Jointly published by Akadémiai Kiadó, Budapest and Springer, Dordrecht

Scientometrics, Vol. 67, No. 1 (2006) 87–105
DOI: 10.1556/Scient.67.2006.1.6

Science in Brazil. Part 2: Sectoral and institutional research profiles

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In the present study a bibliometric meso-level analysis of Brazilian scientific research is conducted. Both sectoral and publication profile of Brazilian universities and research institutions are studied. Publication dynamics and changing profiles allow to the conclusion that powerful growth of science in Brazil goes with striking structural changes. By contrast, citation-based indicators reflect less spectacular developments.

Introduction

The development of scientific and technological infrastructure and the formation and expansion of Brazilian academic community are very recent events in the country. This process started formally in the 1950's and 1960's, when the most important scientific and technological public funding agencies were founded and started supporting research activities and built up the required infrastructure. From the 1970's to 1980's, public policies for science were focused on the training of human resources and, a large national program was created by the federal government. This resulted in the expansion of both the graduate programs and the number of fellowships awarded to Brazilian graduate students. Recently, changing again its focus, Brazilian government recognized the importance of the scientific education for undergraduate students to improve their later performance in graduate schools. The new Fellowship Program, named as Initiation in Science (IC) and supported by federal funds, aims to engage university students in research projects carried out by faculty members. From 1990 to 2002, the number of IC fellowships increased from 7,548 to 18,864 (MCT, 2005). This program is considered one of the most important initiatives undertaken by the Brazilian government as an attempt to improve the training of scientists in the country. (SCHWARTZMAN, 1991a; BAS, 1999)

Received July 15, 2005

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0138–9130/US $ 20.00

Despite all the economic instability, especially in the 1980's, Brazilian science increased fast during the last decades. The foundation of the basic infrastructure and the training of human resources were for sure the drive forces in this growth. But recent reforms in Brazilian higher education system have also contributed to it. As a part of this reform, all higher education institutions started to be evaluated annually while the evaluation of graduate programs, which have been carried for decades, was changed considerably. In this case, the evaluation process takes place every two years and takes into account some variables, as the average time students enrolled in the program take to graduate, the curriculum of each faculty member and scientific productivity (SCHWARTZMAN, 1991b). To assist this evaluation, the Ministry of Education implemented a criterion system for classifying journals, the Qualis system (CAPES, 2005). Based on the impact factor of the *Science Citation Index* of Thomson – ISI (Philadelphia, PA, USA) and peers analysis, both international and national journals are arranged in grades A, B and C (from highest to lowest grade). In order to get a good evaluation researchers are encouraged to publish more in A and B journals. This should guarantee that the graduate programs they are engaged in will keep on receiving some financial support and new scholarships.

The stability of Brazilian economy and currency in the mid 90's (METTENHEIM, 2004) made it possible to establish a set of new governmental initiatives and programs, such as the PRONEX, the Program for Supporting Excellence Research Groups, created in 1996. In 2001, another important program was established in the country: the Millennium Science Initiative. Supported by funds from the Brazilian Ministry of Science and Technology and World Bank, the Millennium aims to increase the funding for the most wide-ranging and relevant scientific research and technological development projects. Among all these initiatives, the implementation of the "Sector Funds", a new modality of funds from the private sector, seems to be the most relevant one (VIEIRA, 2001). The Oil and Gas Sector Fund (CT-Petro) was first to be created by the Ministry of Science and Technology in 1999. CT-Petro aimed at identifying major technologies for the development of both the upstream and the downstream sectors of the industry (NEVES, 2004).

There is no doubt that Brazil is experiencing a particular and promising moment concerning its system of Science, Technology & Innovation. However, there are still many challenges to face. To absorb and create new jobs and positions to the new thousands of PhDs, to expand and decentralize the system with quality throughout the country and to create mechanisms to enlarge the involvement of industry in this activity are for sure some of these challenges. Considering the last one, it is widely known that public institutions are the main producers of knowledge in developing nations, like Brazil. Also, the proportion of public/private expenditures in these countries is almost the opposite of that found for developed nations (UNESCO, 2001). Thus, in the present paper we continue the overview of the Brazilian scientific research performance, based

on the ISI bibliographic data for the period 1991–2003. In this second part, we describe and discuss the enlargement of Brazilian science during the last decades on the basis of a meso-level analysis. At first, we will focus on the trends of scientific activity and impact of private and public sectors. After that, we present an analysis on the evolution trends of the main clusters of likewise institutes in terms of field productivity. We hope the data presented here may help to better understand the dynamics of private and public institutions as well as the main institutional changes that took place in the last decade.

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). Most parts of the study are based only on the *Science Citation Index Expanded* (SCIE); the cluster analysis of institutional publication profiles, however, uses the complete WoS including the SCIE, the *Social Sciences Citation Index* (SSCI) and the *Arts & Humanities Citation Index* (AHCI). According to the principles of data processing described in Part 1 of the study, only document types named as Articles, Letters, Notes and Reviews were taken into consideration. Publications were assigned to Brazilian institutions on the basis of their corporate addresses which appear in the by-line of the publication. For this, all the institute names have been first cleaned-up manually. In the following step, a thesaurus has been made up of cleaned names with all their spelling variances. The correct institutional assignment of addresses has been checked and all institutes have been assigned to their standard names. The addresses were then arranged according to the sector they are related to and to the sort of institution they are. Three main groups arose:

(1) Universities from public sector,
(2) Non-Universities from the public sector and
(3) Private universities and other private institutions (including private hospitals).

The concept of public institution in Brazil is not only related to the fact that they are totally supported by federal, state or by the municipal funds but also the fact that they are totally free of charge.

As for subject classification, the publications from the three main groups were arranged into 12 major fields: Agriculture & Environment, Biology, Biosciences, Biomedical research, Clinical & Experimental Medicine I, Clinical & Experimental Medicine II, Neuroscience & Behavior, Chemistry, Physics, Geosciences & Space Sciences, Engineering and, finally, Mathematics (cf. Part 1 of this study).

For the citation analysis of institutions, 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.

Methods and results

In this part of the study, publication and citation indicators at the level of the three sectoral groups as well as for the clusters according to their publication profile (see below) were calculated. The same set of indicators as applied in Part 1 (GLÄNZEL et al., 2006) has been used for this meso level study, too. According to the specific needs of the analysis, the period 1991–2003 has been split up into different sub-periods each. For the analysis of the evolution of the sectoral profile, the two sub-periods 1991–1995 and 1997–2001 have been used; for the cluster analysis of research profiles, the three sub-periods 1991–1994, 1995–1998 and 2000–2003 have been applied. Since citation analysis was based on three-year citation windows and the last available citation period was 2001–2003, for the citation analysis the shortened sub-periods 1991–1993, 1995–1997 and the year 2001 were used.

Brazilian science: the concentration in the public sectors

During the last decades, the number of Brazilian scientific publications indexed in the ISI database increased significantly. But different from most of the developed countries, Brazilian science is extremely concentrated on the public sector. In the U.S., for instance, the largest fraction of employed scientists works for the private sector (NSF, 2004). In Brazil, according to the Ministry of Science and Technology (MCT, 2005a) approximately 70% of Brazilian scientists works for the public sector (public universities and research institutes). The large concentration of scientists in the public sector pushes these institutions to be the most productive of the country (Figure 1). Such a predominance of research in the (public) universities characterizes the so-called western-type profile which has been already observed, e.g., for Belgium, Finland, Ireland and Portugal (GLÄNZEL & SCHLEMMER, 2005).

From 1991 to 2003, universities from the public sector accounted for more than 80% of the country's total publications in the ISI database, a share that seems to be increasing (inset Figure 1). In this period, the number of publications addressed to these institutions increased from 3,023 to 11,845. In the same period, other institutions from

the public sector (research institutes, hospitals, national enterprises, etc) were responsible for approximately 20% of the country's total publications while the share of publications addressed to institutions from the private sector were not higher than 5%.

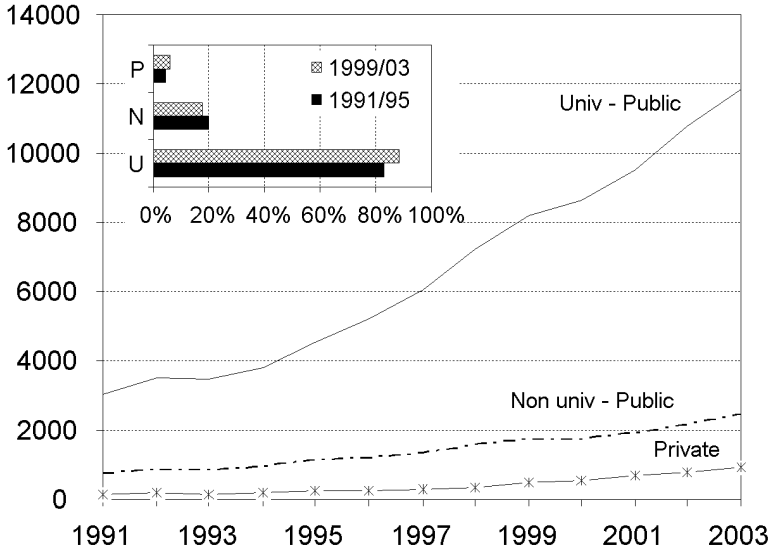

Figure 1. Evolution of Brazilian ISI publications by main sectors. The share of publications from the main sectors in the 1991–1995 and 1997–2001 periods is presented in the inset (U: University – Public, N: Non University – Public, P: Private)

The most productive Brazilian institutions are listed in Table 1. The differences in the share are strongly marked from the public universities to the private sector, where the contribution of each institution drops down considerably. Among the public universities, the University of Sao Paulo is the most prolific, accounting for almost 24% of all the country's publications. All the state universities from Sao Paulo are amongst the top 5 most prolific ones. Particularly in Sao Paulo, the largest and the richest state of the country, 1% of the total state budget is addressed to support science in its institutions. Such an appropriate and constant funding is, for sure, not seen for the rest of the country.

Half of the public universities are located in the southeast region (those marked with *), where most of the research groups, scientists and PhD students are concentrated on (CNPq, 2002). The other universities are from south region (Fed Univ Rio G. Sul, Fed Univ Santa Catarina, Fed Univ Parana, State Univ Maringa and Fed Univ Santa Maria), northeast region (Fed Univ Pernambuco, Fed Univ Ceara, Fed Univ Paraiba,

and Fed Univ Bahia) and central west (Unv Brasilia). It is interesting to see that the share of publications from "small" universities increased significantly when we analyse their performance from 1991–1995 to 1999–2003 (data not shown in the present paper). This is the case of the Federal University of Sao Carlos and the State Univ Sao Paulo. In both cases, such an increase maybe a result of a pioneer program to build in the state of Sao Paulo a well-qualified infra-structure and mass of researchers in molecular biology by supporting the revolutionary project "*Xylella fastidiosa* genome" (SIMPSON, 2000).

Table 1. The most prolific Brazilian institutions by sector (1991–2003)

Public sector				Private sector	
Universities	Share	Non Universities	Share		Share
Univ Sao Paulo *	23.89%	Braz Agr Res Coorp	3.01%	Cath Univ Rio Janeiro	1.60%
Campinas State Univ *	9.69%	Oswaldo Cruz Fdn - RJ	2.77%	Cath Univ Rio G. Sul	0.39%
Fed Univ Rio Janeiro *	9.28%	Braz Center Res Phys	1.78%	Cancer Hosp	0.28%
State Univ Sao Paulo *	6.34%	Natl Inst For Space Res	1.45%	Ludwig Inst	0.28%
Fed Univ Rio G. Sul	5.47%	Natl Com. Nucl Energy	1.28%	Vale Itajai Univ	0.17%
Fed Univ Minas Gerais *	5.19%	Butanta Inst	0.67%	Univ Sao Francisco	0.15%
Fed Univ Sao Paulo *	3.54%	Ctr Aerosp Technol	0.56%	Mogi Cruzes Univ	0.14%
Fed Univ Sao Carlos *	2.88%	Natl Inst Res Amazon	0.52%	Braz Lutheran Univ	0.12%
Fed Univ Santa Catarina	2.35%	Natl Inst Pure&Apll Math	0.48%	Albert Einstein Hosp	0.12%
Fed Univ Pernambuco	2.34%	Adolfo Lutz Inst	0.42%	Cath Univ Campinas	0.11%
Fed Univ Parana	2.11%	Res Ctr Petrobras	0.37%	Vale Rio Sinos Univ	0.11%
Fed Fluminense Univ *	2.07%	Natl Lab Synch Light	0.32%	Passo Fundo Univ	0.10%
Unv Brasilia	2.03%	Natl Observ	0.31%	Santa Ursula Univ	0.10%
State Univ Rio Janeiro *	1.94%	Fed Sch Technol	0.29%		
Fed Univ Vicosa *	1.56%	Natl Inst For Cancer Res	0.25%		
Fed Univ Ceara	1.48%	Military Inst of Engn	0.21%		
Fed Univ Paraiba	1.20%	Natl Lab Scient Comp	0.20%		
Fed Univ Bahia	1.19%	Botanic Inst Sao Paulo	0.20%		
State Univ Maringa	1.11%				
Fed Univ Santa Maria	1.09%				
Number of institutes	61		50		38

A prolific research institution from the north region, the largest size and the most strategic region for the country, appears only among the other institutes from public sector: the National Institute for Research of Amazon (INPA). In this group all the institutions are very specialized in one or two fields of knowledge and with the exception of INPA all the institutes are from the southeast region. The leader public research institutes are: The Brazilian Agricultural Research Corporation (EMBRAPA) and the Oswaldo Cruz Foundation (FIOCRUZ). EMBRAPA is a networking of 37

Research Centres spread all over the country with around 2,200 researchers dedicated to agriculture and biological sciences. Founded in the 1900's in the city of Rio de Janeiro, FIOCRUZ is one of the oldest Brazilian research institutes devoted mostly to the biological and biomedical sciences. Most of these institutions are supported by federal funds with the exception of Butanta Institute, Adolfo Lutz Institute and Research Centre of PETROBRAS (CENPES). The first two are supported mainly by state funds while CENPES is supported by the Brazilian Oil Company, PETROBRAS, one of the largest major oil companies in the world, leading the sector in the implementation of the most advanced deep-water technology, for oil production.

Among the institutes from private sector, the Catholic University of Rio de Janeiro is the most productive. With the exception of this university, the contribution of other private universities is still very incipient due to their recent involvement in research activities. During the 1990's, a large number of new private universities proliferated all over the country. As a result of this expansion, around 70% of all the enrolment in the Brazilian higher education system was concentrated on the private sector in 2002, which are mostly specialized in the social fields, such as administration, law, economics and education (SCHWARTZMAN, 2004). It is though worth mentioning that due to the high costs and the lack of infra-structure and qualified people, just a small number of Brazilian private institutions do support and carry on research projects. The slightly increasing of the number of publications from these institutions (see Figure 1) is probably due to the evaluation process held by the Ministry of Education in the higher education system just as the same as it occurred in the public sector.

Another important aspect to be highlighted is that the most prolific institutes in the private sector group are constituted by (10) universities, (2) hospitals and a single research institute but not by enterprises. The lack of private enterprises in scientific output is not a common scenario only in Brazil but in all Latin American countries as it was well discussed by SUTZ (2000, 2001). In Brazil some important initiatives, such as taxes incentives and new funding, were taken by federal and state governments in order to increase not only the investments but the participation of private sector (industry mainly) in science and technology activities (MCT, 2005b). However, the results of such initiatives are really unclear once the sector is not found as a main actor of either the scientific or the technological output (in this case, estimated by patents) (PINHEIRO-MACHADO & OLIVEIRA, 2004).

Publication profile of Brazilian main sectors

As it was discussed in the previous paper, the pattern of publications from Latin American countries as well as from Brazil follows to the 'bio-environmental model' (see Part 1 of this study: GLÄNZEL et al., 2006). In this model agriculture, biology and earth and space sciences are in the main focus. This model seems to be also applied for

the three main sectors in recent years. But it is quite strong among the Non-Universities Institutes from public sector (see Figure 2). The relative weights of agriculture and biology are almost 3 and 2.6 times higher than the observed in the world, respectively. The patterns shown in Figure 2 are in line with the data presented in Table 1, and reinforce the notion of how concentrated the scientific output from these institutes is. Among the most prolific institutes from this sector, only two would not fit in this profile: The National Institute of Pure & Applied Mathematics (IMPA) and National Institute for Cancer Research (named INCA).

As for the universities from the public sector, a more balanced shape of the scientific output can be observed. The same applies for the private sector but in the recent period only. In fact, as for the period 1991–1995, the publication profile of private institutions was too concentrated on engineering and physics. According to 2nd Edition of the European Report on Science and Technology Indicators (REIST-2, 1997), the previous trends of the private sector publications would be a combination of model II (found in the former socialist countries and characterized for the excessive activity in chemistry and physics) and model IV or the 'Japanese model' (where engineering and chemistry are predominant). The shift may be explained by the newcomers, that is, new research groups that arose inside the private universities and started publishing in more recent years. This is the case of the Vale Itajai University, the University of Sao Francisco, the Mogi Cruzes University and the Brazilian Lutheran University. In the period of 1991–1995, only 10 publications were addressed to these institutions. This number increased to 503 in the period of 1999–2003. According to the 2002 Brazilian census on the scientific community (CNPq, 2002), most of the researchers from these institutions are carrying on research projects on biology and social sciences and humanities. Another reason for that shift may be related to the increase observed also in the sum of publication addressed to Cancer Hospital and Ludwig Institute, both devoted only to medical and biomedical research: from 128 to 365. Thus, the combination of these increasing surpassed the growth of publications from Catholic University of Rio de Janeiro. This university is well-known by its tradition in physics and engineering research, which can be easily observed by the distribution of its researchers: 417 out of 658 are carrying on research on these fields (CNPq, 2002)

As to be also mentioned, we have observed that the relatively high weight of publications from biology and physic is a common feature in the three sectors. It is worthy, thus, to state that these are not only the most traditional research fields but they aggregate the largest number of researchers (SCHWARTZMAN, 1991; RESENDE, 1996; BRAZILIAN ACADEMY OF SCIENCES, 1999; GUIMARAES et al, 2001).

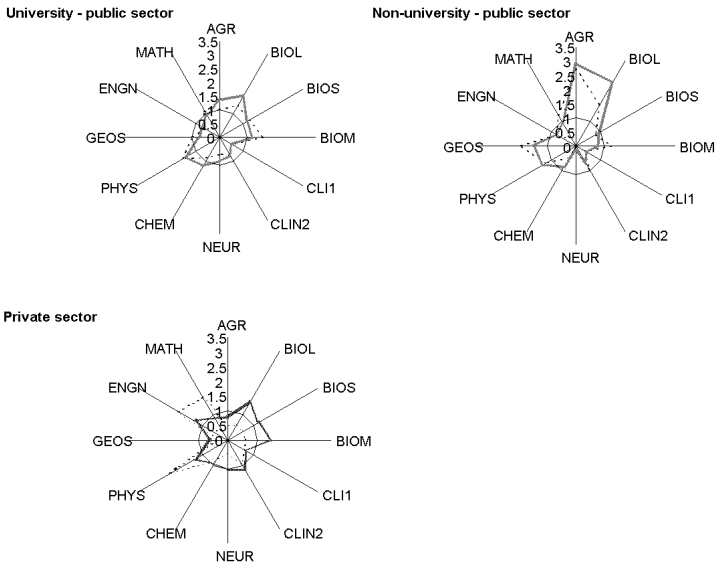

Figure 2. Activity index of Brazil in 1991–1995 (dotted line) and 1999–2003 (thick line). World standard is indicated by a thin solid line

Collaboration among sectors

Collaboration and co-publications among different sectors has been considered as a strong indicator within the metaphoric Triple Helix model by Etzkowitz and Leydesdorff (cf., LEYDESDORFF, 2003). In his study Leydesdorff has analysed the dynamics of Triple Helix relations at the global and national levels in different regions of the world by applying this indicator to scientometric data. GLÄNZEL & SCHLEMMER (2006) have studied changing patterns of sectoral co-publications during the last two decades in six selected European countries. Besides different national patterns of sectoral evolution, they have also found in the European data that growing collaboration among the sectors was typical of all countries. Even co-publications in which all three sectors were involved appeared during the last decade.

In order to visualise collaboration among sectors, we have applied the Jaccard Index to sectoral co-publication links. In order to be able to measure also tri-lateral links we have used a generalised, "multi-dimensional" Jaccard Index ($J_{\mathbf{A}_1 \ldots \mathbf{A}_n}$) which is beyond any doubt the most appropriate measure if bi- and multilateral relationship is analysed simultaneously. Analogously to the two-dimensional case, $J_{\mathbf{A}_1 \ldots \mathbf{A}_n}$ is the ratio of the cardinality of the intersection of two or more sets $\mathbf{A}_i$ ($i = 1, \ldots n, n \geq 2$) and the cardinality of their union, particularly

$$J_{\mathbf{A}_{1..n}} = \frac{\left| \bigcap_{i=1}^{n} \mathbf{A}_i \right|}{\left| \bigcup_{i=1}^{n} \mathbf{A}_i \right|} .$$

For $n = 2$, that is, for two sets **A** and **B** this equation reduces to the well-known similarity measure (Jaccard Index) $J_{\mathbf{AB}} = |\mathbf{A} \cap \mathbf{B}|/|\mathbf{A} \cup \mathbf{B}|$. Also in the "multidimensional case" we have $0 \le J_{\mathbf{A}_1 \ldots \mathbf{A}_n} \le 1$. Moreover, $J_{\mathbf{A}_1 \ldots \mathbf{A}_n} = 0$ if $\exists\ i, j \le n$: $\mathbf{A}_i \cap \mathbf{A}_j = \varnothing$ and $J_{\mathbf{A}_1 \ldots \mathbf{A}_n} = 1$ if $\mathbf{A}_i = \mathbf{A}_j \ne \varnothing$ for $\forall\ i, j \le n$. Finally, the measure obviously monotonously increases if any set is removed (i.e., the "dimension" is reduced), e.g, $J_{\mathbf{A}_1 \ldots \mathbf{A}_{n-1}} \ge J_{\mathbf{A}_1 \ldots \mathbf{A}_n}$.

We have applied this measure to the Brazilian publication data. According to the above-mentioned monotony property, the intensity of collaboration if all sectors are involved is expected to be much lower than in the case of any bilateral relationship. The results are presented in Figure 3. Three trends are obvious: (1) the intensity of co-publication links between any pairs of sectors has considerably increased, (2) the by far strongest co-publication link, however, was established between the University and the Non-university – Public sectors (UN in Figure 3), and (3) the relationship between University – Public and Private (UP in Figure 3) has dramatically intensified, and become the second strongest one by 2003. Although remaining relatively weak, the University – Public/Non University – Public/Private relationship considerably intensified: the share of UNP papers in all Brazilian publications has doubled during the 13 years under study and this development is reflected by the generalised Jaccard Index, too.

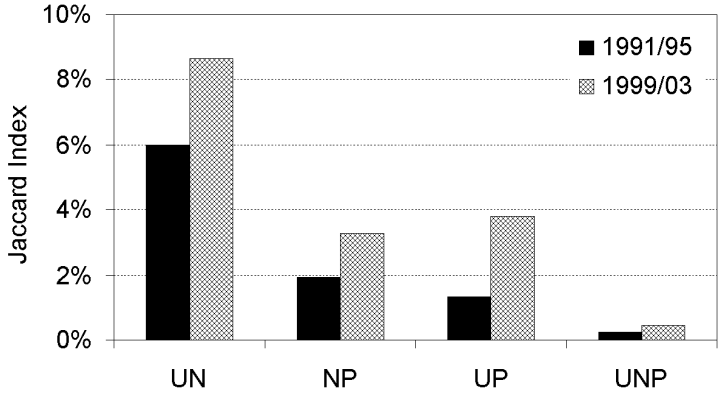

Figure 3. The evolution of collaboration among sectors in Brazil (U: University – Public, N: Non University – Public, P: Private)

Impact of public and private sector's publications

Despite the controversy about the uses and interpretations of citations, this indicator has been widely used to measure and/or estimate the impact of scientific publications. As it can be seen in Table 2, there is a good correlation between the share of publications and the share of citations in the three sectors. For example, universities from the public sector accounted for around 83% and 88% of all Brazilian publications in the two periods studied; the citations received by these publications accounted by similar shares. This proportionality is observed in the other two sectors, too.

Following Brazilian trends, the analysis of self-citations revealed that this indicator did not practically change from 1991–1995 to 1997–2001. But for publications from the private sector a slight increase was observed. Publications of universities from public sector presented the highest share of self-citation while those from private sector presented the lowest one. A similar figure is observed when we analyze the relative citation indexes, RCR and the RCRX (excluding self-citations). In both cases, however, only the publications from the public universities displayed a significant increase from a period to another.

Table 2. Indicators of citation impact of Brazilian sectors in 1991/95 and 1997/01 periods

	University Public Sector		Non-universities Public Sector		Private Sector	
	1991–1995	1997–2001	1991–1995	1997–2001	1991–1995	1997–2001
Publication share in Brazilian total	83.19%	87.55%	20.02%	18.09%	3.99%	5.08%
Citation share in Brazilian total	82.46%	87.45%	20.58%	18.52%	4.84%	5.91%
Share of self-citations in all citations	41.59%	40.95%	38.42%	38.59%	35.94%	37.51%
RCR	0.740	0.814	0.860	0.846	0.834	0.885
RCRX	0.658	0.717	0.797	0.764	0.788	0.789

In this context, we have to mention that the large amount of publications published in domestic journals should contribute to the trends of the citation-impact indicators since lower visibility goes with higher probability of self-citations (cf. GLÄNZEL et al. 2004). As already mentioned in the previous part of the study on Brazilian science there is a plenty of domestic scientific journals in the different knowledge fields in Brazil. Most of these journals are, however, not indexed by the ISI databases, and are mostly targeting at the local public. If we base bibliometric analyses on ISI-indexed literature, we have always to notice that Brazilian scientists still prefer publishing in domestic or Latin American journals. And the situation has not substantially changed during the 13 year under study. This has already been made clear by the macro study (GLÄNZEL et al., 2006). However, the question arises of "do Brazilian scientists in all sectors have the

same publication strategy?" We have analysed the about 15 most frequently chosen journals in 1991 and 2003 (Table 3). Again, we have restricted this analysis to the *Science Citation Index Expanded* (SCIE) because the national language and the target groups might have much stronger effect on journal selection in humanities and social sciences than it has in the sciences.

Table 3. SCIE journals most frequently used for publication by Brazilian scientists affiliated with institutions of different sectors in 1991 and 2003 (Brazilian and Latin American journals are set in bold)

1991						
	University public		Non-university public		Private	
Rank	Cum. share	Journal	Cum. share	Journal	Cum. share	Journal
1	5.44%	**BRAZ J MED**	8.98%	**PESQ AGROP**	4.44%	PHYS REV A
2	7.77%	**MEM I OSW C**	15.65%	**MEM I OSW C**	8.15%	CANCER
3	10.02%	**REV MEX AST**	20.41%	**REV I MED T**	11.11%	**PESQ AGROP**
4	12.17%	PHYS REV B	24.76%	**REV MEX AST**	14.07%	PHYS REV D
5	14.15%	**REV BRA GEN**	27.76%	**REV SAUDE P**	16.30%	COMM MATH P
6	16.11%	**PESQ AGROP**	30.34%	**BRAZ J MED**	18.52%	INT J CANC
7	18.00%	**REV SAUDE P**	31.97%	**BRAZ ARCH B***	20.74%	J CARDIO PH
8	19.86%	**REV I MED T**	33.47%	TOXICON	22.96%	J MAT SCI L
9	21.39%	**REV BRA MED**	34.69%	AM J TROP M	25.19%	J UROL
10	22.70%	**BRAZ ARCH B***	35.92%	HEALTH PHYS	27.41%	PHYSICA C
11	23.85%	**BRAZ J MICR***	37.14%	PHYS REV B	29.63%	**REV BRA MED**
12	24.94%	PHYS REV A	38.37%	PHYS REV D	31.85%	**REV MEX AST**
13	25.98%	SOL ST COMM	39.46%	RAD PROT D		
14	26.89%	PHYTOCHEM	40.41%	HUMAN BIOL		
15	27.69%	J APPL PHYS	41.36%	J GEO R-S P		
16			42.31%	**GENET MOL B***		
2003						
	University public		Non-university public		Private	
Rank	Cum. share	Journal	Cum. share	Journal	Cum. share	Journal
1	1.73%	**BRAZ J MED**	5.12%	**PESQ AGROP**	3.05%	LECT N COMP
2	3.23%	**ARQ NEURO P**	8.47%	**MEM I OSW C**	5.09%	**ARQ NEURO P**
3	4.64%	**QUIM NOVA**	10.70%	**REV BRAS CI**	6.42%	**QUIM NOVA**
4	5.82%	PHYS REV B	12.86%	MATER SCI F	7.54%	LECT N A I
5	6.82%	**ARQ BRAS ME**	14.20%	J GEO RES-A	8.66%	**ARQ BRAS ME**
6	7.79%	LECT N COMP	15.55%	**REV BRAS Z**	9.67%	**REV SAUDE P**
7	8.74%	**PESQ AGROP**	16.74%	**ARQ BRAS ME**	10.49%	J ENDODONT
8	9.65%	PHYS REV D	17.82%	PHYS REV D	11.30%	**BRAZ J MED**
9	10.54%	**J BRAZ CHEM**	18.82%	PHYS REV B	12.02%	NUCL INST B
10	11.40%	**REV BRAS Z**	19.75%	PHYS LETT B	12.73%	EUR PHY J C
11	12.18%	**REV BRAS CI**	20.67%	TOXICON	13.44%	BIOC BIOP R
12	12.96%	**MEM I OSW C**	21.52%	**BRAZ J MED**	14.15%	ARCH OTOLAR
13	13.69%	PHYSICA A	22.36%	**BRAZ J MICR**	14.77%	PHYS LETT B
14	14.42%	**GENET MOL B**	23.17%	ADV SPACE R	15.38%	PHYS REV B
15	15.10%	MATER SCI F	23.94%	ASTRON ASTR	15.99%	INT ENDOD J
16	15.77%	J APPL PHYS				

* Journals not SCIE-indexed in 2003.

As for the publication strategy, the journals analysis showed that, with the exception of physics and materials science, the most frequent journals for other fields were national or regional ones with publications in both English and Portuguese. The most striking feature found in sectoral publication strategies is the rather 'conservative' communication behaviour in the university public sector in the life sciences, which has not changed considerably till 2003. Therefore, Brazilian and Latin American journals are still prevailing in the 2003 list of top preferred journals. This tendency is somewhat less pronounced in the non-university public sector; however, this might be a consequence of its publication profile with relative high activity in physics.

A relatively low share of local journals among the top preferred journals could be observed in the *private sector*. Here publications in computer science and physics are in the foreground and those appeared mainly in international journals. In order to draw fair conclusions from the changes in most preferred journals, we have to take into account that several journals still appearing in the 1991 list are not covered any more in more recent SCIE volumes. These journals are marked in Table 3. Brazilian scientists still frequently publish in these journals as can be found, for instance, in the *Scientific Electronic Library Online* (SciELO) – an electronic library covering a selected collection of Brazilian scientific journals. Finally, we just mention that several journals changed their names and in order to allow comparisons, the current names of those journals have been used for 1991 in Table 3, too.

Cluster analysis of institutional publication profiles

In order to better understand the situation of Brazilian science at the institutional level, a hierarchical clustering analysis was applied for grouping likewise institutes. In a recent paper by THIJS & GLÄNZEL (2006), such analysis has resulted in 6 main clusters for research institutions of six selected medium-sized European countries, particularly,

Cluster I: Eng/Phys/Chem –Technical research institutes: Engineering, Physics and Chemistry
Cluster II: Agri/Bio – Agricultural institutes
Cluster III: GenMed – Research institutes with main focus on medical research
Cluster IV: NonMed – Institutes with a multidisciplinary profile, without medical research
Cluster V: SpecMed – Institutes for specialized medicine
Cluster VI: Geo – Geosciences and Space sciences.

We have repeated this exercise in order to map the Brazilian institutional landscape. For the cluster analysis of institutional publication profiles we have extended publication profiles within the twelve science fields used earlier in this section to a broader scheme, including also social sciences (Social sciences I: General, Regional &

Community Issues and Social sciences II: Economical & Political Issues) and Arts & Humanities. Institutional profile clusters are thus – similarly to those found in Europe – based on fifteen subject areas.

Publication profiles for three different time periods were calculated for all individual institutions (1991–1994, 1995–1998, 2000–2003), Only profiles from the last period were used in a hierarchical clustering, with squared Euclidean distances and Ward-linkage to create clusters of likewise institutes. From a total of 163 institutes, only those with at least 30 publications in the period 2000–2003 were taken into account in this clustering. Unlike in the European case, where we have found six stable clusters, for Brazil the method resulted in five different clusters. The share of publications within each subject field for each group and for the period 2000–2003 is presented in Table 4. Dominant fields (>15%) are highlighted. On the basis of Table 4 one can characterise the profile of the five clusters as follows.

– Cluster A: Phys/Chem/Eng – Research institutes with main focus on natural and technical sciences
– Cluster B: BioSci – Research institutes with main focus on biosciences
– Cluster C: Chem – Research institutes with main focus on chemistry
– Cluster D: Agri/Bio – Agricultural institutes
– Cluster E: GenMed – Research institutes with main focus on medical research

Table 4. Representation of subject fields in profile clusters

Field	Cluster A	Cluster B	Cluster C	Cluster D	Cluster E
Agriculture	7.4%	10.6%	5.1%	**48.3%**	2.1%
Biology	10.8%	**23.1%**	10.2%	**31.5%**	**19.6%**
Biomedical research	7.1%	**16.7%**	4.4%	3.0%	14.9%
Biosciences	10.0%	**19.1%**	6.0%	14.3%	11.6%
Chemistry	**22.6%**	8.2%	**60.0%**	9.9%	1.9%
Engineering	11.2%	4.8%	11.6%	2.6%	1.0%
General & internal medicine	3.0%	8.9%	2.6%	1.2%	**27.0%**
Geoscience	7.7%	2.4%	4.5%	2.9%	0.2%
Humanities	0.7%	0.5%	0.0%	0.2%	0.0%
Mathematics	4.9%	0.5%	1.4%	0.5%	0.2%
Neuroscience and behaviour	3.0%	6.1%	1.6%	0.7%	6.6%
Non-internal med. specialties	8.1%	**22.4%**	4.6%	3.9%	**51.7%**
Physics	**25.0%**	6.3%	**16.8%**	2.7%	0.6%
Social sciences I	1.3%	0.8%	0.4%	0.9%	0.6%
Social sciences II	0.6%	0.4%	0.2%	0.4%	0.0%

Some important differences among Brazilian clusters: Physics and Chemistry have split into two separate clusters; the same has occurred to Biology and Agriculture; just one medical cluster has been observed. Such differences are maybe due to the

consolidate profile of European scientific institutes which are very specialized, especially in engineering & exacts science and medicine. The high costs of equipment and logistic as well as the scarce qualified manpower are certainly factors that reduce the chances of Brazilian institutes to carry on research projects in Medicine and Engineering.

In order to be able to assess the stability of profiles over time we decided to present a temporal analysis. The latest profile and the clustering solution was used as input for a discriminant analysis in order to construct a classification model. This model was applied to the profiles of the two earliest profiles. The research profile of each institute could thus be classified to one of the 5 types that we have defined. This classification allows us to observe some important shifts among Brazilian clusters (see Table 5). Only those institutes that have a classification in the 3 periods are presented.

Table 5. Number of Brazilian institutes within the 5 clusters in three different periods

Cluster	1991–1994	1995–1998	2000–2003
Cluster A (Phys/Chem/Eng)	58	64	64
Cluster B (BioSci)	19	22	17
Cluster C (Chem)	5	7	12
Cluster D (Agri/Bio)	22	17	18
Cluster E (GenMed)	31	25	24
Total of institutes	135	135	135

The temporal analysis indicates that 78 institutes had a stable profile over the three periods while 57 shifted from one cluster to another. Over the time, clusters D and E have "lost" some institutes while clusters C and A have gained institutes. Among the shifts, we highlight the following ones:

- From Cluster B to Cluster A: Federal University of Para and Federal Rural University of Rio de Janeiro. Both universities are well-known as their research projects in biological sciences. Our data, however, show a new tendency towards a research in natural and technical sciences
- From Cluster D to Cluster A: State University of Norte Fluminense. Founded in the countryside of Rio de Janeiro state, this university was designed to be dedicated to agriculture projects mainly. Almost 15 years after its foundation, the new PhD programs have changed its prior characteristics.
- From Cluster E to Cluster B: Ludwig Institute and National Institute for Cancer Research. Both institutes are devoted to cancer research and they are renowned by the strong association between clinical assistance and research. However, our data suggest that their current research is more related to biology issues (which includes for instance Biotechnology & Applied Microbiology, Microbiology) rather than to medicine.

For recent years' analysis, we have found that Cluster A, the largest one, is mostly composed by public universities (42 out of 64 should be the total). Also, the most prolific private universities and some specialized institutes are included in this cluster. As for Cluster B, we have found that private institutes are predominant (8 out of 17) while for Cluster C we have found a mixture of the three types of institutions. In Cluster D, there is a clear predominance of non-universities institutes from public sector (12 out of 18) and finally Cluster E is composed mostly by hospitals and medical institutes either from private and from public sectors (20 out of 24). Only four universities are included in this cluster; two from the public sector, the Federal University of Sao Paulo (so called UNIFESP) and Medical School Triangulo Mineiro and other two from private sector, Estacio de Sa University and Gama Filho University. Different from the last two institutes, since the late 40's, when the first basic research centre was founded, UNIFESP is one of the leaders in experimental and clinical medicine research in the country.

We have also processed the data of self-citations, RCR and RCRX for each of the clusters as presented in Table 6. For this analysis, we have used a 3-year window for counting citation of the 1991–1993, 1995–1997 and 2001 publications. We have found that there is a slight tendency to reduce the self-citations in Cluster A (from 42% to 40%) and Cluster D (from 39% to 36%); such tendency was more pronounced in Cluster B (from 42% to 36%) and Cluster E (from 35% to 28%).

Table 6. Main citation indicators for the five Brazilian clusters

	Share of self citations			RCR			RCRX		
	1991–1993	1995–1997	2001	1991–1993	1995–1997	2001	1991–1993	1995–1997	2001
Cluster A	42%	43%	40%	0.707	0.783	0.836	0.628	0.684	0.743
Cluster B	42%	36%	36%	0.750	0.708	0.750	0.658	0.652	0.656
Cluster C	47%	41%	48%	0.609	0.676	0.831	0.582	0.685	0.711
Cluster D	39%	42%	36%	0.749	0.757	0.795	0.746	0.692	0.751
Cluster E	35%	34%	28%	0.788	0.834	1.023	0.729	0.776	0.963

For recent years, Cluster C, characterized by having the main focus on chemistry research, presented the highest share of self-citation while Cluster E, distinguished by its focus on medical research, displayed the lowest share. Such a tendency was also observed for world data (GLÄNZEL et al., 2004). However, in both cases, the shares of self-citations found for the institute clusters are higher than the world averages, which are approximately 30% and 12%, respectively.

For some clusters, the reduction in self-citation resulted in an increasing of the Relative Citation Rate. This applies to Cluster A, and is even more evident for Clusters C and E. This tendency is kept on when we exclude self-citations but there is a reduction in overall rates.

Conclusion

The institutional analysis showed that Brazilian S&T capacity is concentrated in a few number of institutions mainly from its wealthy states. It is clear that the international "state-of the art" science exists in certain parts of the country but it is almost incipient in others. A good example is the state of Amazonas, the largest Brazilian state in terms of size. Its surface is covered by the largest world forest and by many important rivers. The region's natural resources and their potential for application in pharmaceutical, agricultural or biotechnological projects should be target for more and detailed scientific investigation even for strategic reasons or for environmental ones, too. But, the scientific output of the region's main institutes is indeed too timid. Some national initiatives seem, however, to be arisen in order to increase the region's scientific competency. Recently, the Brazilian Ministry of Education announced a national program to stimulate PhDs and scientists from other parts of the country to start a new research projects in the Amazonas state (CAPES, 2005).

Our data has also pointed out the completely absence of private companies and firms within the Brazilian science. Brazilian companies ought to be conscious that new technologies are one of the most important issues in a competitive world. Therefore, these companies should develop their own facilities for research or even establish agreements with research institutions. However, in the meantime, we see almost all Brazilian science been carried out by universities. Recently, some new funds were created in order to improve the link between industry and academia. Besides this endeavor, bibliometric data already show a considerable increase of collaboration between universities and the private sector. Also the link between non-university public research and the private sector has grown, however, to a less spectacular extend. In this context, it is important to note that in most of this collaboration, universities and hospitals are the main actors from the private sector.

As for the fields, the data clearly present physics, agriculture and biology as the most prolific fields. These are also the "oldest" fields in Brazil. And again the striking changes in the publication profiles have to be mentioned. Besides the predominance of natural sciences and general medicine clusters, the growth of the chemistry cluster and the decline of the general medicine cluster were the most striking feature of the development in the last fifteen years. Studying institutional dynamics has shed light at different aspects of national patterns of scientific communication among others at sectoral and institutional research profiles, and thus provides a better interpretation of national science indicators and their evolution.

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