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Science in Brazil. Part 1: A macro-level comparative study

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In the present paper, the evolution of publication activity and citation impact in Brazil is studied for the period 1991-2003. Besides the analysis of trends in publication and citation patterns and of national publication profiles, an attempt is made to find statistical evidences of the relation between international co-authorship and both research profile and citation impact in the Latin American region. Despite similarities and strong co-publication links with the other countries in the region, Brazil has nonetheless a specific research profile, and forms the largest potential in the region.

Introduction

Bibliometric national science indicators reflect dramatic changes in the international research landscape during the last 10-15 years. Spectacular growth rates in several countries are contrasted by patterns of certain decline in other countries or regions. Insufficient investment in education and R&D in several developing countries is commonplace; but stiff international competition and decreasing public funds for research are only two of the various problems even developed countries have to cope with. Reunification has pushed Germany to the forth rank in the list of most productive nations according to the *Science Citation Index*. At about the same time bibliometricians still discussed about the continuing decline of British science (MARTIN et al., 1987; LAMB, 1990). The growth of publication activity in European countries like Spain, Portugal, Greece and the spectacular dynamics of Irish science, being in line with that of Irish economy characterising national economy as 'Celtic tiger' (e.g., BATTEL, 2003), are to a certain extent results of European integration. The situation in Scandinavia is rather heterogeneous: the growth in Finland is contrasted by the relative decline in Sweden (GLÄNZEL et al., 2003) and also partially in Denmark (for instance, INGWERSEN, 2002). On the other hand, Europe has taken the lead in international publication activity during the last decade (REIST-3, 2003). So, who are the winners and losers in the international competition? The answer on this question is not simple;

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developments have to be viewed from different perspectives, particularly from the global, local (in the context of the geopolitical environment) and regional viewpoint. Moreover, the decomposition of national indicators combined with the strict use of relative and normalised bibliometric measures is necessary to the 'anatomy' of decline or increase (GLÄNZEL et al., 2003). And finally one has to investigate which structural changes are accompanying the observed developments.

When analysing national publication dynamics, the triad Japan-USA-EU is, of course, in the centre of interest. EU and USA contribute with more than 30% each to the world total of publication output; Japan published almost 10% of all scientific papers according to the ISI database. Nonetheless, the mot spectacular changes take place outside this triad. China is on its way to turn into a scientific superpower; in terms of publication activity in international journals it is already catching up with France and challenging UK and Germany. In Latin America Brazil has the lead, and shows with more than 8% annual growth rate of the share in the world's publication output the most dynamic growth beyond Mexico. At present, Brazil holds rank seventeen in the list of most active countries. Both its position and its growth have attracted the attention of bibliometrics and science policy quite early. LETA & DE MEIS (1996) have studied the research profile of Brazilian science in the Mid 1990's, the report by the BRAZILIAN ACADEMY OF SCIENCES (1999) prepared for the World Conference on Science in Budapest, 1999, point to the growing importance of Brazilian science but also to problems in the national science and educational system.

In this paper we present an overview of scientific research performance of Brazil based on bibliometric data for the period 1991–2003. The first part, forming this paper, is concerned with the macro patterns of Brazilian research. In particular, we will focus on (1) the trends in the publication activity, (2) the national publication profiles, (3) the development of the citation impact, and (4) the international scientific collaboration of Brazil. According to the principle introduced above, we will shed light on structural and dynamic aspects of Brazilian research performance from the global perspective and the geopolitical context of Latin America. Thus we will study science in Brazil along the following research questions: What is the actual scenario of the scientific output in Latin American countries? What are the main differences among Brazil scientific output and the most prolific countries? The present study aims to portray the main trends and characteristics of Brazilian scientific publications and compare them with Argentinean, Chilean and Venezuelan.

Science in Brazil – Background

The Iberian cultural heritance is by far the strongest linkage among Brazil and other countries from South and Central America and Mexico. But for sure the so-called Latin American countries have in common some other features and trends. After the

2nd World War, for example, most of these countries watched the enlargement of their urban population as well as the increase in higher education enrolment as a consequence of the university reform. Latin American countries have also gone through dictatorship periods, in which a large number of intellectuals went out to exile. As for the science and technology system of some countries from this region, the academic "Diaspora" has meant the ending of whole fields of knowledge (AROCENA & SUTZ, 2001). However, with the return of the democratic governs in the mid 80's this situation changed. Public universities recovered their universal tasks, being not only the most important institutions in the higher education system but also those to embrace the largest fraction of scientific activities.

After a dramatic stagnation of their economies in the 1980's, some Latin American countries put forward some new initiatives to enlarge the financial support of research thus expanding their scientific activity (LATORRE, 2001). In the case of Brazil, a huge national program for training human resources to science activities has been supported since then. With this program hundreds of new graduate programs, within all fields of science, were established throughout the country. Besides, thousands of scholarships were granted to Brazilian graduate students, enlarging remarkably the number of Master and PhD degrees awarded yearly in the country. As to illustrate, a total of 3,865 Master degrees and 1,005 PhD degrees were awarded in Brazil in 1987. By 2003, these numbers increased to 27,648 and 8,094, respectively. (MCT, 2005)

Despite all efforts, science in Brazil but mostly in other Latin American countries still faces serious problems, specially the instability in funding (VIEIRA, 1998). The GERD, expressed as a proportion of the GDP, is almost 1% – a proportion much lower than that in developed most countries – and is thus far from the desired situation. And merely 23% of the total investment in R&D come from private companies (DE CASTRO MOREIRA, 2003). Such common situation reduces the chances of these countries to participate and to compete at the edge of scientific and technological development. Far and wide it is known that in such a process not only financial resources are required but also qualified manpower and infrastructure for research. Together, these factors can develop a core of scientific and technologic knowledge, one of the main features to reach the economic and social development. In the case of Brazil, the country consolidated a huge system of science & technology as well as a large scientific community during the last decades. This has – despite the heterogeneous picture described among others by DE CASTRO MOREIA (2003) – pushed the country far ahead from its neighbours. Such differences among Brazilian science and that from the other countries may represent an obstacle for the scientific development of the whole region.

Data sources and data processing

The results of the present study are based on the bibliographic data extracted from the 1991–2003 annual updates of the Web of Science (WoS) of the Institute for Scientific Information (ISI – Thomson Scientific, Philadelphia, PA, USA). Only document types named as Articles, Letters, Notes and Reviews were taken into consideration. Publications were assigned to countries on the basis of their corporate addresses which appear in the by-line of the publication. All countries indicated in the address field were considered.

As for subject classification, publications were arranged into 12 major fields: Agriculture & Environment, Biology (Organism & Supra-organismic level), Biosciences (General, Cellular & Subcellular Biology, Genetics), Biomedical research, Clinical & Experimental Medicine I (General & Internal Medicine), Clinical & Experimental Medicine II (Non-Internal Medicine Specialties), Neuroscience & Behaviour, Chemistry, Physics, Geosciences & Space Sciences, Engineering and, finally, Mathematics. This field division was developed by GLÄNZEL & SCHUBERT (2003) on the basis of the field assignment of journals.

For the citation analysis, a three-year citation window had been applied for the 1991–2001 publications. Citations received by these publications have been determined by the period beginning with the publication year up to 2003, on the basis of an item-by-item procedure, using special identification keys, made up of bibliographic data elements. The definition of self-citation applied in this study was the same as that applied earlier, e.g., by SNYDER & BONZI (1998). According to this definition, a self-citation occurs whenever the set of co-authors of the citing paper and that of the cited one are not disjoint, that is, if these sets share at least one author. For this particular analysis, we would like to highlight that the reliability of this methodology is affected by homonyms and spelling variances and/or misspelling of author names.

In the present study, publication and citation indicators on a micro-level were calculated and the following indicators were used:

- *Activity Index* (AI) is defined as the ratio of the share of a given field in the publications of a given country to the share of the same field in the world total publications. This indicator (known and used in economics as Comparative Advantage Index typically calculated with export data) has originally been introduced by FRAME (1977) in bibliometrics and long used in macro studies (for instance, SCHUBERT et al., 1989). It is easy to see that AI may take values in the range $[0, \infty]$; its neutral value is 1. $AI = 0$ indicates a completely idle research field, $AI < 0$ indicates a lower-than-average and $AI > 1$ a higher-than-average activity. It is important to note that AI reflects a certain internal balance among the fields in the given country, that is, $AI > 1$ values in several

fields must always be balanced by AI < 1 in others: in no country can all AI values be greater (less) than 1.

- *Mean Observed Citation Rate* (MOCR) is defined as the ratio of citation count to publication count (BRAUN et al., 1985).
- *Mean Expected Citation Rate* (MECR) is a journal-based indicator. It expresses the expected citation rte of a given paper set. The journal-based expected citation rate of a single paper is defined as the average citation rate of all papers published in the same journal, in the same year, in a three-year citation window. MECR is defined as the average of these individual expectations over a given paper set (BRAUN et al., 1985).
- *Relative Citation Rate* (RCR) is the ratio of MOCR to MECR. RCR = 0 corresponds to uncitedness; RCR < 1 represents lower-than-the-average; RCR > 1 represents higher-than-the-average; finally RCR = 1 means that the papers received the number of citations expected on the basis of the average citation rate of the publishing journals (BRAUN et al., 1985).

The following three indicators are the counterparts of the previous one excluding author self-citations with analogous definitions:

- Mean Observed Citation Rate eXcluding self-citations (MOCRX)
- Mean Expected Citation Rate eXcluding self-citations (MECRX).
- Relative Citation Ratio eXcluding self-citations (RCRX).

For the analysis of the Brazilian international collaboration strength, we have used the Salton's cosine measure. A link between two countries was established, whenever the two given countries co-occurred in the corporate address field of a publication. The analysis of international co-authorship patterns by country pairs is the most intelligible approach to analyse the strength of a given country's collaboration links with other countries. Strictly speaking we are going to analyse co-authorship links between country pairs. The following example might illustrate this approach: a paper with co-authors from Brazil, Belgium and the Netherlands defines three co-publication links, namely, one between Brazil and Belgium, Belgium and the Netherlands and the Netherlands and Brazil. The co-publication link between Belgium and the Netherlands is not of interest in our study since we are only interested in Brazil's links with other countries. Instead of one single co-publication we are analysing two co-publication links defined for Brazil by the paper in question. Salton's measure is then defined as the number of joint publications (e.g., publications co-authored by Brazilian and Belgian scientists) divided by the square root of the product of the number of total publications of the corresponding countries (for instance, total publications of Brazil versus total publication of Belgium). In order to get statistically reliable results, we have chosen only countries that have published together with Brazil in at least 30 publications in the each of the two periods studied, 1991-1993 and 2001–2003. The strength of

collaboration linkage among Brazil and joint countries was classified as: strong links (Salton's measure ≥ 2.5%), medium strength (Salton's measure ≥ 1% and < 2.5%) or weak links (Salton's measure lower than 1%).

Science in Latin America: a timid contribution

According to a recent study from UNESCO (2001), the so-called developed countries encompass around 72% of all the world researchers. Also, they are responsible for almost 85% of the world investments in science and technology and they produce more the 85% of all scientific literature registered in the database of Web of Science. Such concentration in scientific output can be easily observed in Table 1, where only the five top leader countries encompass more than half of all world publications.

Among Latin America countries, Brazil is best ranked country, accounting for almost 1.5% of the world publication in the period of 1999/2003. From one period to another, Brazil shifted from the 23rd to the 17th position in the ranking list and surpassed some important European countries, such as Israel and Belgium. As for the rest of the region, with the exception of Guatemala, all the other countries have their scientific output increased. For most of these countries (those marked with *), such an increase has resulted in a shift to a better position in the world ranking of the number of ISI publication, from the 1991–1995 to the 1999–2003 period.

Although it is clear that during the 1990's some changes in the scientific output occurred the general performance of the whole region is still very timid. Far and wide, it is known that part of the timid performance in the ISI database is due to many variables, including lack of a solid and consolidate infra-structure, mass of researchers and language barriers that push researchers of these countries to publish in domestic journals. Although, some initiatives are been carried out to minimize the amount of "peripheral science" (MENEGHINI, 2003), it is clearly that scientific activity is really incipient in a large part of Latin American countries.

Brazil and the most prolific countries: trends in scientific expertises

Despite the similarities in their history and recent troubles in their economies and politics, Latin America is a region of highly diversity. Differences in size and demography and a widely range of different natural features and cultural habits are perhaps the most evident. As for science, Latin American countries do also display some differences, such as the share of the region's most productive countries in the world's total publications (Figure 1). Among these countries, the share of Brazilian and Mexican publications have had the strongest increased, from 0.65% to 1.61% and from 0.26% to 0.70%, respectively. The share of Argentinean, Chilean and Venezuelan

publications have also grown but in a low rate, 0.34% to 0.56%, 0.19% to 0.30% and 0.08% to 0.13%, respectively.

Table 1. Scientific output, ranking and world share in publications of the top 5 countries, the top 10 countries with less then 2% in the world and Latin American countries

	1991–1995				1999–2003		
Countries	Publication	Ranking	World share	Countries	Publication	Ranking	World share
Top 5							
USA	1174603	1	34.89%	USA	1284415	1	31.48%
UK	297940	2	8.85%	Japan	378029	2	9.26%
Japan	274849	3	8.16%	UK	364585	3	8.93%
Germany	248554	4	7.38%	Germany	346305	4	8.49%
France	193504	5	5.75%	France	249929	5	6.12%
Top 10 with less than 2%							
Sweden	58755	14	1.75%	South Korea	79777	14	1.95%
Switzerland	52539	15	1.56%	Sweden	78520	15	1.92%
China	48052	16	1.43%	Switzerland	73075	16	1.79%
Israel	37675	17	1.12%	Brazil	59361	17	1.45%
Belgium	36140	18	1.07%	Taiwan	54694	18	1.34%
Poland	31961	19	0.95%	Poland	54460	19	1.33%
Denmark	29333	20	0.87%	Belgium	53554	20	1.31%
Finland	25528	21	0.76%	Israel	49312	21	1.21%
Taiwan	24984	22	0.74%	Denmark	40340	22	0.99%
Brazil	24018	23	0.71%	Austria	38963	23	0.95%
Latin American countries							
Argentina	11548	*33*	0.34%	Mexico	26616	*27**	0.65%
Mexico	1131	*34*	0.34%	Argentina	23030	*29**	0.56%
Chile	6310	*45*	0.19%	Chile	10849	*39**	0.27%
Venezuela	3025	*50*	0.09%	Venezuela	5227	*51*	0.13%
Cuba	1282	*62*	0.04%	Cuba	3248	*58**	0.08%
Colombia	1176	*66*	0.03%	Colombia	3326	*57**	0.08%
Costa Rica	825	*79*	0.02%	Uruguay	1665	*74**	0.04%
Peru	660	*87*	0.02%	Costa Rica	1234	*78**	0.03%
Uruguay	657	*88*	0.02%	Peru	1133	*82**	0.03%
Panama	350	*101*	0.01%	Ecuador	621	*95**	0.02%
Guatemala	291	*107*	0.01%	Panama	613	*96**	0.02%
Ecuador	286	*108*	0.01%	Bolivia	463	*104**	0.01%
Bolivia	231	*114*	0.01%	Guatemala	237	*121*	0.01%
French Guiana	97	*138*	–	French Guiana	185	*133**	–
Dominican Rep	90	*140*	–	Dominican Rep	125	*140*	–
Honduras	70	*148*	–	Nicaragua	120	*142**	–
Paraguay	60	*155*	–	Paraguay	118	*143**	–
Nicaragua	66	*151*	–	Honduras	114	*145**	–
Guyana	45	*160*	–	Guyana	61	*160*	–
El Salvador	23	*171*	–	El Salvador	52	*164**	–

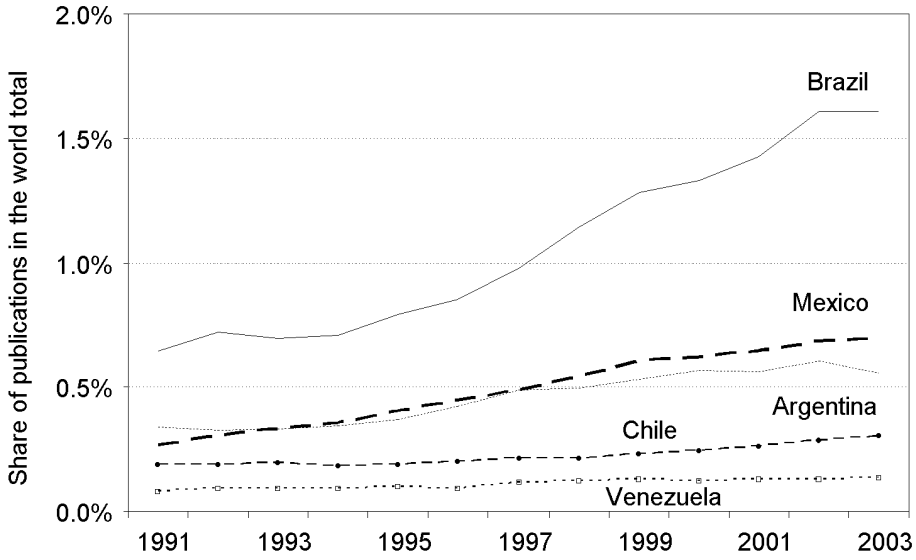

Figure 1. Share of publications in the world total of the most prolific Latin American countries, 1991–2003

Besides the share in the world's total publication, this relative growth is an important indicator of national dynamics. In order to deepen the above insights and to compare Brazil's growth with that of countries outside Latin America, Table 2 presents both the annual growth rate of the national world share and the overall change of relative publication activity, in the period 1991–2003, for the 44 most productive countries publishing at least 500 papers in 1991. Countries are ranked by the annual growth rate. This group is lead by Korea with an almost unbelievable 18.8% annual growth rate (of course with respect to the overall growth of the database). Nonetheless, Brazil's growth is impressive, too. Both Brazil and Mexico has an annual growth rate of 8%-9%, and have increased their world share by roughly 150%.

As for Brazilian scientific output, such a huge enlargement can be attributed to the continuity of a national program for training human resources to science during the 1990's. This program has ensured the increasing of the number of Master and PhD degrees as well as the number of PhD Programs throughout the country, which are evaluated every two years. As one of the requisite of this evaluation process is the scientific productivity of each faculty member, the total number of Brazilian publications were affected and increased.

Table 2. Most dynamically growing countries in 1991–2003.
Annual growth rate of the national world share (AGR) and overall
change of world share (Growth) for countries with at least 500 papers in 1991

Rank	Country	AGR	Growth
1	South Korea	18.8%	669.3%
2	Turkey	16.6%	517.9%
3	Singapore	13.5%	344.9%
4	China PR	13.4%	341.6%
5	Portugal	10.9%	243.5%
6	Taiwan	9.4%	189.1%
7	Mexico	8.5%	164.3%
8	Romania	8.8%	161.5%
9	Brazil	8.1%	148.8%
10	Greece	6.2%	103.3%
11	Spain	5.0%	78.3%

Similarity and diversity in Latin America's publication profiles

The diversity of Latin American science is also clear within their Activity Indexes (Figure 2), that reveals whether a specific field of a specific country has a relatively higher or lower share than its overall share in the world total publication. In earlier studies (REIST-2), four basic paradigmatic patterns in publication profiles have been distinguished, namely,

I. the 'western model' with clinical medicine and biomedical research as dominating fields,

II. the characteristic pattern of the former socialist countries with excessive activity in chemistry and physics,

III. the 'bio-environmental model' with biology and earth and space sciences in the main focus

IV. the 'Japanese model' with engineering and chemistry being predominant.

At a first sight one could conclude that all Latin American countries presented in Figure 2 follow the III. paradigmatic pattern with biology, agriculture and earth and space sciences in the main focus. Regarding the general trends, the relative weight of the scientific output of the 12 fields seems to be better balanced in Brazil than in the other countries. This can be a result of a two-decade extensive support from the Federal Government that resulted not only in an increase of postgraduate programmes but also in a diversification of the basic science fields (MCT, 2005). As another general tendency, the Biological sciences and Agriculture play important roles in the scientific output of all the five countries. In the first case, this is more evident for Argentina and Venezuela, where the relative weight of this field is twofold or higher then the observed for the world. For Agriculture, in Mexican and Brazilian science this field has a strong

weight. On the other hand, with the exception of Argentina and Chile in Medicine I, the fields of Neuroscience and Medicine are the less representative fields among the studied countries.

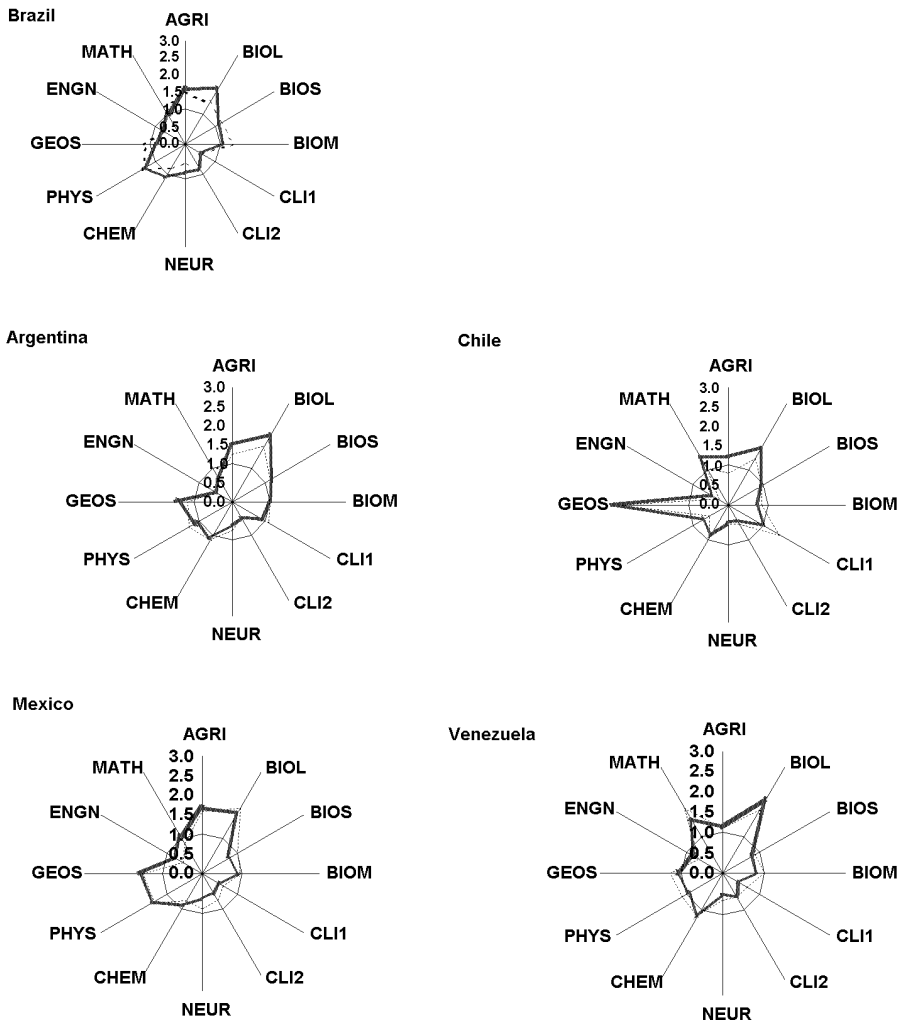

Figure 2. Activity index of the most prolific Latin American countries, 1991–1995 (dotted line) and 1999–2003 (thick line). World standard is indicated by a thin solid line

For Argentinean science but even more for Chilean and Mexican, the field of Space & Geosciences does play a very strong role. In the case of Chile the relative weight of this field is almost three times higher than that for the world. Been the country with one of the best conditions for astronomic investigation, Chile has attracted some of the world most important research projects on astronomy, such as the Project Genimi Laboratory (CONICYT, 2005). With such huge projects installed in its land, Chilean scientists in the fields of space science and earth sciences have enlarged the national output and became one of the world leaders in astronomy and astrophysics.

About Venezuelan science, we have found that the relative weight of mathematics publications is much higher than the other region countries but for the recent period it has been reduced. The Venezuelan tradition in the mathematics field dates from the end 50', been the turn point the foundation of the School of Engineering in the University of Los Andes and in the Central University of Venezuela. From this point many Venezuelan mathematicians have made important scientific contributions to world knowledge (LEON, 2000).

Impact of Latin American science

The impact of Brazilian science and the most prolific countries in Latin America is shown in Figures 3 and 4. Concerning the RCR, Relative Citation Rate, we have found that, despite the low relative contribution of papers from Medicine (Figure 2), citations from these publications are relatively higher in Chile, Argentina, Brazil and Venezuela but not in Mexico. Also surprisingly, publications from Engineering are cited in Venezuela as much as in the world even though the field is not as much as productive. Confirming the data of the Activity Index (Figure 2), the Chilean citations within the field of Space & Geosciences exceed the world average indicating again how strong this field is for the whole Chilean science.

According to GLÄNZEL et al. (2004a), self-citation is a natural component of scientific communication, accounting for around 26%–30% of the world's total citations in the sciences and based on a three-year citation window. But it varies a lot among the subject fields and it also decreases rapidly when compared to foreign citations (GLÄNZEL & THIJS, 2004). Of course, self-citation shares largely deviating from the corresponding world standard have to be viewed critically. In Table 3, it is clear that self-citations play an important role in the visibility of Latin American publications. In this macro-level analysis, Brazil has the largest share of self-citations while Chile the lowest. For all the five countries, it is observed a reduction in the share of self-citation from 1991–1995 to 1997–2001. For most, such a decrease resulted in an increase of both RCR and RCRX, except for Venezuela. This occurs if the observed

ratio of self-citations and foreign citations coincides with the ratio of the expected self-citations and foreign citations; it should be mentioned that this does not necessarily imply that the share of self-citations corresponds to the world standard or that RCR takes its neutral value.

Table 3. Share of self citation, RCR and RCRX

Country	Share of self - citation		RCR		RCRX	
	1991–1995	1997–2001	1991–1995	1997–2001	1991–1995	1997–2001
Argentina	41.3%	36.8%	0.741	0.831	0.666	0.770
Brazil	40.2%	39.4%	0.769	0.825	0.697	0.741
Chile	35.3%	33.8%	0.879	0.950	0.846	0.901
Mexico	38.8%	35.6%	0.768	0.811	0.711	0.766
Venezuela	37.1%	36.2%	0.784	0.773	0.746	0.730

A reduction of the average citation rate in most of the fields and for most of the countries can be observed when the self-citations are excluded (Figure 4). The main exceptions are the medicine fields in Chile, Argentina and Brazil, the field of Space & Geosciences in Chile and the engineering in Venezuela. In the case of Medicine, GLÄNZEL et al. (2004) have shown that this field is among those with the lowest rate of self-citations. Thus, it would not be expected large changes in these fields after removing the self-citations. As for Space & Geosciences, the data of RCRX reinforce the importance of this field in Chile's scientific output. This is not only the most relatively productive field in the country but also the one with the highest visibility.

As it is known, there are probably thousands of domestic scientific journals in the different knowledge fields in the region. However, most of these journals are not indexed by any of the available databases and are mostly oriented to the local public. Thus, the estimative of the impact of Latin American scientific output takes into account the number of citations of ISI publications only. This indicator has been plenty used also in meso and micro-level evaluation processes but its real meaning and value is for sure not so clear, especially for those who take part in such processes. But even if we base bibliometric analyses on ISI-indexed literature alone, we have to notice that, for instance, Brazilian scientists still prefer publishing in domestic or Latin American journals. We have analysed the 35% and the 25% most frequently chosen journals, respectively in 1991 and 2003, which account for about 1,400 and 3,500 publications. Expect for Physics and Materials Science, most of this set of journals were national or regional ones with publications in both English and Portuguese. The situation has not substantially changes during the 13 year under study. More than one half of those top journals were Brazilian journals. This publication strategy, which could be observed above all in the life sciences, is clearly to the detriment of visibility and according to GLÄNZEL et al. (2004) lower visibility goes with higher probability of self-citations. In the other Latin American countries under study, this trend is less pronounced.

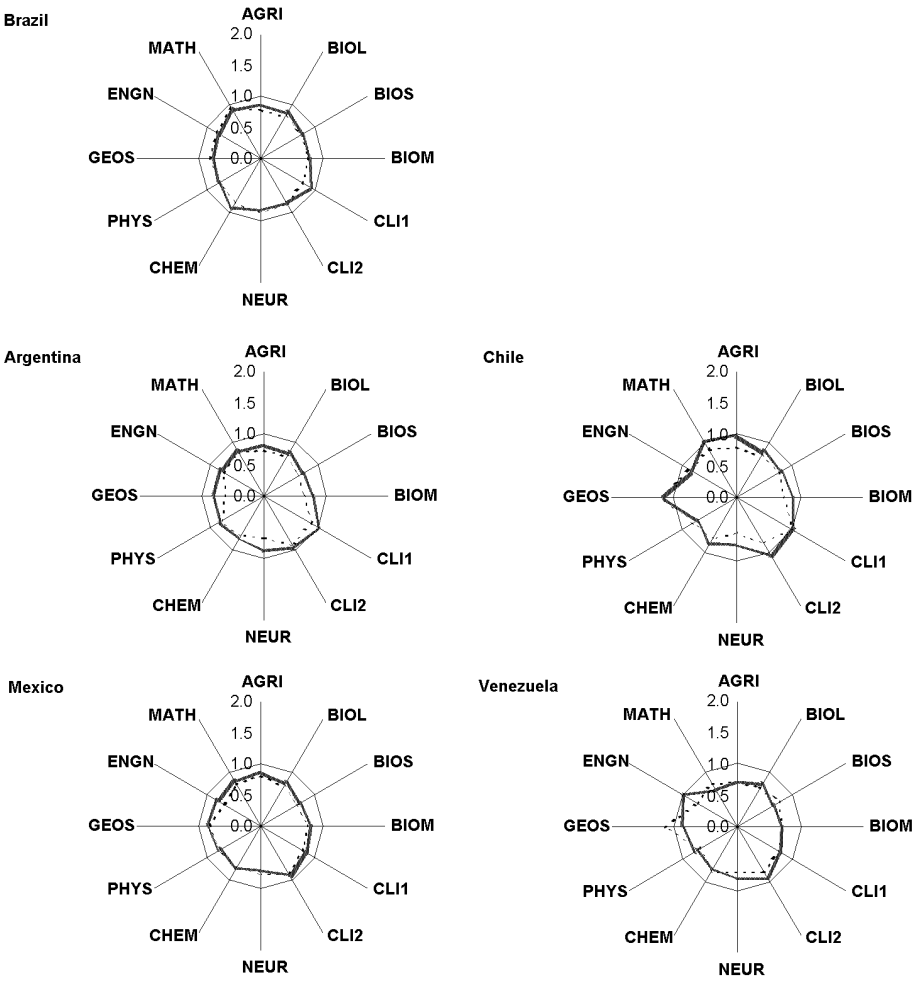

Figure 3. Relative Citation Rate of the most prolific Latin American countries, 1991–1995 (dotted line) and 1997–2001 (thick line). World standard is indicated by a thin solid line

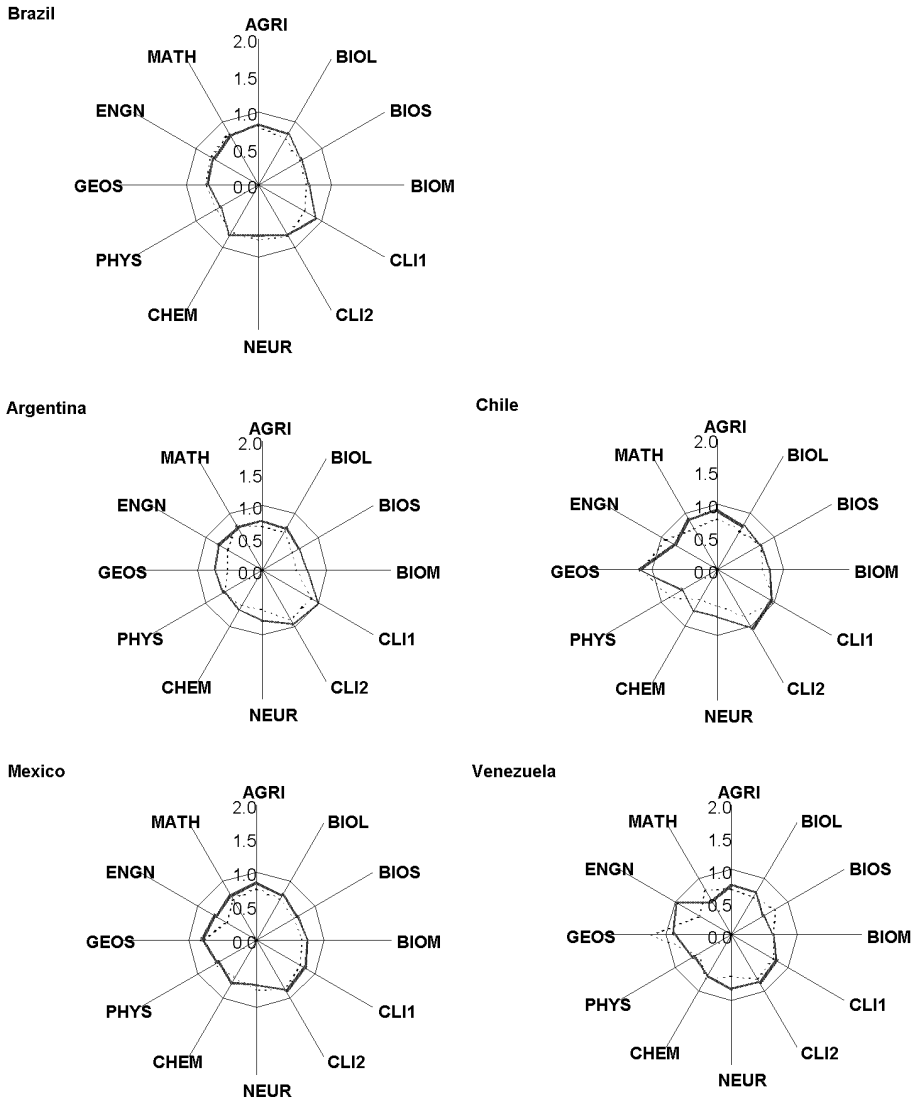

Figure 4. Relative Citation Rate eXculding self-citations for the most prolific Latin American countries, 1991–1995 (dotted line) and 1997–2001 (thick line). World standard is indicated by a thin solid line

International collaboration

International collaboration in science has been registered since the 19th century. However, many recent studies have shown that this phenomenon has increased during the last decades (LECLERC & GAGNE, 1997; GLÄNZEL, 2001; GLÄNZEL & SCHUBERT, 2004). Several factors, such as cost-savings, the growing importance of interdisciplinary fields and geographical, economical or cultural interests are pointed out to contribute for the establishment of international collaboration (KATZ & MARTIN, 1997).

Figure 5 presents the share of the international collaboration for each of the five Latin American countries, estimated by the share of international co-authored publications in the country total publications. With the exception of Brazil, the share of scientific co-publications increased significantly in the other four countries. Venezuela and Chile are the ones with the largest shares, around 48% and 52%, respectively. In the case of Brazil, the country not only displays a steady share in international co-publications but also displays the lowest share. In a recent article, LETA & CHAMOVICH (2002) has discussed the remarkable increase in the share of scientific co-publications in Brazilian science during the 1980's as well as its drop down in the 1990's. Such a trend should be interpreted as a part of the process of establishment and consolidation of Brazilian science. It is known that Brazilian researchers were greatly encouraged to collaborate with international peers during the 1980's but the same did not occur a decade later.

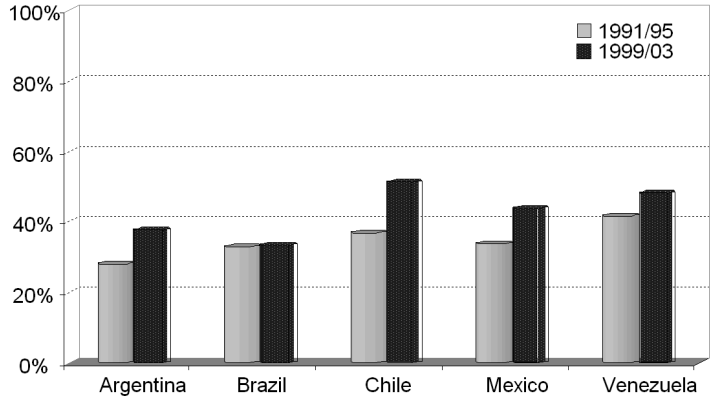

Figure 5. Share of international co-publications in Latin American countries, 1991–1995 and 1999–2003

Although the share of Brazilian international co-publications was almost constant from the 1991–1995 to the 1999–2003 period, the number of links as well as the number of strong links among Brazil and other joint countries increased remarkably in one decade (Figures 6–7). Such increase was even more notably among Brazil and Latin American countries. Different from the beginning of the 90's, Brazil has intensified its scientific collaboration with neighbour countries. Together with USA, Argentina became the most important Brazilian partner in science. This collaboration has been intensified with Mexico while with some other Latin American countries, such as Uruguay, Peru, Ecuador, Venezuela and Cuba, a new strong linkage has appeared.

Figure 6. International co-publication links of Brazil in 1991–1995 based on Salton's measure (dotted line ≥ 1.0%, solid line ≥ 2.5%)

Figure 7. International co-publication links of Brazil in 1999–2003 based on Salton's measure (dotted line ≥ 1.0%, solid line ≥ 2.5%)

USA has become Brazil's most important partner outside Latin America. According to the 2nd Edition of the European Report on Science and Technology Indicators (REIST-2, 1997), Brazilian share of co-publications with the EU slightly exceeded that with USA in the 1990's. Within the European Union, French, UK, German and Italian scientists are among the most frequent co-authors in Brazil publications. If the strength of co-authorship links is considered, then also the strong tie with Portugal is worth mentioning. Besides the strong integration in the Latin American geopolitical region is characterised by intensifying collaboration patterns, only North America and European countries have strong or medium strong links with Brazil. Collaboration with China and the developed Asian communities, however, is less pronounced.

Conclusion

Science in Brazil can be understood only in the Latin American context. Brazil proved the leader in this region and its scientific community is characterised by intense international collaboration with its geopolitical environment as well as with North America and Europe. According to ZITT & BASSECOULARD (2004), collaboration in research is only one aspect of internationalisation, globalisation and convergence in science. Other aspects of scientific communication such as 'publication strategy' and research profiles point out the country as a typical representative of the region.

Brazilian scientists still prefer publishing in national or regional journals, sometimes even in their national language. This implies both a lower-than-average visibility and a relatively low citation impact accompanied by high shares of author self-citations. Nonetheless, Brazil has the most balanced publication profile among the Latin American countries. The most striking structural change in publication profile took place in earth and space sciences, biomedical research with a distinct decrease as well as in neuroscience and chemistry with a pronounced growth of relative national activity. The increasing activity in chemistry is accompanied by a measurable increase of citation impact. Brazil reached its highest Relative Citation Rate in Chemistry and Internal Medicine in the second sub-period. In these fields, observed citation impact almost coincides with the expected one.

For the whole region, the combination of the relatively low scientific activity in neurosciences and medicine with the data from WHO's report (WHO, 2001) should be taken into account seriously by the respective governments. The increasing prevalence of *mental illnesses* and *neurological disorders* as well as the poor statistics of basic health indicators in the region urges for some national and regional debate on the enlargement of investments not only in the health system, but also in basic and applied research in these fields.

A deeper insight in the structural evolution of Brazilian science requires a detailed analysis of the development of publication profiles and citation impact of Brazil's main actors at the institutional level. This analysis will be part of the second part of the Brazilian Science Study called **"**Science in Brazil. Part 2: Sectoral and institutional research profiles"**.**

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