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Recognition and international collaboration: the Brazilian case

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The number of Brazilian publications in the Institute for Scientific Information database, ISI, increased significantly in the last 20 years, comprising more than 1 percent of the database in the last two years. The relationship between size and recognition of Brazilian science, estimated by number of ISI-indexed publications, p, and citations, c, obeyed a power law, $c = k\ p^n$. The value of n, a known indicator of such relationship was 1.42 ± 0.04, significantly higher than that found for the whole set of ISI-indexed world publications. The recent growth of Brazilian publication was not solely due to international collaboration, since over the last six years international collaboration, estimated as the percentage of Brazilian publications having at least one foreign address, reached a constant value of ca. 30%. International collaboration increased the impact of Brazilian publications. Although the most frequent collaborating countries are those that produce the largest percentage of world's science, Brazilian collaboration with Argentina and Chile exhibit impacts comparable to the major science producers.

Introduction

Recognition is directly proportional to the size of a scientific community. The correlation between size and recognition, using bibliometric data of the countries that produce almost 80% of world science, has been characterized.[1,2] The relationship between recognition, measured as citations, c, and number of publications, p, can be described by Eq. 1:

$$c = k\ p^n\ , \qquad (1)$$

where k and n are constants.

Recognition, as measured by the c/p ratio, also grows with the number of authors and collaboration.[3-6] Collaboration in science, both within the country and with other countries, is registered as early as the 19th century.[7] Recently, a notable increase in collaboration has been described.[8] Several factors, such as cost-savings, the growing

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importance of interdisciplinary fields and geographical, economical or cultural interests, contribute for the establishment of collaboration.[9-11]

Both on methodological and sociological grounds, it is relevant to investigate if the relationship between size and recognition, as well as the relationship between collaboration and recognition, observed in the major science producers apply to communities that play a quantitatively minor role in the world's scientific publications. Here we analyze the effect of size and international collaboration in the increasing recognition of Brazilian science. The data show that both variables that increase recognition in developed regions are applicable to science produced in Brazil.

Methodology

Data source

Citation and publication data were obtained from a *Brazilian Science Indicators* (BSI) database purchased from ISI (in a CD-Rom version) and was examined using the Microsoft Access 97. The BSI database contains information about 116,123 publications published in journals included in the *Science* and *Social Science Citation Indexes* (SCI and SSCI), from 1981 to 2000, with at least one Brazilian address. Information includes type of publication, full reference; citations received yearly, authors' name and address, including the name of the institution, city, state and country. All data regarding 2000 were discarded, since information may be incomplete, reducing the total of Brazilian publications to 104,196. Since we have chosen the multi-address approach to determine Brazilian international collaboration, two new tables were built based on the name of the author's country: a "domestic table" with information of Brazilian publications without international co-authorship (75,093 publications) and a "foreign table" with information of Brazilian publications co-authored with scientists from other countries (29,103 publications).

Size and recognition: the power law relationship in Brazilian science

The number of publications, p, and citations, c, were used as indicators of scientific size and recognition of Brazilian science system, as described in previous studies of other countries.[1,2] The publication data refer to the sum of full articles, notes and reviews published yearly from 1981 to 1998. Citation data represent the sum of a 3-year citation window received for such publications. For example, for publications of 1990, citations in 1990, 1991 and 1992 were added. This was repeated for each publication

year. Publications sum up 71,339, representing 77.8% of the 91,649 Brazilian total publications published in the 1981-1998 period, that includes, proceeding papers, meeting abstracts, letters, reprints, corrections, discussions and editorials. The total amount of citations received by the 71,339 publications, in a 3-year window, was 125,535 representing 91.1% of all country's citations for all publications. The power law distribution described in Eq. 1 (see Introduction) represents a non-linear dynamic process and can be represented linearly. Analyzing the correlation between c and p, the value of n is ca. 1.27, and constant over time and countries.[1,2]

Impact analysis

The impact of Brazilian publications was determined by the c/p ratio. The variable "number of authors" is available in the BSI database. In analyzing collaboration, we focus particularly on those publications where Brazil appears together with an Argentinean or a Chilean address.

Results and data analysis

The correlation between recognition and size in Brazilian science

The correlation between size, p, and recognition, c, throughout the 1981-1998 period is presented in Figure 1. The number of publications from Brazil has steadily increased in the last 20 years[12,13] and the data points represent the values of the variables in one of the 19 years studied. It is clear that the c/p relationship obeys Eq. 1. For the Brazilian ensemble the value of n (1.49 ± 0.04) was significantly higher than that found for the world science and for some developed countries' science (where $n = 1.27$). The difference in n indicates that the non-linearity in the recognition/size function is higher in Brazil than in those countries studied by *Katz*.[1,2] One possible reason for this difference is that Brazilian science has been experiencing a remarkable growth in the number of publications during the last decades, leading to an increase of the country's share in the ISI database.[13] Thus, a higher value for Brazilian curve slope may reflect a system that is growing faster than world literature.[14] The value of n for world publications has been determined by a small number of countries, where science has been consolidated for decades and that produce more than 80% of the world's science.[15,16]

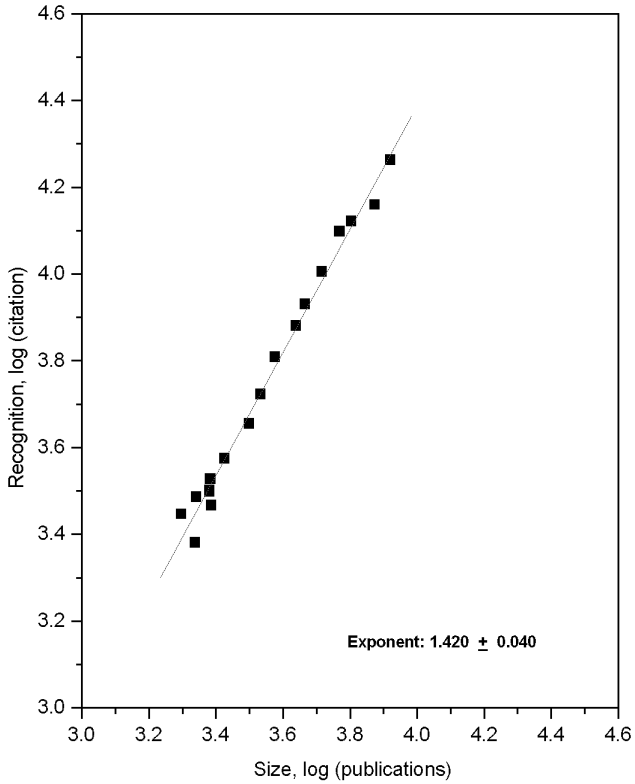

Figure 1. Size versus recognition in Brazilian science system. Publication data include full articles, notes and reviews published in the 1981-1998 period. Citation data represent the sum of a 3-year citation window of the 1981-1998 publications.

International collaboration within Brazilian publications from 1981 to 1999

Scientific cooperation worldwide increased from 11.3% to 20.0% in the 1980-1990 period.[8] In particular, about 30% of European publications are internationally co-authored.[17] For Brazil, collaborative publications increased from 21.6% to 26.7% from 1981 to 1990.[18] A more detailed study of collaboration suggested that the increase in national and international collaborative publications was responsible for the growth of Brazilian participation within the ISI database from 1981 to 1993.[19] Here we show

that such assertion no longer applies, since the percentage of publications with international collaboration reached an apparent plateau after 1993, while the total number of publications from Brazil continues to grow steadily (Figure 2). A series of factors, including a significant increase in the graduate student pool and the effort of a national evaluation of graduate programs may be the source of the continuing growth of Brazilian publications.[20]

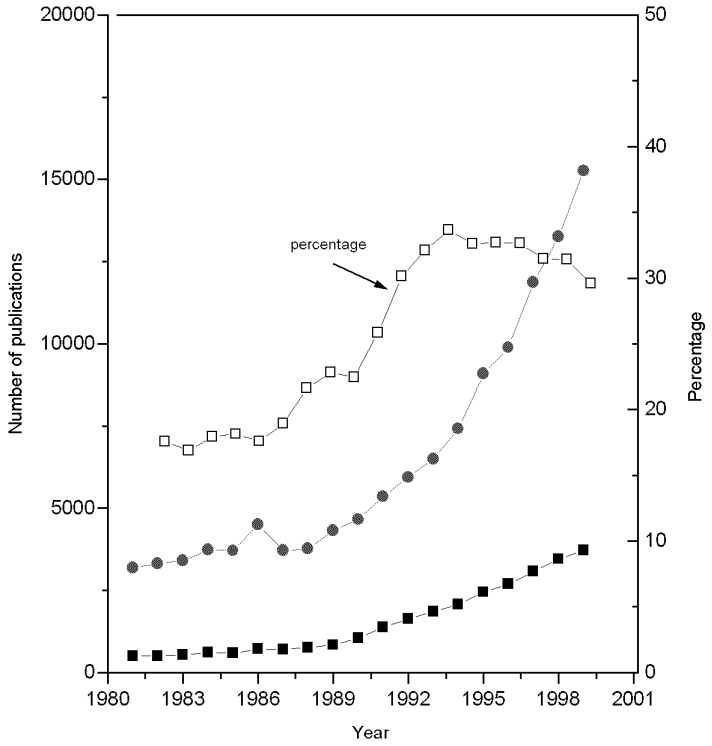

Figure 2. Brazilian indexed publications: distribution of international collaborations, 1981-1999. Data include all types of publications. Percentage (open symbol) represents the ratio between Brazilian collaborative publications (■) and Brazilian total publications (●).

Collaborator countries

The number of Brazilian publications in the ISI database with a foreign address and the share of collaboration are presented in Figure 3, where countries were arranged into seven groups for clarity. Some of the publications have more than one collaborating country; hence the sum of percentages is higher than 100%. The most frequent collaborators in Brazilian publications are those from European and Central & North American institutions. Middle East and African countries constitute a minor part, ca.1.5%. The number of Brazilian publications with at least one Latin American address is increasing and represents about 10% of all Brazilian collaborative publications in the period. The United States appears in 40.5% of Brazilian international collaborative publications. Present data confirm previous analysis showing that South/South collaboration is limited.[15,16] Scientists in developing countries tend to collaborate intensively with colleagues in the Northern hemisphere and, in particular, with those in the leader country of their geo-economic region.[21,22]

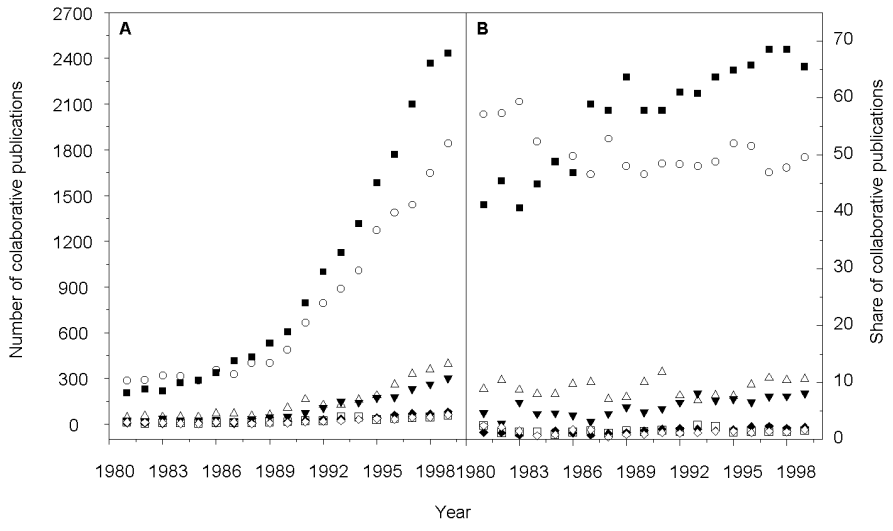

Figure 3. Distribution of Brazilian international collaboration. Data include all types of Brazilian publications co-authored with countries from: Africa (□), Asia (▼), Central & North America (O), Europe (■), Middle East (◊), Oceania (◆) and South America (Δ).

The impact of collaborative and non-collaborative publications in Brazilian science

The effect of international collaboration in the science impact of the major science producers has been described.[3-6] The same effect for Brazilian science has been previously reported in biochemistry and for the ensemble of Brazilian publications in the 1981 – 1993 period.[19,23] Here we present the effect of international collaboration in the impact of Brazilian ISI-indexed publications in a more extended time frame. Figure 4 presents the evolution of Brazilian 3-year window citations, c, publications, p, and impact, c/p, for the country's total publications and for those with a foreign collaboration. Although c/p increases throughout the period for both total number of publications and for those with collaboration, the values of c/p for collaborative publications are clearly higher.

Another way to analyze the collaboration impact has been presented in an extended analysis of European publications.[3] Using a similar analysis, we observed that, on average, Brazilian single authored publications have an impact 40% lower than those with more than one author (Table 1). A higher difference is found when non-collaborative and collaborative publications are compared: the impact increases from 0.79 or 1.12 to 3.39. Higher impact values are also observed within publications co-authored with Argentina and Chile. In the case of Argentina, the impact value found was higher than the average impact of collaborative publications and ca. four fold higher than the average impact of a Brazilian publication published by a single author. The impact of publications co-authored with Chile is also much higher than that for Brazilian non-collaborative publications. The data are in good agreement with other studies of leading science producers, where it has been shown that international visibility is enhanced by scientific collaboration.[3-6]

Table 1. Impact of author and foreign collaboration. Data include only full articles, notes and reviews

	Citations (3-year window)	Papers (1981-1998)	Impact
1 author, Brazil only	6,669	8,476	***0.79***
> 1 author, Brazil only	47,720	41,892	***1.12***
Brazil and with any country	71,146	20,971	***3.39***
Brazil and Argentina	3,451	917	***3.76***
Brazil and Chile	1,233	444	***2.78***

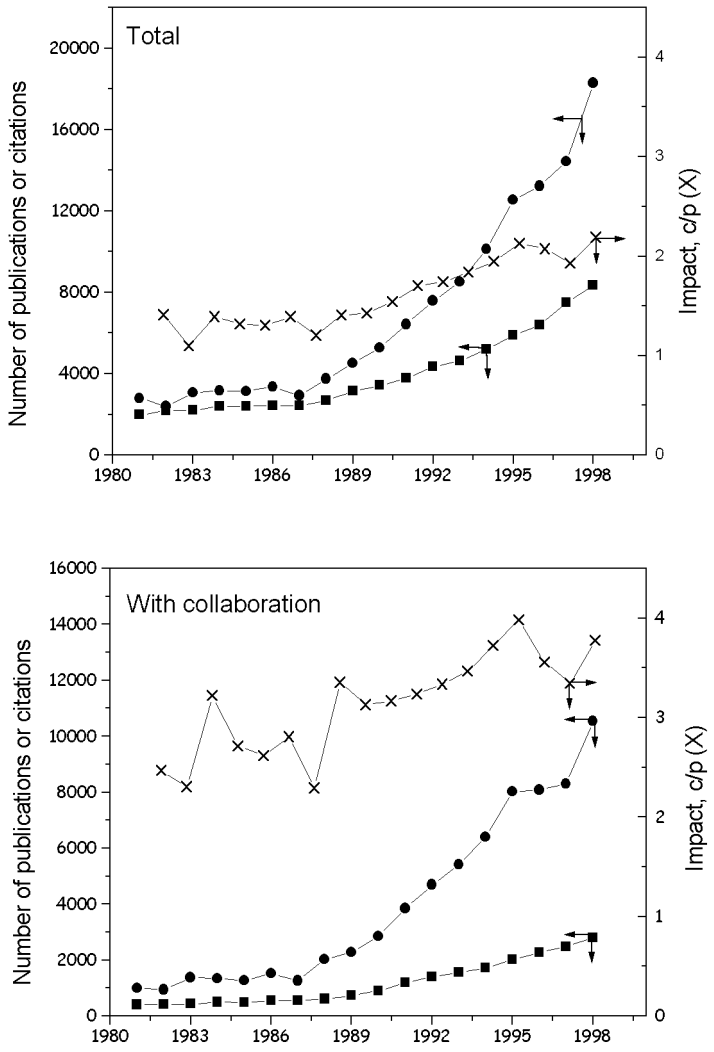

Figure 4. Impact within Brazilian total and collaborative publications through the 1981 - 1998 period. Data include only full articles, notes and reviews. The impact (cross line) represents the ratio between the sum of a 3-year citation window (●) and the publications of a certain year (■)

Discussion

A large fraction of scientific research from developing regions, including Brazil, is published in national journals, which are underrepresented in the ISI database.[24-26] In the case of international collaboration, the use of publications, such as those in the ISI database, have limitations.[9] Therefore, our results do not represent the total Brazilian science publications but only publications indexed in the ISI database. Moreover, collaboration does not necessarily result in a jointly published paper and, inversely, there are cases where peripheral or indirect collaboration yields co-authored papers.[9]

As shown here Brazilian ISI-indexed publications have increased rapidly during the last decades, enlarging the country's visibility in the world's mainstream science.

Our analysis shows that Brazilian papers gain recognition, measured as citations, in a form comparable to other studies[1,2] (Eq. 1; Figure 1). Such correlation obeys Eq. 1, characterizing an exponential growth with an exponent, n, that is higher than that described for world science.[1,2] Therefore, international recognition of Brazilian science seems to be more affected by size. The difference in recognition and size function (n) between Brazil and world literature may be related with the relative stability of the science systems. This correlation has been carefully studied in countries where the science output, measured in published publications, is growing at a lower rate when compared with Brazil.[14] Indexed publications from Brazil are the result of a recent and growing science system which is undergoing a consolidating process.

Although it has been demonstrated that one of the benefits of international cooperation is the increase of scientific productivity,[3-6] our data indicate that the very recent increase in publications is not related only to collaboration. However, the effect of international collaboration on the recognition of science produced in the country is clear (see Table 1). It is important to register that the fundamental unit of collaboration is the direct co-operation between two or more researchers. Profits on cost-savings, transferring and sharing of knowledge and skills, cross-fertilization of ideas and new insights, intellectual companionship[9] and, as shown in this report, on enhancing the international visibility are strong reasons for establishing programs for increasing scientific collaboration. Brazilian present programs do not seem, however, to encourage Brazilian researchers to collaborate with Latin America. Our data demonstrated that collaboration with such countries exists and the results, in terms of the c/p index, are comparable to those resulting from collaboration with more developed countries. We note that in spite of the absence of permanent and well-supported programs for scientific collaboration within Latin America, the share of Brazilian collaboration with Chile and Argentina is relatively high. Taking for example the last five years, the percentages of

Brazilian papers with a Chilean or an Argentinean address were 1.7% and 4.1%, respectively (not shown). On the other hand, Chile and Argentina contributions to world ISI-indexed papers, in the same period, were 0.17% and 0.43%, respectively.[14] It is clear, therefore, that using this form of measurement, Brazilian collaboration with Chile and Argentina is higher than the contribution of these countries to world science.

Collaboration between countries of the southern hemisphere tends to be small and subject-dependent.[21,26] The extent of the Brazilian collaboration with neighboring countries may therefore be subject-related and occur among the most productive Brazilian scientists, a very select group already recognized by the world's science. Using the same data set, we are presently investigating these relationships in detail.

The present results suggest a direction towards increasing international recognition of Brazilian science. The continuing formation of new research groups may be one of the driving forces to maintain the rate of increase in the number of publications and, as shown here, to increase recognition. This process involves a variety of factors, such as financial support, evaluation of graduate programs and international collaboration. Since collaboration is effective in the increasing recognition of Brazilian science, specific mechanisms for enlarging scientific collaboration among Brazilian scientists with Latin American patterns should be encouraged. This collaboration will help to promote the increase in international visibility of the region as a whole as well as the increase in local competencies and skills, essential components for the development of a competitive scientific and technological system.

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