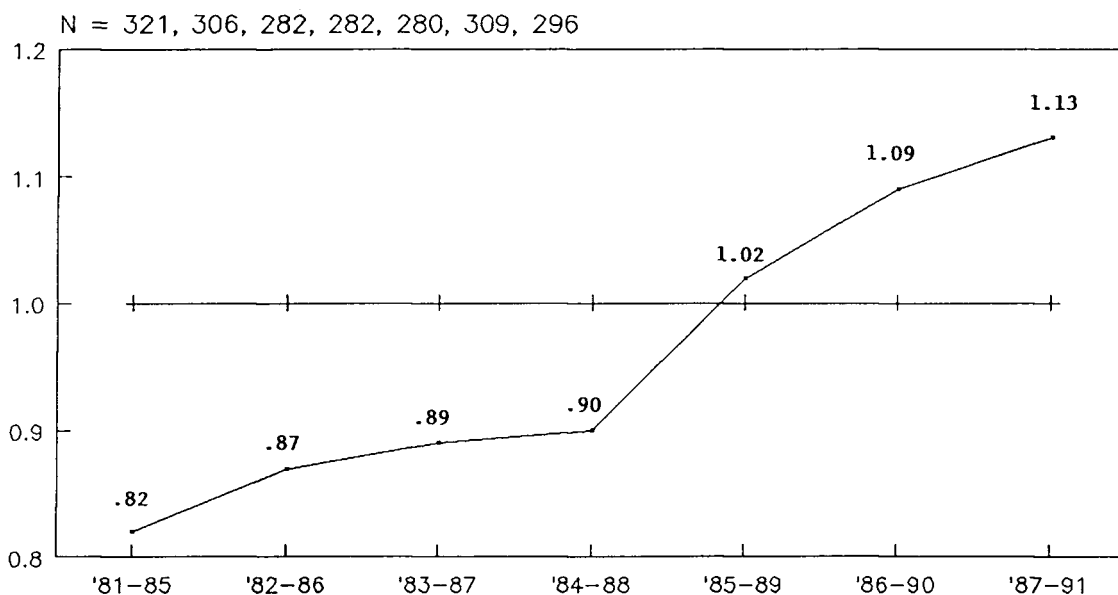


Fig 6. Biochemistry / biophysics. Chile's cited impact vs South America baseline. Numbers of papers in this specialty for each five-year period shown above the box. ISI science indicators database. ●, Chile; +, South America. (Copyright, 1993, ISI).

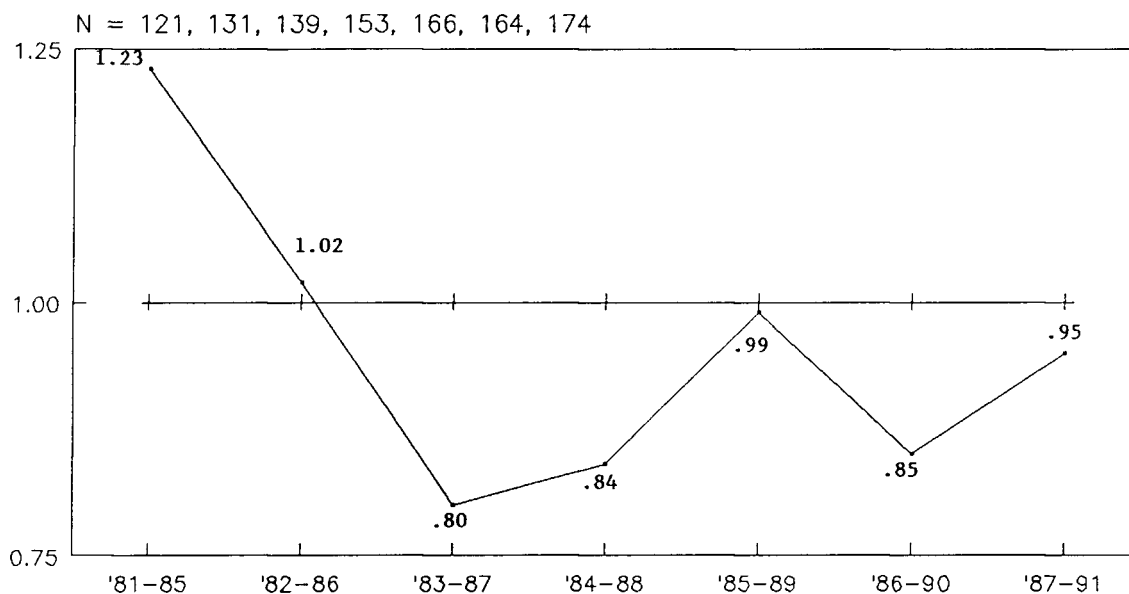


Fig 7. Pharmacology. Chile's cited impact vs South America baseline. Numbers of papers in this specialty for each five-year period shown above the box. ISI science indicators database. ●, Chile; +, South America. (Copyright, 1993, ISI).

a low of about 20 percent below average in 1981-1985 to equal the average in both 1982-1986 and 1983-1987. The Chilean average then declined somewhat to wind up just 6 percent below the baseline in both 1986-1990 and 1987-1991, an overall increase of 15 percent. Parallel to Chile's increased relative cited impact is an increased output of neurosciences papers, a gain of 50 percent over the 11-year period.

In absolute terms, the cited impact of Chilean neurosciences papers increased by 4 percent over this time period, from 3.80 in 1981-1985 to 3.95 in 1987-1991.

*Environment / Ecology*

Figure 9 shows that Chile's output of papers in environment/ecology doubled over the 11-year period, and its cited impact exceeded

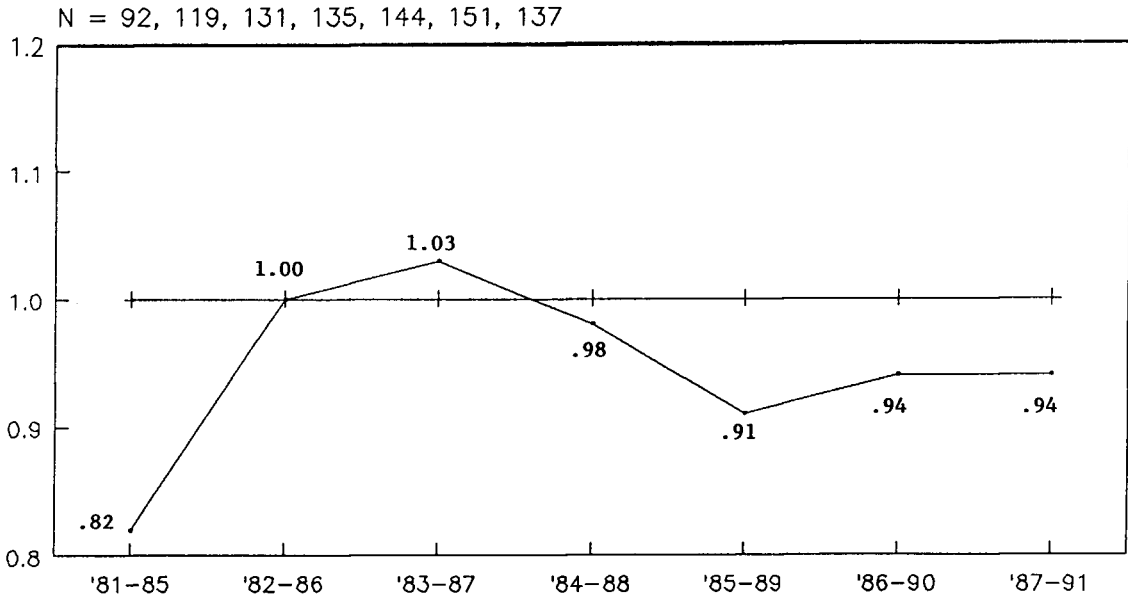


Fig 8. Neurosciences. Chile's cited impact vs South America baseline. Numbers of papers in this specialty for each five-year period shown above the box. ISI science indicators database. ●, Chile; +, South America. (Copyright, 1993, ISI).

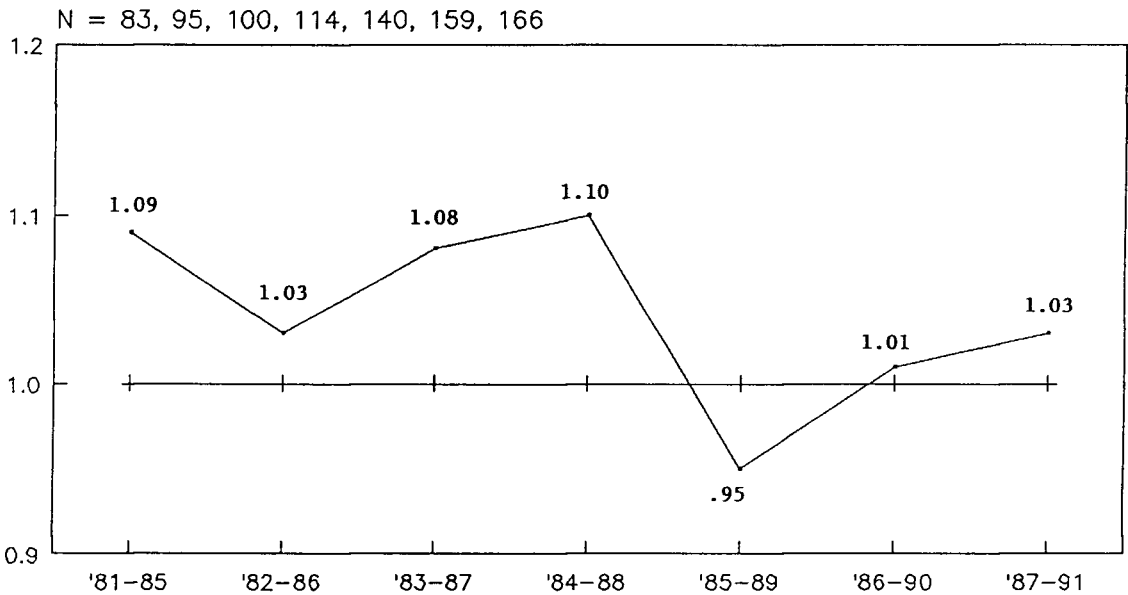


Fig 9. Environment / ecology. Chile's cited impact vs South America baseline. Numbers of papers in this specialty for each five-year period shown above the box. ISI science indicators database. ●, Chile; +, South America. (Copyright, 1993, ISI).

the South American average throughout virtually the entire 11-year period. Overall, its relative cited impact declined slightly (6%) over this time. In absolute terms, Chile's cited impact declined by 12 percent, from 3.32 in 1981-1985 to 2.91 in 1987-1991.

*Microbiology / Cell Biology*

Chile's output increased by 32 percent in microbiology/cell biology (Fig 10). While the trend in relative cited impact is somewhat volatile, Chile consistently exceeded the South American baseline. At the beginning



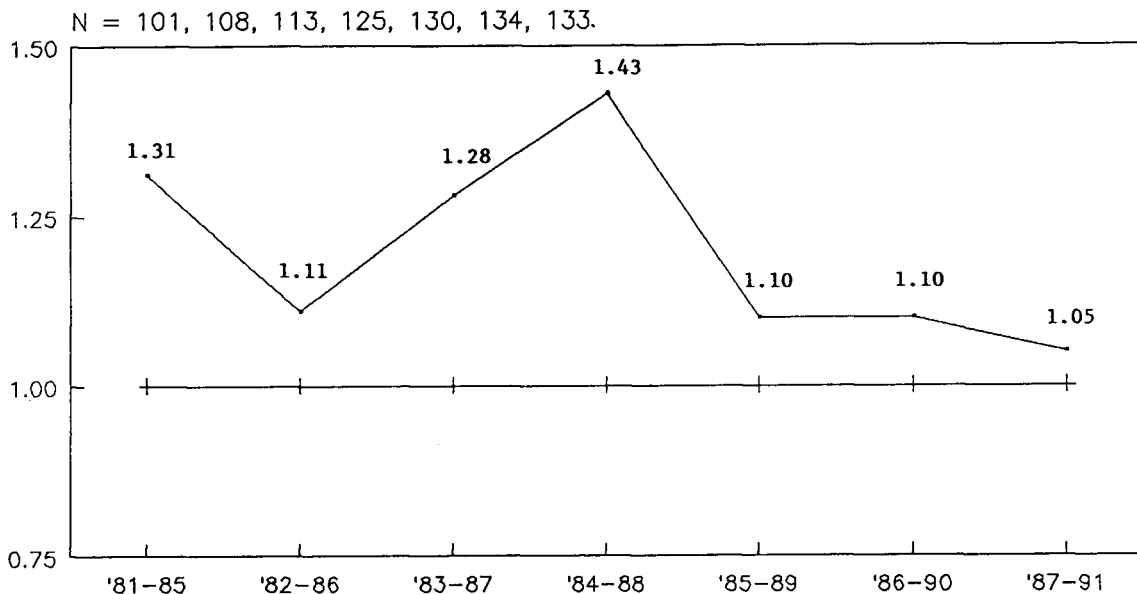


Fig 10. Microbiology / cell biology. Chile's cited impact vs South America baseline. Numbers of papers in this specialty for each five-year period shown above the box. ISI science indicators database. ●, Chile; +, South America. (Copyright, 1993, ISI).

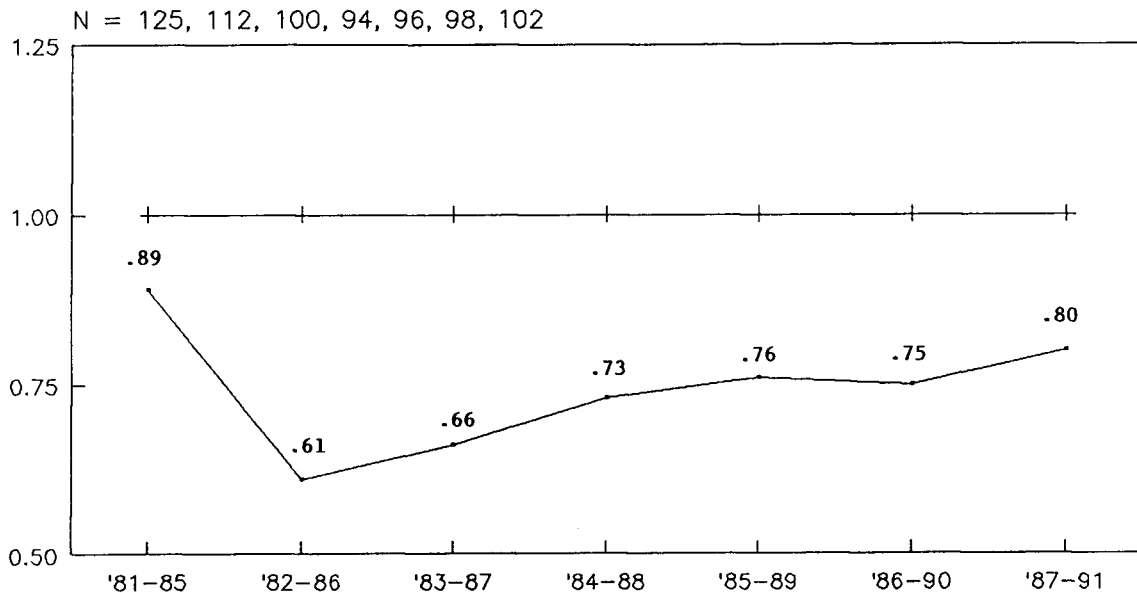


Fig 11. Animal sciences. Chile's cited impact vs South America baseline. Numbers of papers in this specialty for each five-year period shown above the box. ISI science indicators database. ●, Chile; +, South America. (Copyright, 1993, ISI).

of the period, Chile's cited impact was 31 percent higher than the region's average. By the end of the period, it was just 5 percent higher than average. This represents a 20 percent decline in relative cited impact. In absolute terms, the cited impact of Chilean microbiology and cell biology papers declined by just 2 percent, from 4.34 at the beginning of the period to 4.27 at the end.

*Animal Sciences*

In the animal sciences (Fig 11), Chile's output declined by 18 percent over the 11-year period and its cited impact was consistently below the South American baseline. Its relative cited impact declined by 10 percent from 1981-1985 to 1987-1991. However, since the period 1982-1986, Chile's relative cited impact steadily improved by 31 percent.

Chile's absolute cited impact declined by a modest 5 percent, from 1.77 in 1981-1985 to 1.68 in 1987-1991. But since 1982-1986 (1.32), its absolute cited impact increased by 27 percent.

(0.66), but has increased steadily since then to virtually equal the average by 1987-1991 (0.96). Overall, Chile's relative cited impact decreased by 12 percent.

In absolute terms, Chile's cited impact increased slightly by 3 percent, from 2.63 in 1981-1985 to 2.71 in 1987-1991.

*Plant Sciences*

Chile's output of plant sciences papers remained essentially constant during this period (Fig 12). Its cited impact relative to the South American baseline declined sharply from 1981-1985 (1.09) to 1984-1988

*Physiology*

Chile's output of physiology papers nearly quadrupled during this period (Fig 13), from

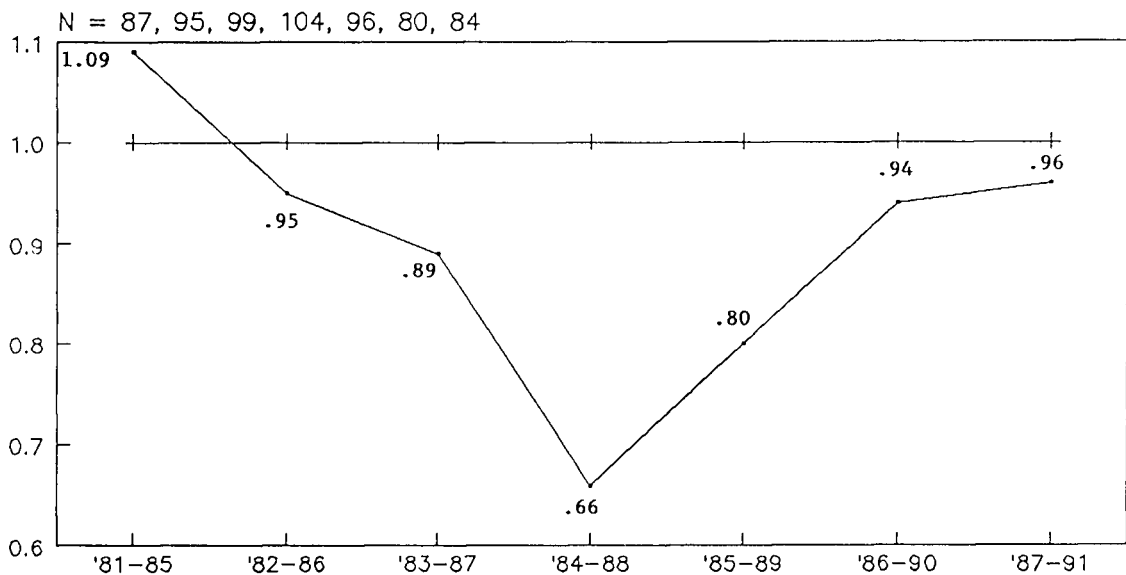


Fig 12. Plant sciences. Chile's cited impact vs South America baseline. Numbers of papers in this specialty for each five-year period shown above the box. ISI science indicators database. ●, Chile; +, South America. (Copyright, 1993, ISI).

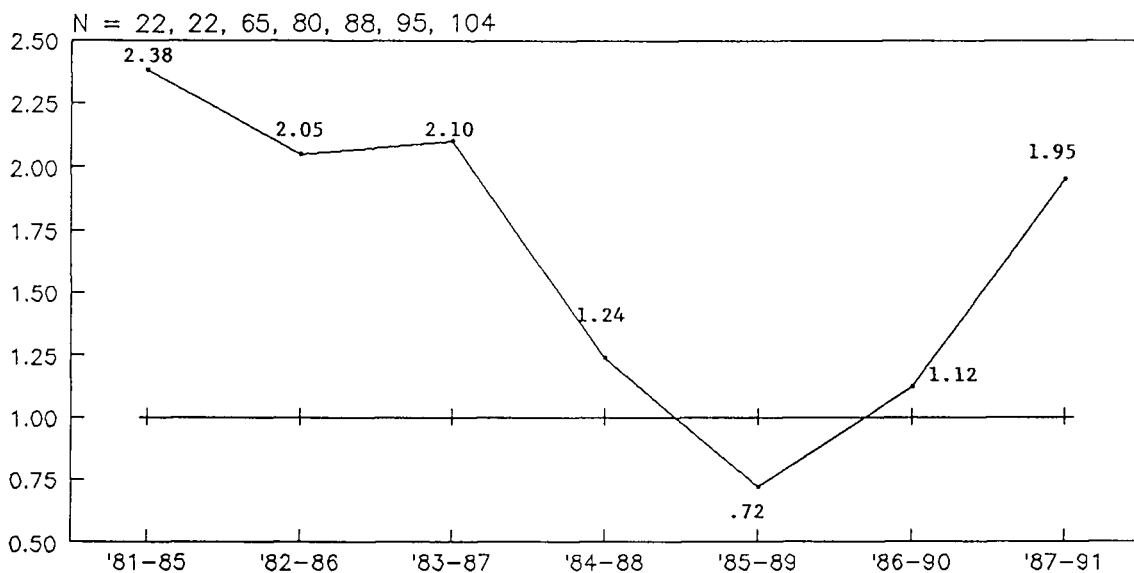


Fig 13. Physiology. Chile's cited impact vs South America baseline. Numbers of papers in this specialty for each five-year period shown above the box. ISI science indicators database. ●, Chile; +, South America. (Copyright, 1993, ISI).

22 in 1981-1985 to 104 in 1987-1991. The trend in relative cited impact is one of sharp decline -and sharp recovery. Compared to the South American baseline, Chile's papers were cited about 2.4 times as often at the beginning of the period but declined to about 30 percent below average by 1985-1989. However, Chile's performance improved thereafter, rising to nearly double the average cited impact for South America by the most recent period, 1987-1991.

In absolute terms, Chile's cited impact declined by 36 percent, from 10.91 at the beginning of the period and 7.03 at the end. But note that there were just 22 papers at the beginning of the period -just one or two highly cited papers might account for the high cited impact of 10.91 in that time.

*Reproductive Sciences*

The number of reproductive sciences papers from Chile increased by 27 percent over the 11-year period (Fig 14). Relative to the South American baseline, Chile's cited impact declined over the first four periods before increasing over the last four. Overall, Chile's relative cited impact declined by just 5 percent. In absolute terms, Chile's cited impact increased by 12 percent, from 4.26 in 1981-1985 to 4.79 in 1987-1991.

*Molecular Biology / Genetics*

Figure 15 shows that Chile's output of papers in molecular biology/ genetics increased by 48 percent, but it should be noted that the numbers of papers in any five-year period is comparatively small -less than 50. The overall trend in relative cited impact is downwards. At the beginning, the cited impact of Chilean papers in this specialty was about 1.5 times as great as the South American average. But by the end, it was 15 percent below the baseline.

This downward trend is also reflected in Chile's absolute cited impact factor. It decreased by 41 percent, from 4.50 at the beginning of the period to 2.64 at the end.

*Immunology*

Chile's immunology paper output increased by 87 percent, but the numbers of papers are still comparatively small -ranging from 23 to 43 in each five-year period (Fig 16). The trend in relative cited impact in this specialty is a sharp increase. At the beginning of the period, Chile was about 15 percent lower than the South American average for this specialty. But by the end, Chile's performance was about 2.5 times as great. This represents an increase of 182 percent.

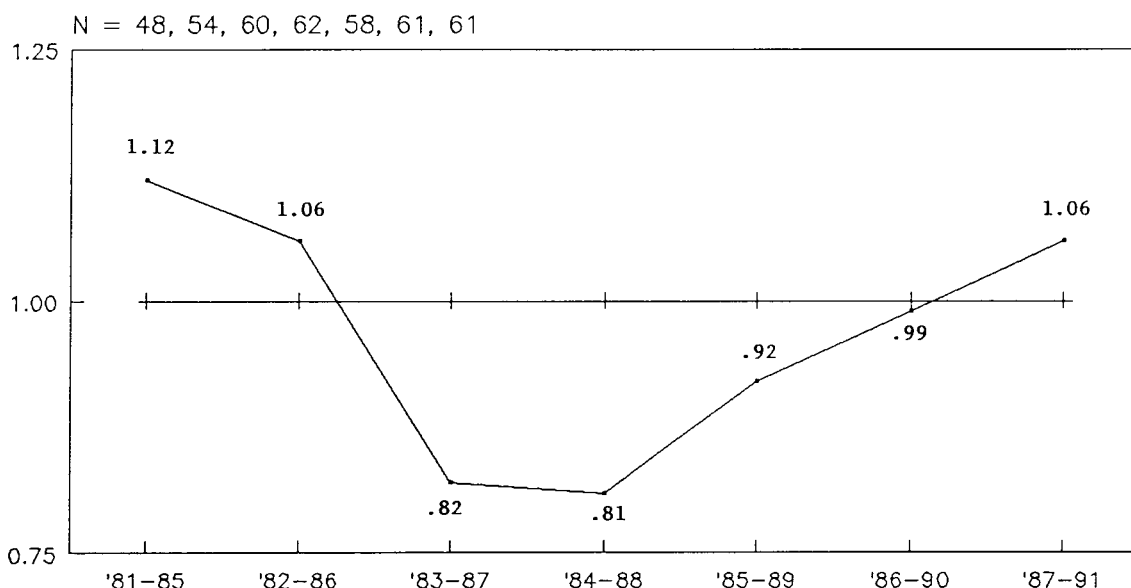


Fig 14. Reproductive sciences. Chile's cited impact vs South America baseline. Numbers of papers in this specialty for each five-year period shown above the box. ISI science indicators database. ●, Chile; +, South America. (Copyright, 1993, ISI).

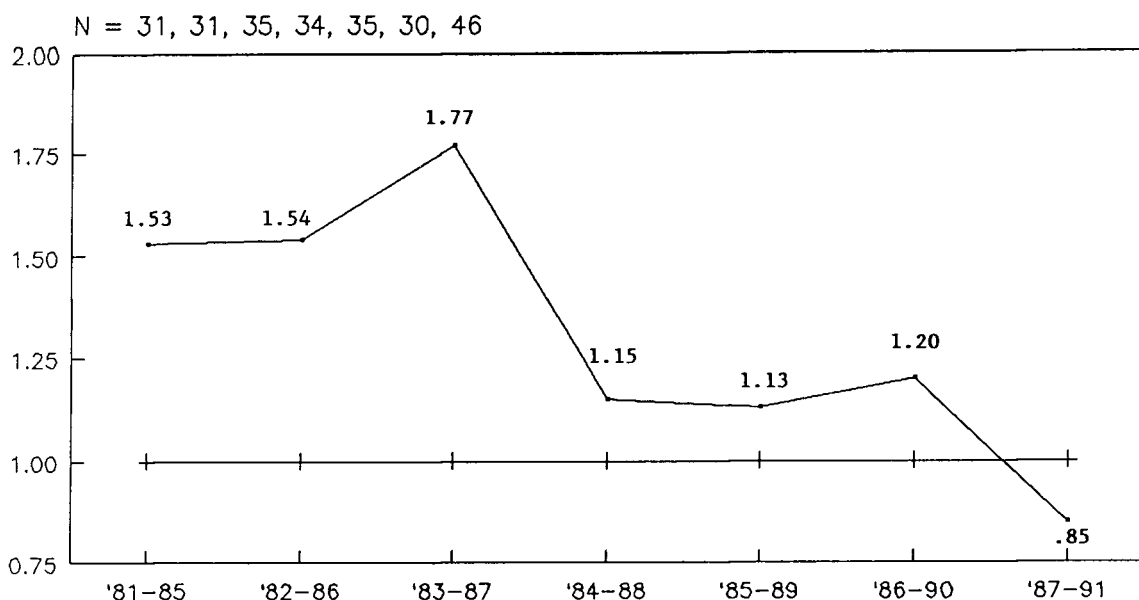


Fig 15. Molecular biology / genetics. Chile's cited impact vs South America baseline. Numbers of papers in this specialty for each five-year period shown above the box. ISI science indicators database. ●, Chile; +, South America. (Copyright, 1993, ISI).

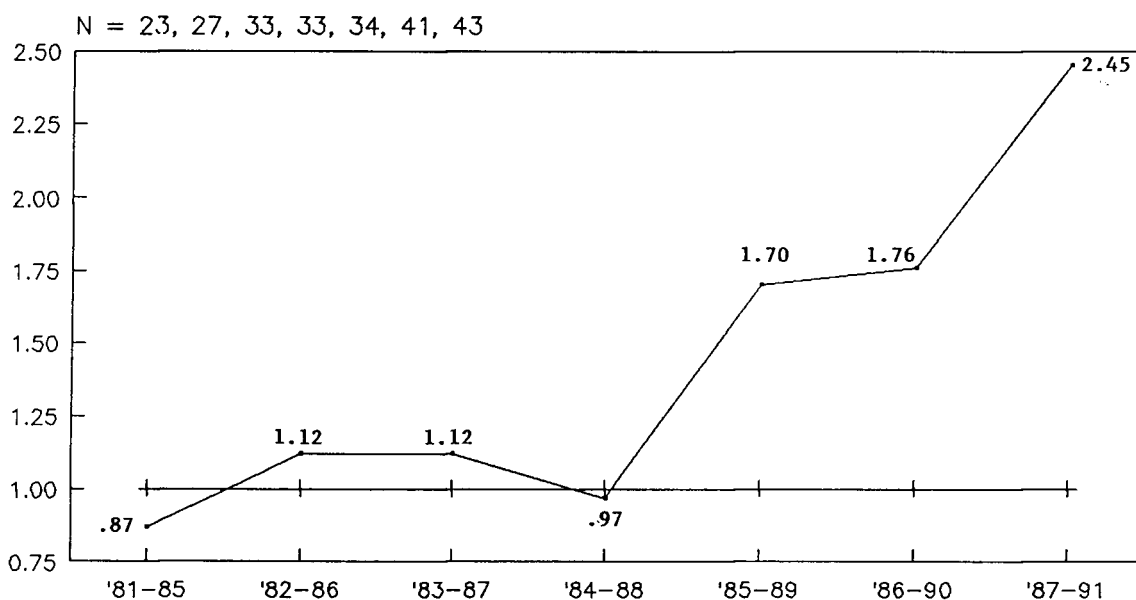


Fig 16. Immunology. Chile's cited impact vs South America baseline. Numbers of papers in this specialty for each five-year period shown above the box. ISI science indicators database. ●, Chile; +, South America. (Copyright, 1993, ISI).

In absolute terms, Chile's cited impact in immunology increased even more -by 215 percent, from 4.00 at the beginning of the period to 12.58 at the end.

#### DISCUSSION

In summary, Chile accounted for about 20 percent of South America's output of 1981-

1991 papers in the biological sciences -after Brazil (40%) and Argentina (35%), and ahead of Venezuela (6%). But the smallest producer (Venezuela) was the leader in terms of impact -that is, average citation frequency of its cited papers- and the largest (Argentina) was the laggard for most of the 11-year period.

Chile's cited impact trend is remarkable. For most of the recent past decade, it was

third behind Venezuela and Argentina. But in the 1985-1989 period, it improved sharply to share first place with Venezuela by 1987-1991. An interesting interpretation of this trend has been made since preliminary data of this study were first presented at the 35th Annual Meeting of the Society of Biology of Chile, in Puyehue, November 1992 (12). In 1982, the National Fund for Scientific and Technological Development ("*Fondo Nacional de Desarrollo Científico y Tecnológico*", FONDECYT) started operating with a peer-reviewed process for grant awards. This fund is administered by the previously existing National Commission of Scientific and Technological Research ("*Comisión Nacional de Investigación Científica y Tecnológica*", CONICYT). Since there is a two- or three-year lag between grant award, research investigation, and publication, the coincidence of the sharp increase in research impact and major shift in science policy is intriguing.

A post-1982 impact surge is evident in the majority, although not all, of the 12 biological sciences specialties -biochemistry/biophysics; pharmacology; environment/ecology; plant sciences; physiology; reproductive sciences; and immunology. In the largest specialty -experimental biology/medicine- the trend is not observed. And in 3 other specialties, the trend is contradicted -neurosciences; microbiology/cell biology; and molecular biology/genetics. Whether or not

these trends can be attributed to CONICYT policies certainly merits further investigation by specialists.

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