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SPATIAL DISTRIBUTION OF SCIENTIFIC ACTIVITIES IN BRAZIL, 2000-2010

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RESUMO

A literatura que analisa a distribuição espacial da produção científica e tecnológica no Brasil identifica diferenças na distribuição regional dos recursos científicos e tecnológicos. Nosso objetivo é contribuir para a discussão sobre o assunto, analisando a dinâmica da produção de novos conhecimentos científicos nos estados que mais contribuem para a produção científica nacional, ou seja, São Paulo, Rio de Janeiro, Minas Gerais e Rio Grande do Sul ('quarteto científico') no período de 2000 a 2010. A hipótese específica deste estudo é que, mesmo com as políticas federais voltadas para a ampliação e descentralização da produção de novos conhecimentos científicos, sua produção ainda é fortemente ancorada no 'quarteto científico'. Identificamos ainda uma concentração da produção científica em três grandes áreas do conhecimento: ciências agrárias, biológicas e da saúde.

Palavras-chave: Universidades, Produção de Conhecimento, Sistema Nacional de Inovação, Brasil.
Código Jel: O30, O31, O38, R10.

ABSTRACT

The literature that analyzes the spatial distribution of scientific and technological production in Brazil identifies the differences in regional distribution of scientific and technological resources. We aim to contribute to the discussion on this subject, analyzing the dynamics of the production of new scientific knowledge in the states that contribute most to the national scientific production, namely, Sao Paulo, Rio de Janeiro, Minas Gerais and Rio Grande do Sul ('the scientific quartet') in the period 2000 to 2010. The specific hypothesis of this study is that even with federal policies aimed at the expansion and decentralization of the production of new scientific knowledge, its production is still strongly anchored in the 'the scientific quartet'. We identified a concentration of scientific production in three major areas of knowledge: agricultural sciences, biological and health.

Key-words: Universities, Knowledge Production, National Innovation System, Brazil.

INTRODUCTION

The spatial allocation of scientific and technological production in Brazil is marked by strong disparities in the regional distribution of scientific and technological resources. Intellectual and research assets are heavily concentrated in the South-East region, particularly in the state of Sao Paulo (Barros, 2000; Albuquerque et al., 2002, 2005; Diniz and Gonçalves, 2005; Santos and Caliari, 2012; Faria et al., 2011).

A part of this concentration can be explained through the historical trajectory of the emergence of science and technology (S&T) institutions in the country, particularly the universities and research institutes, described in Suzigan and Albuquerque (2011). These institutions were built in waves throughout the nineteenth and twentieth centuries. Most of them were created in the southeastern states of the country, mainly in the states of Sao Paulo and Rio de Janeiro, given the economic strength of these two states in the coffee plantation and the public administration activities.

We chose to focus the analysis on Sao Paulo, Rio de Janeiro, Minas Gerais and Rio Grande do Sul states ('scientific quartet'), by showing the bibliographic production dynamism of these states over the period 2000-2010, from a static comparative analysis, once they are the epicenter of Brazilian science. This article therefore constitutes an additional contribution to the existing literature on the national spatial distribution of scientific production in Brazil, since it does not restrict the analysis to a given year, but over a period of a decade (2000-2010), allowing to identify their temporal and spatial evolution throughout the decade. In this regard, it is worth noting that in Brazil, the process of decentralization of S&T promotion is relatively new but it has been advancing intensively in the last ten years, *pari passu* with the strengthening of the National Innovation System (NIS), and contrasts with the centralization observed in the 1970's and 1980's (CGEE, 2010).

The hypothesis of this study is that even with federal policies aimed at the expansion and decentralization of production of scientific knowledge (e.g., from the creation of new federally funded universities in the North and Northeast, what could be considered as another wave of university establishments), the national scientific production is still strongly anchored in the 'scientific quartet' throughout the decade of 2000.

To achieve the goal proposed here, the article was structured in the following manner: the first section presents the main conceptual structure of a National Innovation System (NIS) and its immaturity and concentration in Brazil. The second presents the database and section three focuses on the four states which form the epicenter of Brazilian science (Sao Paulo, Rio de Janeiro, Rio Grande do Sul and Minas Gerais) over the 2000 to 2010 using the Directory of Research Groups (DRG) censuses of the National Council for Scientific and Technological Development (CNPq), evaluating the distribution of scientific activities between them and comparing them to other Brazilian states. The fourth section presents the distribution of scientific production of the 'quartet' by major field of knowledge and its evolution over the period analyzed. Finally, the last section will make final remarks about this study.

1 THEORETICAL BACKGROUND

1.1 Universities and Public Research Institutes in National Innovation Systems

The National Innovation System (NIS) can be characterized as an institutional arrangement that involves various constituents that interact and interrelate with each other, namely: (1) firms, with their laboratories for research and development (R&D) and their cooperation and interaction networks, (2) universities and research institutes, (3) educational institutions, (4) financial system capable of supporting innovative investment, (5) legal systems, (6) market and non-market mechanisms of selection; (7) governments and (8) mechanisms and coordination institutions (Nelson, 1993; Lundvall, 1988, 1992; Freeman, 1995).

Basic science and technology are guided by theory and by experiment and are designed primarily, but not exclusively, in universities and public research laboratories (Metcalfe, 2003). Universities and public research institutes (PRIs) therefore play a central role in the creation and dissemination of knowledge through traditional functions, such as education and basic research, thus constituting key

elements within the NIS. Thus, creating and renewing the stock of existing knowledge in the countries where they operate. They also play an important role in technological development, whether in the education and training of engineers and industrial scientists or as a source of research results and techniques of considerable relevance to the technical advancement of industry (Nelson and Rosenberg, 1993).

Additionally, universities and PRIs develop and provide new insights that influence the productive sector through research disseminated in publications, cooperative research projects or consultancy (Schartinger et al., 2001, 2002). That is, in the NIS, these institutions have a role of producers and distributors of scientific knowledge and not just training and qualification of human resources (Cohen et al., 2002).

It should be noted that the literature suggests the existence of specific functions of universities in peripheral countries. For Albuquerque (1999), the main difference lies in the contribution they can offer to the process of catching up. According to the author, the scientific infrastructure in the peripheral countries can act as an 'antenna' in the identification of technological opportunities, connecting the NIS to international scientific and technological flows.

A peculiarity of the immature NIS[1], as the case of Brazil, is the existence of 'partial connections' between the scientific infrastructure and technological activities (Albuquerque, 1999; 2003) which limit the importance of interaction among its various constituents. This is because the flow of knowledge between science and technology is restricted to a small number of connections or interactions (Rapini, 2007; Suzigan and Albuquerque, 2008). Additionally, firms generally develop few R&D activities, which makes university-industry interactions and the strengthening of the innovative capacity of the country difficult (Rapini et al., 2009). It is noteworthy that these studies suggest that in addition to the traditional functions (information source, providing skilled labor force, training, etc.) universities in immature NIS can play a dual role, i.e. they replace and complement firms' R&D.

1.2 Regional distribution of scientific activities in Brazil

As well as the immature character of the Brazilian innovation system, the country has three other important features: its continental dimension; the regional disparities regarding its technical and scientific infrastructure, and the concentration of scientific production in public universities and in public research institutions.

It is important to note, from the historiographic work of Suzigan and Albuquerque (2008), that the main institutions of S&T research, as well as higher education were established in the second wave of creation of these institutions at the end of the nineteenth century, most surrounding the economic strength and modernization of the cities of Rio de Janeiro, then the capital, and Sao Paulo, the financial and administrative center coming from the coffee cycle. The tradition of agricultural research in many different cultures, research in public health and parasitology dates from this time and, therefore, the competence of the researchers involved in these areas and these sites also tend to be notorious (Suzigan and Albuquerque, 2008).

Moreover, Diniz and Gonçalves (2005), in a diagnostic of the knowledge infrastructure distribution in Brazil characterized by academic university system, research institutions and the distribution of skilled human resources, identified a concentration of active research and technological development in the most developed economic centers of the country. To Diniz (2001), the fact that major universities and research institutions, professional labor market and modern urban infrastructure services are located in major cities of the center-south region of the country, means there is a tendency to

[1] Albuquerque (1999) suggests a typology that distinguishes the NISs according to their level of development: mature in developed countries; immature countries at an intermediate level, such as the Latin American countries, South Africa and India; 'nonexistent or rudimentary' NIS in less developed countries. There are intrinsic elements to peripheral economies that hinder the 'maturity' of the innovation system. The dependence of the production of new knowledge in core economies is important, moreover, peripheral economies have built their bases and insufficient accumulation below the needs for a technological breakthrough, therefore, are unable to turn knowledge and science into innovation, and have an atrophied financial sector, problems of inequality and poverty, in short, a sort of diverse structural problems (Oliveira, 2003).

emphasize the strength of the network services in the region, enhancing regional concentration, given the regional distribution of production and income in Brazil.

Additionally, Barros (2000) identified that the large regional differences regarding the technical-scientific basis installed in Brazil reflected particularly in the concentration of skilled human resources for research in the Center-South and the channeling of most federal public investments allocated to S&T in those regions. The three less dynamic regions (Northeast, Midwest and North) aggregated together, had only 18% of researchers in Brazil in a survey done by the author using the Directory of Research Group Census of the National Council for Scientific and Technological Development (DRG/CNPq) in 1997. Barros (2000) also showed a reproduction of the observed concentration in expenditures by federal sources in the mid-1990s, in the case of state and local investments that aim at technical and scientific development.

In an effort to measure the S&T concentration in Brazil, Santos and Caliari (2012) assessed the degree of concentration of the structures to support technological innovation in the country, taking as parameter the degree of inequality between the fifty largest micro-regions of the country, in the years 2003 and 2008. The authors have identified a high concentration of these technological innovation structures in a small number of Brazilian micro-regions. Therefore, such scenario has not changed in this period.

However, Barros (2000) also found that despite the political instability of the vast majority of state systems of S&T, the performance of some states of the federation (as Ceara, Rio Grande do Sul, Pernambuco and Bahia, among others) represented on the national scene were more promising, not only because they were increasing their investments in S&T, but also because they were enhancing their institutional organization, their articulations and performances.

According to CGEE (2010), the advancement and the institutional structuration of the decentralization of the promotion of science, technology and innovation (ST&I) in Brazil at the end of the 90's and in the first decade of the 2000's was based on: a) the creation of the so-called *Fundos Setoriais* (Sectorial Funds), in which a portion of the resources in a given sector (petroleum, electric power) is used to finance research projects in these sectors with universities and public research institutions (PRIs), at the federal level, after 1997; b) the initiative of the institutional organizational of the states in the area of ST&I (state funds of ST&I, state foundations to support the research activities, especially within medium and small companies[2]) and; c) the creation of federal programs of support that are shared with states and the private sector, such as the RHAE[3] program, which stimulates the insertion of master and doctorate degrees within firms, by funding research projects that interests the companies through Sectorial and state funds (CGEE, 2011).

Most private higher education institutions in Brazil are focused only on teaching. Considering that it is not the intention of this paper to discuss the relevance or quality of the training offered by the Brazilian private higher educational institutions, we only emphasize that private institutions dedicated to scientific research are rare exceptions in Brazil, being the production of scientific knowledge mainly in charge of public universities (Chiarini et al., 2012). Following the classification proposed by Nowotny et al. (2001), we can say that the private universities in Brazil, roughly speaking, are concerned with knowledgeability, i.e. with the formation of a more educated and enlightened population. In contrast, the Brazilian public universities are engaged, besides the knowledgeability, with the production of scientific knowledge *per se*.

The government effort to increase capacity for the production of scientific knowledge in other regions of the country deprived of infrastructure, especially the North and Northeast, is represented in Table 1. We could consider this as another wave of creation of public higher education infrastructure.

[2] The most notable example of such programs is PIPE, which supports innovation activities in small companies from Sao Paulo state by funding research projects.

[3] *Recursos Humanos em Áreas Estratégicas* (Human resources in strategic areas).

TABLE 1 – Universities, Public Universities, Federally Funded Universities, total and per Federal Unity, Brazilian regions, 2000 e 2010.

	Universities				Public Universities*				Federally Funded Universities				Federative Unities (F.U.)	University/ (F.U.)		Public University/ (F.U.)		Federally Funded University/ (F.U.)	
	2000		2010		2000		2010		2000		2010			2000	2010	2000	2010	2000	2010
		%		%		%		%		%		%	Total	-	-	-	-	-	-
BRA	156	100	190	100	71	100	101	100	41	100	58	100	26 + F.D.	5.77	7.03	2.62	3.74	1.52	2.14
Southeast	71	46	80	42.1	21	29	28	28	13	32	19	33	4	17.75	20.00	5.25	7.00	3.25	4.75
Northeast	28	18	35	18.4	22	30	29	29	10	24	15	26	9	3.11	3.88	2.44	3.22	1.11	1.66
South	36	23	46	24.2	13	18	21	21	7	17	11	19	3	12.00	15.33	4.33	7.00	2.33	3.66
North	9	6	15	8	9	12	14	14	7	17	8	14	7	1.28	2.14	1.28	2.00	1.00	1.14
Central-west	12	8	14	7	7	9	9	9	4	10	5	9	3 + D.F.	3.00	3.50	1.75	2.25	1.00	1.25

Source: Authors' own. Data sourced from Education Ministry (MEC).
Note: F.D. refers to Federal District. (*)Public Universities is the sum of Federal, State and Municipal universities.

There was an increase in federal universities in all regions of Brazil and universities increased by federative unit[4]. The Brazilian Northeast, which in 2000 had 1 federally funded university per state in 2010 had increased slightly to 1.1 per state. What one can notice is the concern of the central government to expand the supply of higher education institutions able to help boost the NIS. The most important figures shows that the number of universities in the northeast region increased 25% in ten years, and in the north region, 66%, as the number of universities in the southeast region increased by 13% in the same period. The public universities accounted for 83% of the total in northeast and for 93% in the north region.

2 ABOUT THE DATABASE

The work proposed here makes use of data provided in the Directory of Research Groups (DRG), which was initiated in 1992 by the National Council for Scientific and Technological Development (CNPq), a public agency of the Brazilian Science, Technology and Innovation Ministry (MCTI) Since then, with a biannual frequency, the agency provides a census of research capacity in the country, measured by active groups in each period. The DRG/CNPq gathers information from various institutions, among them, there are information regarding the public (federal, state, municipal) and private universities, research institutes, public and private R&D laboratories, and nongovernmental organizations (NGOs) permanently engaged in scientific and technological research. However, private firms in the industrial sector are not included in this directory.

The DRG/CNPq comprises detailed information regarding research activities in Brazil using 'research group' as the unit of analysis. It includes references from the existing research groups in the country and lists several of their characteristics. The DRG's definition of research group is a hierarchical set of researchers, students, and personnel with specific technical scientific competencies that perform scientific research in a specialized field, sharing or not physical space and resources.

Among the information gathered in the DRG/CNPq, disaggregated by region and time, State and institution, are those related to human resources of the research groups, such as researchers, students and technical areas of research pursued by these groups; knowledge areas, industry sectors involved, the

[4] In the 2000's the following federal universities were created: a) Central-West region: Universidade Federal da Grande Dourados (UFGD); b) North region: Universidade Federal Rural da Amazônia (UFRA) and Universidade Federal do Tocantins (UFT); c) Northeast region: Universidade Federal de Campina Grande (UFCG), Universidade Federal Rural do Semi-Arido (UFERSA), Universidade Federal do Recôncavo da Bahia (UFRB); Universidade da Integração Internacional da Lusofonia Afro-Brasileira (UNILAB) and Universidade Federal do Vale do São Francisco (UNIVASF); d) South region: Universidade Federal da Fronteira Sul (UFFS); Universidade Federal da Integração Latino-Americana (UNILA); Universidade Federal do Pampa (UNIPAMPA) and Universidade Tecnológica Federal do Paraná (UTFPR); Southeast region: Universidade Federal do ABC (UFABC), Universidade Federal de São João Del Rei (UFSJ), Universidade Federal do Triângulo Mineiro (UFTM), Universidade Federal do Vale do Jequitinhonha e Mucuri (UFVJM), Universidade Federal de Alfenas (UNIFAL) and Universidade Federal de Itajubá (UNIFEI). According to the Brazilian Ministry of Education (MEC), four other federal universities will be created in the coming years in the North and Northeast regions: Universidade Federal do Sul e Sudeste do Pará (UFSPA), Universidade Federal da Região do Cariri (UFRC), Universidade Federal do Oeste da Bahia (UFOBA) and Universidade Federal do Sul da Bahia (UFESBA). Furthermore, it is noteworthy that the UFSJ, UFTM, UFVJM, UNIFAL, UNIFEI, UFRA, UFERSA and UTFPR existed before, but were either educational foundations, federal schools or federal technical schools. It can be seen that, in 2000, 18 new federal universities were created, of which eight are located in states outside the 'quartet' and if we do not consider the federal schools of higher education that became universities, we have that from 10 universities effectively created in the 2000s, only three (UFABC, UFFS and UNIPAMPA) are part of the 'quartet'.

production of scientific and technological researchers and students groups, and patterns of interaction with the productive sector.

The DRG/CNPq provides an excellent proxy for studying research activities in Brazil, even though adherence to it is voluntary (Povoa and Rapini, 2010), however, researchers are highly encouraged to participate, mainly to have access to public funding to scientific research and other incentives. The universe of DRG/CNPq has grown in recent years and now covers a representative part of the national scientific community (Carneiroand Lorenzo, 2003).

Taking as the unit of analysis the researcher, this article describes the spatial distribution of scientific activities in Brazil, from scientific published articles (a proxy for scientific production) and researchers (an indicator of human resources allocated to scientific activities), as Albuquerque et al. (2002) did.

3 THE SCIENTIFIC PRODUCTION OF THE 'QUARTET'

In this section, we focus on the temporal and spatial evolution of the relative shares of the epicenter of Brazilian science, i.e. the four units of the federation, namely Sao Paulo, Rio de Janeiro, Minas Gerais and Rio Grande do Sul (the 'scientific quartet') in national scientific production from 2000 to 2010. This research is a contribution to the assessment of the degree of (de)concentration of activities in science. We present, initially, a comparison between the numbers of researchers (including researchers with PhD degree) in different regions of the country and within the 'quartet'. Later, we deepen this research by examining the degree of dispersion and inequality in the distribution of scientific productivity of Brazilian researchers between the states and the 'quartet' and within the 'quartet'.

3.1 Growth of knowledge production of Minas Gerais, Rio Grande do Sul compared to Sao Paulo and Rio de Janeiro: towards convergence?

The DRG/CNPq shows that, in 2000, the less dynamic regions of the country - Northeast, Central-West and North - were responsible for 25.8% of national researchers, and, of the national total, 13.0% were PhD researchers of these three regions. The other 74.2% of the national researchers were located in the South and Southeast of the country (where, of the national total, 36.0% of the researchers had a PhD degree from these regions).

In 2010, the less dynamic regions (Northeast, Central-West and North) have concentrated 34.0% of national researchers, with only 20.0% of the national total were PhD researchers in these regions. As for the other regions (South and Southeast), which accounted for 74.2% of researchers in 2000, in 2010 accounted for 66.0% of all national researchers.

Sao Paulo, Minas Gerais, Rio de Janeiro and Rio Grande do Sul alone, concentrated, in 2000, 64.3% of all Brazilian researchers. In 2010, these four states participating in the national total dropped to 57.7% (Table 2), which, however, is still quite high. This devolution might be explained by the growing demand for researchers and professors at other institutions of education and research in the country, to form a professional body of higher level and thus able to raise the capacity of these institutions in the national S&T production. This was due to the federal government's attempt to expand the network of public teaching and research in other states. This can be considered an important step in leveraging the scientific development of a region towards the consolidation of a set of actors with an advanced scientific basis, since there is the possibility, on the one hand, to increase the supply of skilled highly qualified labor and at the same time, increase the supply of research that can be used by various sectors of the economy, especially industry.

TABLE 2 - Number of researchers and total bibliography production volume for Sao Paulo, Rio de Janeiro, Rio Grande do Sul and Minas Gerais and percentages relative to the national total, 2000-2010.

	Researchers	%	Articles	%
2000	33,987	64.3%	128,319	76.2%
2002	38,956	61.5%	185,788	75.3%
2004	54,430	62.0%	279,126	75.2%
2006	62,221	60.9%	367,823	74.8%
2008	70,309	59.6%	428,417	74.1%
2010	85,147	57.7%	531,953	73.3%

Source: Authors' own. Data sourced from the Directory of Research Groups in Brazil's National Council for Scientific and Technological Development (DRG/CNPq).
Note: 'Researcher' refers to the number of researchers of Sao Paulo, Rio de Janeiro, Rio Grande do Sul and Minas Gerais registered in the DRG/CNPq, regardless of the degree of titration researcher and 'articles' refers to the sum of complete articles published in national and journals of researchers of Sao Paulo, Rio de Janeiro, Rio Grande do Sul and Minas Gerais.

Sao Paulo is the state with most researchers and there has been a growth of 121.9% in the period 2000-2010, although its share in the national total has dropped from 30.5% to 24.2%. The state of Rio de Janeiro, although it has also experienced a growth of 136.6% in the number of researchers, has its share of total national reduced from 14.7% to 12.4%. Minas Gerais, in turn, was the state that had the highest growth rate of researchers, 249.1%, reaching, in 2010, 16,678 researchers. It is interesting to note that the state of Rio de Janeiro always had more researchers than Minas Gerais in the period 2000-2010, although the latter state has had a growth rate much higher than the former, thus approaching that state participation in number of researchers (11.3%). These analyses suggest the occurrence of a small devolution of scientific-technical base in the 'quartet'. Table 3 shows the evolution of these numbers.

TABLE 3 – Number of researchers in absolute values and percentage in relation to total national; growth rate per period of the number of researchers, for selected states, 2000-2010.

	Minas Gerais		Sao Paulo		Rio de Janeiro		Rio Grande do Sul		BRA	
	Absolute	%	Absolute	%	Absolute	%	Absolute	%	Absolute	%
2000	4,777	9.0%	16,111	30.5%	7,756	14.7%	5,343	10.1%	52,864	100%
2002	5,682	9.0%	18,117	28.6%	7,931	12.5%	7,226	11.4%	63,342	100%
2004	8,069	9.2%	25,150	28.7%	11,653	13.3%	9,558	10.9%	87,727	100%
2006	9,916	9.7%	28,412	27.8%	13,224	12.9%	10,669	10.4%	102,184	100%
2008	11,853	10.0%	31,725	26.9%	14,853	12.6%	11,878	10.1%	118,015	100%
2010	16,678	11.3%	35,756	24.2%	18,353	12.4%	14,360	9.7%	147,638	100%
Growth rate										
(2000-2002)	18.9%		12.5%		2.3%		35.2%		19.8%	
(2002-2004)	42.0%		38.8%		46.9%		32.3%		38.5%	
(2004-2006)	22.9%		13.0%		13.5%		11.6%		16.5%	
(2006-2008)	19.5%		11.7%		12.3%		11.3%		15.5%	
(2008-2010)	40.7%		12.7%		23.6%		20.9%		25.1%	
(2000-2010)	249.1%		121.9%		136.6%		168.8%		179.3%	

Source: Authors' own. Data sourced from the Directory of Research Groups in Brazil's National Council for Scientific and Technological Development (DRG/CNPq).
Note: 'absolute' refers to the number of registered researchers, no matter the degree of researcher title; (%) refers to the percentage of the absolute value of each selected state relative to the national total.

Regarding the scientific literature, the 'quartet' concentrated in the 2000's over 70.0% of all domestic production of articles published in national and international journals (Table 2). This argument supports previous studies that had signaled the existence of spatial concentration of scientific-technical base in southern and southeastern Brazil (Barros, 2000; Albuquerque et al., 2002, 2005; Diniz and Gonçalves, 2005; Santos and Caliari, 2012; Faria *et al*., 2011). The period 2000-2010 maintains the centralization of production of new scientific knowledge (measured by article production volume, i.e., national and international articles published in indexed journals) in the South-East, and once more Sao Paulo stands out as the main state. Those states concentrated 76.2% of all articles published in Brazil in 2000. In 2010, 73.3% (Table 2).

In absolute terms, Sao Paulo is the state of the federation that publishes more (proxy for production of new scientific knowledge), reaching to a total of more than 243,000 articles in 2010 and its growth rate of scientific production in 2000-2010 was of 291.0%. There was a slight decrease in the gap of production of new articles published in the state of Sao Paulo and the other three states that published (Minas Gerais, Rio de Janeiro and Rio Grande do Sul), as Rio Grande do Sul and Minas Gerais had growth rates greater than that of Sao Paulo, 414.0% and 357.0%, respectively, over the same period (2000-2010). The publishing rate of Rio de Janeiro state, in turn, was lower than Sao Paulo, both of which are lower than the growth rate of the country (which was 331.0% between 2000 and 2010) (Table 4). Thereby contributing to the reduction of this gap within the 'quartet' was the rapid growth of publications by researchers of Minas Gerais and Rio Grande do Sul.

TABLE 4 – Total bibliographic production in absolute and percentage compared to the national total; bibliographic production per researcher and per period growth rates for selected states, 2000-2010.

	Minas Gerais			Sao Paulo			Rio de Janeiro			Rio Grande do Sul			BRA		
	Absolute	(%)	P/R	Absolute	(%)	P/R	Absolute	(%)	P/R	Absolute	(%)	P/R	Absolute	(%)	P/R
2000	21,618	12.8%	4.5	62,234	36.9%	3.9	26,972	16.0%	3.5	17,495	10.4%	3.3	168,435	100%	3.2
2002	31,765	12.9%	5.6	91,233	37.0%	5	36,249	14.7%	4.6	26,541	10.8%	3.3	246,837	100%	3.9
2004	44,528	12.0%	5.5	139,552	37.6%	5.5	54,411	14.7%	4.7	40,635	11.0%	4.3	371,050	100%	4.2
2006	58,572	11.9%	5.9	182,944	37.2%	6.4	70,374	14.3%	5.3	55,933	11.4%	5.2	492,041	100%	4.8
2008	70,301	12.2%	5.9	209,110	36.2%	6.6	80,379	13.9%	5.4	68,627	11.9%	5.8	577,854	100%	4.9
2010	98,900	13.6%	5.9	243,243	33.5%	6.8	99,940	13.8%	5.4	89,870	12.4%	6.3	725,782	100%	4.9
Growth Rate															
(2000-2002)	47%	-	24%	47%	-	28.2%	34%	-	31.4%	52%	-	1%	47%	-	22%
(2002-2004)	40%	-	-2%	53%	-	10.0%	50%	-	2.2%	53%	-	29%	50%	-	8%
(2004-2006)	32%	-	7%	31%	-	16.4%	29%	-	12.8%	38%	-	21%	33%	-	14%
(2006-2008)	20%	-	0%	14%	-	3.1%	14%	-	1.9%	23%	-	12%	17%	-	2%
(2008-2010)	41%	-	0%	16%	-	3.0%	24%	-	0.0%	31%	-	9%	26%	-	0%
(2000-2010)	357%	-	31%	291%	-	74.4%	271%	-	54.3%	414%	-	91%	331%	-	53%

Source: Authors' own. Data sourced from the Directory of Research Groups in Brazil's National Council for Scientific and Technological Development (DRG/CNPq).
Note: 'Absolute' refers to the sum of complete articles published in journals of national and international circulation; (%) refers to the percentage of the absolute value of each selected state compared to the national total; (P/R) refers the 'per researcher', i.e., the total production of items divided by the number of registered researchers, no matter the degree of titration researcher.

Additionally, to verify the output per researcher, though Sao Paulo has an absolute advantage in terms of articles, its productivity is only slightly higher than the other states in the analysis. Minas Gerais contributed to 21,618 publications in indexed national and international journals in 2000 and 98,900 in 2010, representing a growth of 357.0%. Its participation in the national total, which was 12.8% in 2002, rose to 13.6% in 2010, approaching the participation of Rio de Janeiro, which has appropriated 16.0% of national publications in 2002 and fell to 13.8% in 2010.

Figures 1 and 2 show the evolution of peer-reviewed published articles and peer-reviewed articles per researcher for the four states of the 'quartet'.

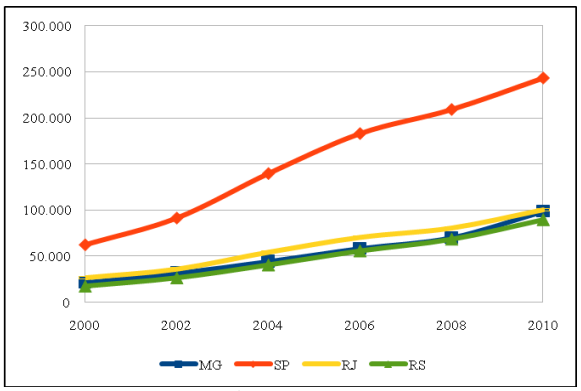

FIGURE 1 - Evolution of published articles, selected states, 2000-2010.
Source: Authors' own. Data sourced from the Directory of Research Groups in Brazil's National Council for Scientific and Technological Development (DRG/CNPq). Note: Complete articles published in journals of peer-reviewed national and international circulation.

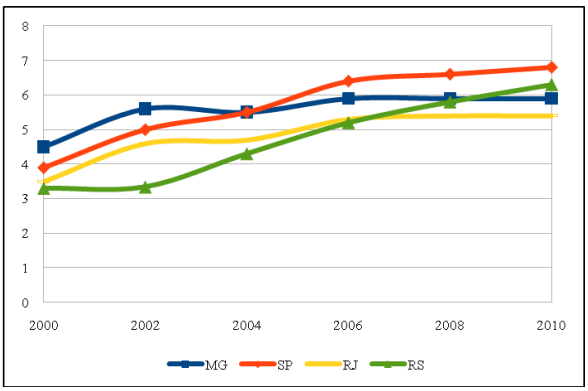

FIGURE 2 – Articles published per researcher, selected states, 2000-2010.
Source: Authors' own. Data sourced from the Directory of Research Groups in Brazil's National Council for Scientific and Technological Development (DRG/CNPq). Note: Complete articles published in journals of peer-reviewed national and international circulation.

The good performance of Minas Gerais took place due to the high scientific productivity of some institutions of that state that influenced the increase in the state average (5.9), as was the case, for example, the Institute of Education and Research of Santa Casa de Belo Horizonte (IEP/SCBH), the Foundation Center of Hematology of Minas Gerais (Hemominas), Research Center René Rachou (CPqRR/FIOCRUZ) and the Agricultural Research Corporation of Minas Gerais (EPAMIG) (primarily in the areas of health, life sciences and agricultural sciences, as will be seen in the next section). Interestingly, in this case, the federal universities had lower scientific productivity than the PRIs, an aspect that deserves more detailed studies later. The most dynamic universities in terms of productivity were Federal University of Lavras (UFLA), Federal University of Viçosa (UFV) and Federal University of Minas Gerais (UFMG), in that order.

However, surprisingly, in the analyzed period, the increase in productivity was the researchers of Rio Grande do Sul, measured in terms of published papers per researcher, which rose 91.0%, a rate higher than the states of Sao Paulo (74.4%), Rio de Janeiro (54.3%) and Minas Gerais (31.0%). Rio Grande do Sul, which in 2000 published just over 17,000 articles, reached 2010 with a total of 89,870 articles, representing a growth of 414.0%, much higher than the other states. This growth has not only increased by researchers, but also by increasing the productivity of those, who changed from 3.3 to 6.3 articles per researcher in the decade under review.

The excellent performance of Rio Grande do Sul occurred due to the high productivity of some institutions such as the Brazilian Institute of Technology for Leather, Footwear and Artifact (IBTEC), Clinics Hospital of Porto Alegre (HCPA) and the Federal University of Health Sciences of Porto Alegre (UFCSPA), which had, in 2010, a very high productivity: IBTEC with 15.6 articles per researcher, HCPA with 11.0 and UFCSPA with 8.5, positively influencing the performance of Rio Grande do Sul[5] (all basically in the health and biological sciences as will be seen in the next section). The same feature weight of public research institutes in the relevant scientific production can also be observed for the Rio Grande do Sul, although less than in Minas Gerais.

The previous analysis provide evidence for the argument that significant increases of scientific productivity of researchers of Rio Grande do Sul and Minas Gerais may be related to higher rates of growth of the infrastructure of these states in order to decrease a relative delay in relation to the infrastructure and institutions of science of Sao Paulo and Rio de Janeiro.

3.2 Devolution of knowledge production in the country?

Figure 3 does not indicate the occurrence of dispersion of national scientific production per researcher in all the Brazilian states and within the 'quartet'. In fact, it is interesting to note that, notwithstanding there has been an increase in scientific productivity in all states of the federation in the years analyzed, highlighting some states in the North, Northeast and Midwest (Piaui -PI, Sergipe-SE, Acre-AC, Amazonas-AM, Maranhao-MA, Rio Grande do Norte- RN, Rondonia-RO), whose output per researcher grows at rates even higher than those of the leading states (Table 5), the researchers of the 'quartet' remain in the two strata of greater scientific productivity of the country in 2000 and 2010. Additionally, it appears that even with growth rates in excess of researchers and scientific production, the states of Minas Gerais and Rio Grande do Sul remain in a lower stratum of scientific output per researcher in relation to the state of Sao Paulo in the year 2010.

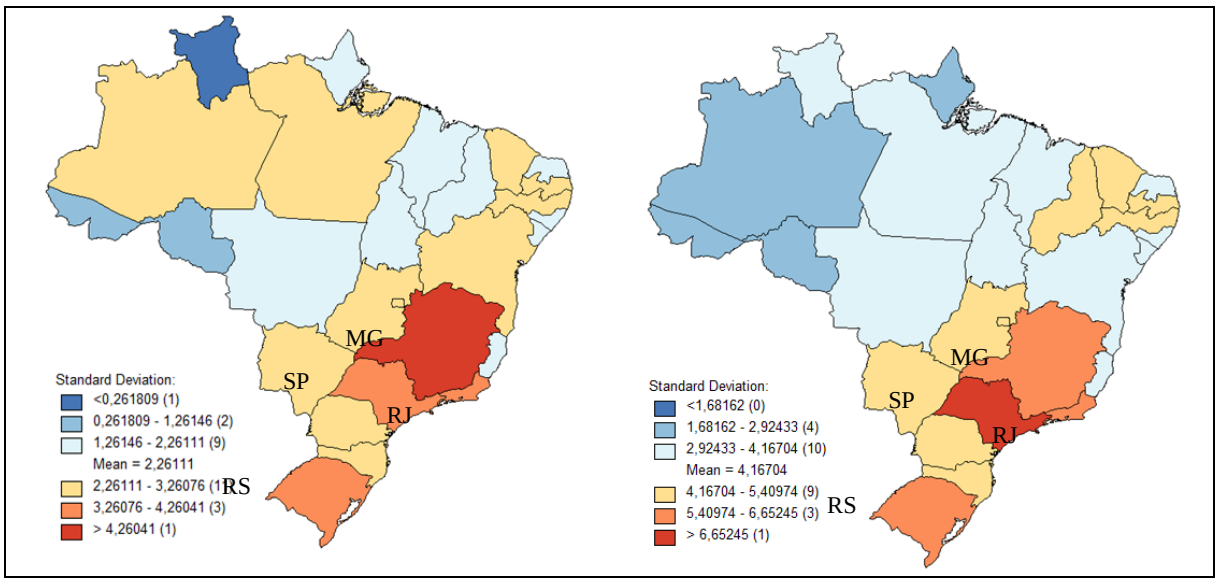

FIGURE 3 - Standard deviation of bibliographic production per researcher, by state, 2000-2010.

[5] Other factors not captured by the data, may have influenced the rapid growth of both Minas Gerais and Rio Grande do Sul, such as public policies of each state. This is a big challenge to the paper that needs to be discussed in another study.

Source: Authors' own. Data sourced from the Directory of Research Groups in Brazil's National Council for Scientific and Technological Development (DRG/CNPq). Note: This map corresponds to the left side year 2000 and right side year 2010. In each figure we can identify the average production per researcher. In 2000, it was 2.3 articles per researcher and in 2010, it was 4.2.

Likewise, FIG. 4 shows that there were no changes in the distribution of national bibliographic production per researcher per quintile, in 2000 and 2010. The 'quartet' stays on top quintile in the two years analyzed.

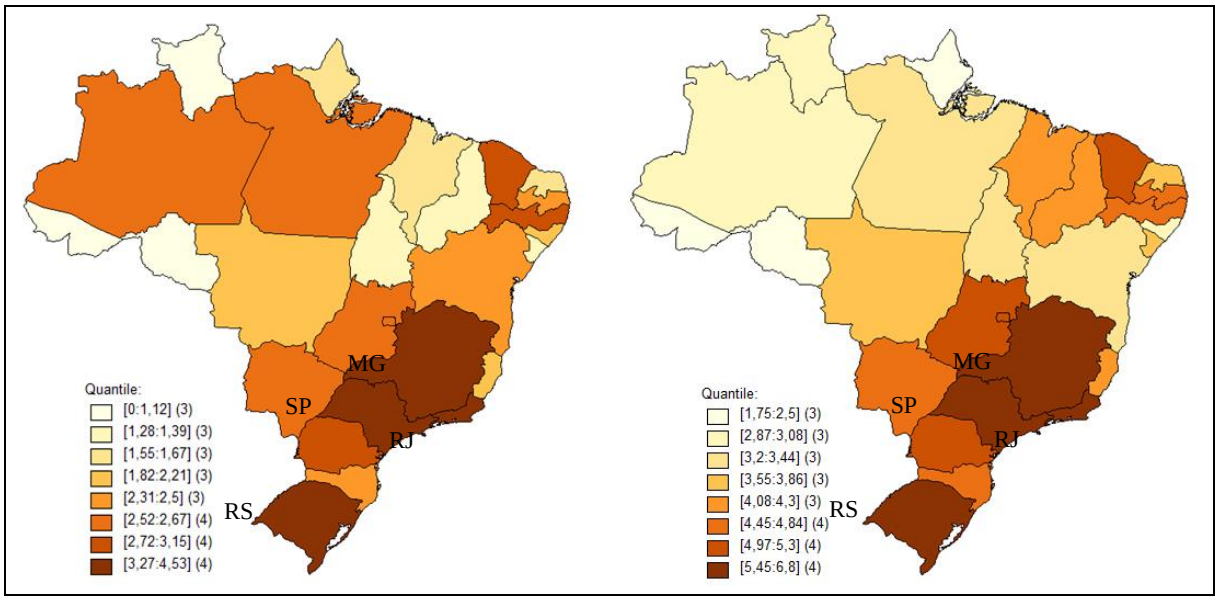

FIGURE 4 – Maps of bibliographic production distribution per researcher per quintile, 2000-2010.
Source: Authors' own. Data sourced from the Directory of Research Groups in Brazil's National Council for Scientific and Technological Development (DRG/CNPq). Note: This map corresponds to the left side year 2000 and right side year 2010.

However, when measuring the degree of inequality in the distribution of productivity of researchers (using the data distribution of Table 5), based on the calculation of the index of inequality Theil-T[6], to check the evolution of inequality in productivity between Brazilian states in the period from 2000 to 2010, there was a slight reduction in inequality of distribution, i.e., the data became less unequal. The following results were found: in 2000 the Theil-T was 0.048 in 2010 and 0.019, confirming the slight fall in inequality in the production of articles per researcher. Disaggregating the index, it was verified that there was a fall both within the group formed only by the 'quartet' as the group formed by the remaining states (in 2000 inequality within the 'quartet' was 0.0033 and fell to 0.0014 in 2010, since the inequality within the group formed by the remaining states was from 0.044 to 0.014). The data indicate that productivity within the 'quartet' was much more homogeneous than the productivity of the group formed by the remaining 22 federal units and the Federal District.

[6] This choice was mainly due to the fact that it can be decomposed into a measure of inequality and inter groups on a weighted average of inequality measures intra groups. In addition to this property, this index is more sensitive to changes in the extremes of the distribution (HOFFMANN, 2006). It is important to use an index with such property as the variables to be analyzed present distribution in the lower and upper end.

TABLE 5 - Bibliographic production per researcher and growth rates in the period 2000-2010, by state.

Production per researcher

	2000	2010	Growth (%)		2000	2010	Growth (%)
Acre - AC	0.59	1.75	199	**Paraiba - PB**	2.5	4.65	86
Alagoas - AL	2.21	3.08	39	**Parana - PR**	2.72	5.05	86
Amapa - AP	1.55	2.16	39	**Pernambuco - PE**	2.85	4.84	70
Amazonas - AM	2.52	2.87	14	**Piaui – PI**	1.39	4.3	210
Bahia - BA	2.33	3.37	45	**Rio de Janeiro - RJ**	3.48	5.45	57
Ceara - CE	3.05	5.3	74	**Rio Grande do Norte - RN**	1.67	3.86	131
Distrito Federal - DF	3.15	5.11	62	**Rio Grande do Sul - RS**	3.27	6.26	91
Espirito Santo - ES	2.14	4.08	91	**Rondonia - RO**	1.12	2.5	122
Goias - GO	2.67	4.97	87	**Roraima - RR**	-	3.01	-
Maranhao - MA	1.65	4.09	148	**Santa Catariana - SC**	2.31	4.45	93
Mato Grosso - MT	1.82	3.55	95	**Sao Paulo - SP**	3.86	6.8	76
Mato Grosso do Sul - MS	2.53	4.58	81	**Sergipe - SE**	1.28	3.86	202
Minas Gerais - MG	4.53	5.93	31	**Tocantins - TO**	1.28	3.2	150
Para - PA	2.58	3.44	33	**Brazil**	3.3	5.33	61

Absolute production*

	2000	2010	Growth (%)		2000	2010	Growth (%)
Acre - AC	96	783	716	**Paraiba - PB**	2,943	18,470	528
Alagoas - AL	566	4,961	777	**Parana - PR**	9,921	63,269	538
Amapa - AP	31	500	1,513	**Pernambuco - PE**	6,960	28,213	305
Amazonas - AM	1,535	9,150	496	**Piaui – PI**	430	6,072	1,312
Bahia - BA	4,135	28,173	581	**Rio de Janeiro - RJ**	26,972	99,940	271
Ceara - CE	3,560	21,144	494	**Rio Grande do Norte - RN**	966	12,045	1,147
Distrito Federal - DF	5,229	23,665	353	**Rio Grande do Sul - RS**	17,495	89,870	414
Espirito Santo - ES	991	7,348	641	**Rondonia - RO**	200	1,879	840
Goaias - GO	2,727	15,589	472	**Roraima - RR**	0	1,242	-
Maranhao - MA	934	5,569	496	**Santa Catariana - SC**	5,188	32,678	530
Mato Grosso - MT	315	8,733	2,672	**Sao Paulo - SP**	62,234	243,243	291
Mato Grosso do Sul - MS	1,687	13,547	703	**Sergipe - SE**	447	6,392	1,330
Minas Gerais - MG	21,618	98,900	357	**Tocantins - TO**	187	3,142	1,580
Para - PA	2,104	12,266	483	**Brazil**	179,471	856,783	377

Source: Authors' own. Data sourced from the Directory of Research Groups in Brazil's National Council for Scientific and Technological Development (DRG/CNPq).
Note: 'Absolute' refers to the sum of complete articles published in journals of national and international circulation.

The intra group inequality decreased from 0.03407 in 2000 to 0.01177 in 2010 and intergroup inequality fell from 0.01478 to 0.0073, which proves that both intra and inter- group inequalities were responsible for the slight decrease in inequality of output per researcher in the analyzed period (Table 6).

TABLE 6 - Index of inequality of Theil-T for absolute production and productivity, 2000-2010.

	Index for Absolute Production (*)		**Index for Productivity (**)**	
	2000	**2010**	**2000**	**2010**
Within Grup 1(***)	0.0590	0.0439	0.0034	0.0014
Within Grup 2(****)	0.2505	0.1849	0.0442	0.0147
Intra grup	0.1135	0.0974	0.0341	0.0118
Inter grup	0.3532	0.2531	0.0148	0.0074
Theil-T	0.4668	0.3505	0.0489	0.0191

Source: Authors' own. Data sourced from TAB 5.
Note: (*) Production refers to the absolute sum of complete articles published in journals of national and international circulation, in all areas of knowledge, (**) Productivity is articles per researcher; (***) group 1 refers to the 'quartet' (SP, MG, RJ and RS), (****) group 2 refers to other states and the F.D. Log (27) = 1.4313; would be the maximum inequality.

Interestingly, although the inequalities within and between groups with respect to productivity (i.e., articles by researcher) have reduced inequalities, absolute production (Table 5) is still very accentuated and is higher in the group formed by other states, other than the 'quartet' (compared to the 'quartet'). The Theil-T index in 2000 was 0.46678 and 0.35046 fell, confirming the slight fall in inequality in the distribution of absolute production. A breakdown of the index is in Table 6.

4 MAJOR AREAS OF KNOWLEDGE AND THE MAIN PRODUCERS OF KNOWLEDGE INSTITUTIONS IN THE 'QUARTET' IN 2000-2010

The scientific expertise within such higher productive states of the country is equally important. Albuquerque et al. (2002) identified the areas of the most influential Brazilian states in producing scientific knowledge in Brazil. Thus, Minas Gerais State had expertise in the area of biological and agricultural sciences. In turn, the specializations of Sao Paulo State were the health sciences and engineering. The authors found also that the state of Rio de Janeiro specialized in engineering and

physical and earth sciences, while scientific specializations identified for the state of Rio Grande do Sul were health sciences and secondarily agrarian sciences. The distribution of this scientific production by large areas of knowledge can be explained by the historical trajectory of S&T in Brazil, where the tradition of research formed and consolidated in the areas of agricultural sciences, biological and health.

In this section, the research focuses on the evolution of scientific production of states belonging to the 'quartet' in the years 2000 to 2010, by major area of knowledge and knowledge-producing institutions. This investigation contributes to the identification of their scientific specializations and how they relate to the dynamics of national scientific production in this period.

Concerning the work of Albuquerque et al. (2002), already mentioned, which identified the 'scientific expertise' of the most influential states in national scientific production, it appears that just Minas Gerais still maintains the scientific specializations taking into account the year 2010. In other states there is a change in specialization towards three areas of knowledge: agricultural sciences, biological and health. So, the bibliographic production of the four more dynamic states focuses in these areas.

One can check that in the four states the most productive areas of knowledge are agricultural sciences and biological sciences (not to mention the health sciences in Sao Paulo). Examining the specific area of agricultural sciences, it appears that Minas Gerais was the most productive state in 2010, with 10.0 articles per researcher, and Sao Paulo, the second most productive, with 9.8 articles per researcher. Already analyzing the biological sciences we have that the Rio Grande do Sul state was the most productive, followed by Sao Paulo, with 10.9 and 10.4 articles per researcher, respectively. Table 7, shown below, explores this discussion.

TABLE 7 - Production per researcher and growth rates in the period, for selected states, 2000-2010.

	Minas Gerais			Sao Paulo			Rio de Janeiro			Rio Grande do Sul			BRA		
	2000	2010	Growth	2000	2010	Growth	2000	2010	Growth	2000	2010	Growth	2000	2010	Growth
Agricultural Sciences	8.37	10.00	19%	4.80	9.84	105%	4.01	8.20	105%	5.60	9.74	74%	4.34	7.46	72%
Biological Sciences	5.98	9.77	63%	5.36	10.40	94%	5.19	8.70	68%	4.71	10.88	131%	4.51	7.99	77%
Health Sciences	4.16	7.21	73%	4.18	9.83	135%	3.43	7.85	129%	3.63	8.30	129%	3.48	7.11	104%
Exact Sciences and Earth	5.07	7.50	48%	6.06	8.80	45%	4.38	6.61	51%	4.36	7.29	67%	4.66	6.25	34%
Humanities	2.34	2.61	12%	2.01	3.34	66%	2.45	3.36	37%	2.24	3.82	71%	1.82	2.46	36%
Applied Social Sciences	1.66	3.15	90%	1.52	3.09	103%	2.02	2.58	27%	2.09	3.68	76%	1.50	2.66	77%
Engineering	2.48	4.19	69%	2.52	5.03	100%	2.50	4.19	68%	1.72	4.38	155%	2.14	3.68	72%
Linguistics, Letters and Arts	2.42	2.70	12%	1.97	2.76	40%	2.69	2.78	4%	2.24	2.90	30%	1.94	2.18	12%

Source: Authors' own. Data sourced from the Directory of Research Groups in Brazil's National Council for Scientific and Technological Development (PGD/CNPq).

The distribution of the production of articles by major field of knowledge in the states that showed a relative increase in output per researcher allows us to realize that productivity in the health sciences in this distribution increased over time and became more relevant than the exact and earth sciences, except in Minas Gerais.

Another important detail revealed in table 7 is the low production of articles in the area of engineering in all members of the 'quartet'. Thus, not only the observed spatial concentration of bibliographic production of the country, though with some tendency of decentralization that knowledge production towards less productive states both within the 'quartet', as to the rest of the country, as well as its concentration in large areas of agricultural sciences, biological and health.

Rio Grande do Sul, which increased the productivity of its researchers, measured in terms of published papers per researcher, rose 91.0% between 2000 and 2010, being the highlight of the 'quartet', as mentioned in the previous section, had its success thanks to increased productivity in the areas of biological and agricultural sciences. This fact stems from the existence of institutions that are related to characteristics of productive segments of the state, as shown by Costa et al. (2011), linked to the areas of agriculture and health. The main institutions responsible for the excellent performance of Rio Grande do Sul in 2010 were already mentioned in the previous section (IBTEC, HCPA and UFCSPA, in health and biological) and also the EMBRAPA/RS, the State Foundation for Agricultural Research (FEPAGRO), both in area of agricultural sciences; FZB/RS, in the biological sciences; the Institute of Cardiology/Cardiology University Foundation (IC-FUC) in the area of health sciences and the UFPEL, UFRGS and UFSM (in several areas, particularly in agricultural sciences, biological and health).

Likewise, the state of Minas Gerais, which increase the productivity of its researchers rose 31.0% over that period, had increased its resulting productivity of institutions in the areas of health sciences, biological and agricultural sciences (IEP/SCBH, HEMOMINAS, CPqRR/FIOCRUZ and EPAMIG). I.e.:

IEP/SCBH with 23.7 articles per researcher, HEMOMINAS with 17.5 articles per researcher, CPqRR FIOCRUZ with 13.8 and EPAMIG with 9.1 articles per researcher. The federal universities of Minas Gerais were less productive than the public research institute: UFLA (approximately with 10.6 articles per researcher) UFV (9.7) and UFMG (6.5).

However, it is noteworthy that although the productivity of the institutions mentioned above have been the greatest in those states, they were not responsible for the large volume of scientific production in Minas Gerais and Rio Grande do Sul, which was made possible by the federal universities. Table 8 shows this.

TABLE 8 - The five institutions with greater participation in the production of each state and the five most productive institutions in each state, 2010.

Percentage to total of each state							
Minas Gerais		**Rio de Janeiro**		**Rio Grande do Sul**		**Sao Paulo**	
Universidade Federal de Minas Gerais – UFMG	29.00%	Universidade Federal do Rio de Janeiro – UFRJ	28.31%	Universidade Federal do Rio Grande do Sul – UFRGS	31.57%	Universidade de São Paulo - USP	33.45%
Universidade Federal de Viçosa – UFV	16.03%	Universidade Federal Fluminense - UFF	12.77%	Universidade Federal de Santa Maria – UFSM	13.16%	Universidade Estadual Paulista - UNESP	17.34%
Universidade Federal de Uberlândia – UFU	8.69%	Universidade Estadual do Rio de Janeiro – UERJ	12.36%	Universidade Federal de Pelotas – UFPEL	9.51%	Universidade Estadual de Campinas - UNICAMP	11.68%
Universidade Federal de Lavras – UFLA	7.93%	FIOCRUZ/RJ	11.02%	Pontifícia Universidade Católica do Rio Grande do Sul – PUCRS	8.99%	Universidade Federal de São Paulo - UNIFESP	5.84%
Universidade Federal de Juiz de For a – UFJF	5.19%	Universidade Federal Rural do Rio de Janeiro - UFRRJ	5.18%	Universidade Federal do Rio Grande – FURG	4.06%	Universidade Federal de São Carlos - UFSCAR	4.83%
Productivity (production *per* researcher)							
Minas Gerais		**Rio de Janeiro**		**Rio Grande do Sul**		**Sao Paulo**	
IEP-SCBH	23.75	Instituto Nacional de Câncer – INCA	12.48	Instituto Brasileiro de Tecnologia do Couro. Calçado e Artefatos - IBTEC	15.6	Hospital Heliópolis - HELIOPOLIS	17.83
HEMOMINAS	17.46	Centro Brasileiro de Pesquisas Físicas – CBPF	10.73	Hospital de Clínicas de Porto Alegre – HCPA	11.01	Fundação Antônio Prudente - FAP	16.45
FIOCRUZ/RJ*	13.78	Universidade Estadual do Norte Fluminense Darcy Ribeiro – UENF	9.95	Fundação Universidade Federal de Ciências da Saúde de Porto Alegre – UFCSPA	8.48	Faculdade de Medicina de São José do Rio Preto - FAMERP	14.42
Universidade Federal de Lavras – UFLA	10.55	EMBRAPA/RJ**	8.29	Universidade Federal de Pelotas – UFPEL	7.95	Instituto Israelita de Ensino e Pesquisa Albert Einstein - IIEPAE	13.7
Universidade Federal de Viçosa – UFV	9.72	Instituto de Pesquisa Jardim Botânico do Rio de Janeiro - IP/JBRJ	7.67	Fundação Zoobotanica do Rio Grande do Sul - FZB/RS	7.91	Instituto Ludwig de Pesquisa sobre o Câncer - ILPC	13.54

Source: Authors' own. Data sourced from the Directory of Research Groups in Brazil's National Council for Scientific and Technological Development (PGD/CNPq). Note: The information was corrected due to the presence of outliers.

It may be noted, as had already been mentioned in the previous section, in Minas Gerais that much of the knowledge production is borne by the federal universities (Chiarini and Vieira, 2012). UFMG, in 2010, accounted for 29.0% of all bibliographic production in the state, followed by UFV (16.0% and UFU (8.7%). However, these institutions have not been the most productive (in terms of academic output per researcher). Of the five largest producers of knowledge in Minas Gerais, just UFLA and UFV appear as institutions with high productivity.

The same can be submitted to Rio Grande do Sul, as was previously stated. The UFRGS accounted for 31.6% of the scientific production of the entire state, then UFSM and UFPEL, however, among the five most productive institutions of the state, and only UFCSPA and UFPEL stand out.

Rio de Janeiro is the only state belonging to the 'quartet' that among the five largest institutions responsible for the production of new knowledge in the state appears a non university which is FIOCRUZ/RJ (responsible for 11.0% of the scientific production in Rio de Janeiro).However, the other

four positions are occupied by public universities (federal and state funded universities): UFRJ (28.3%), UFF (12.8%), UERJ (12.4%) and UFRRJ (5.2%). However, also as with Minas Gerais and Rio Grande do Sul, the most productive institutions were not universities, but the INCA, CBPF, EMBRAPA/RJ and IP/JBRJ. It also appears as an institution with high productivity, in Rio de Janeiro, the UENF.

The great contribution of new knowledge takes place in Sao Paulo from its state universities. In fact, USP, UNICAMP and UNESP were the main institutions in 2010, followed by federally funded institutions UNIFESP and UFSCar. Again, the high productivity does not occur in universities, but in the research centers HELIOPOLIS, PAF, IIEPAE and the LICR. The only educational institution that is among the five most productive institutions of Sao Paulo is the FAMERP, Sao Paulo state college and one of the most prestigious schools of medicine and nursing in the country.

The reasons for the greater dynamism in certain areas of knowledge may be related to two factors, according to Faria et al. (2011). The first one relates to the areas of expertise of leading universities and science research centers in Brazil. Moreover, the PRIs, responsible for devolution for this production relative to traditional universities, are concentrated in the southeastern states, particularly Sao Paulo and Rio de Janeiro. Thus, in biological and agricultural sciences, for example, it is possible to observe the influence of institutions such as EMBRAPA and FIOCRUZ in scientific production of these states. The other factor is the existence of this scientific production in line with that held in developed countries and in catching up, where the main areas of scientific expertise are medicine, physics and chemistry.

FINAL CONSIDERATIONS

This study allowed us to detail some relevant information to a better understanding of the Brazilian Innovation System. The presentation of the spatial distribution of science production explains particular structural features of the Brazilian NIS, i.e., a system whose knowledge production is highly uneven. Only four states can be classified as highly productive ('scientific quartet', formed by Sao Paulo, Rio de Janeiro, Rio Grande do Sul and Minas Gerais) and they form the epicenter of Brazilian science. This conclusion allows us to affirm that the Brazilian NIS is still concentrated in the South-East, although there was a small devolution of knowledge production in either direction to less productive states within the 'quartet', as to the rest of the country. Brazilians are experiencing a recent new wave of infrastructure creation of federally funded universities in the country.

We could also speculate that the above mentioned concentration in the 'quartet' is a result of the concentration of economic activities in these four states, once they are also economic powerhouses of the country. It would be interesting to check the correlation of science concentration to economic/industrial concentration, but this is a further step of this study.

When analyzing the states that form the 'scientific quartet' in Brazil, it was noted that there was a reduction in disparities of these states with respect to total scientific production (measured by the volume of scientific papers published in national and international journals) by researcher and productivity (measured by the volume of articles per researcher). Proof of this was found constructing the T-Theil index for both indicators, although inequality in productivity has been lower than the inequality of total production. There was a greater dynamism of researchers of Minas Gerais and Rio Grande do Sul *vis-à-vis* the other states, especially in certain areas of knowledge (agricultural, biological and health), leveraging the performance of these states.

Disaggregated data by area of knowledge suggest an alignment of Brazilian research with the international research community, supporting in part the study of Faria et al. (2011), while they are in line with the traditions of historical research in the country, as Suzigan and Albuquerque (2008) suggest.

Although the public universities still continue to be the main agents of production of new knowledge in the 'quartet', they are not the most productive institutions. In other words, researchers from PRIs appear as more productive than the university researchers, although more studies on this aspect are needed to identify the reasons and support this result.

From these findings, we can conclude that (1) even with federal policies aimed at expanding and deconcentrating production of new scientific knowledge, its production is still strongly anchored in the 'quartet'; and (2) the highest growth of national scientific production in the fields of agricultural sciences,

biological sciences and health sciences, relates to the scientific expertise of the states analyzed and increased scientific productivity of the 'quartet', particularly, Rio Grande do Sul and Minas Gerais.

The hypothesis of the article was confirmed with the data presented, in which the 'quartet' is still in the top quantile of bibliographic production per researcher. Nevertheless, there was a small devolution[7] regarding the less productive states within the 'quartet'.

The first two findings suggest that the effect of decentralization exists, but that there are gradual steps - first within the states of the 'quartet' and later in other states. We must take into account that federal policies aimed at decentralizing scientific production to other regions of the country tend to have an effect over the long term.

The occurrence of this effect (decentralization within the 'quartet') is due to greater scientific skills and infrastructure already present within the less productive states of the 'quartet', in comparison with the other states of the country. It also should be noted, as pointed by Barros (2000), that state or regional policies can also affect the distribution of scientific production over time.

It was also demonstrated that the excellent performance of researchers of Minas Gerais and Rio Grande do Sul, with respect to their productivity (articles per researcher) takes exactly the most dynamic areas of agricultural sciences, biological and health, which increased the average bibliographic production of such states. Finally, some of such expertise tend to be in line with the scientific production observed in developed nations, as observed in biological and health sciences, taking the quartet as a whole. This is pointed by Faria et al. (2011), and could be due to the greater participation of Brazil in international scientific cooperation in certain areas, such as bioprospection, as pointed by Lima et al. (2007). This Brazilian participation is mainly represented by the states of quartet and, therefore, spots this region among others in the big web of worldwide co-publications.

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[7] I.e. a decrease of differences with respect to productivity per researcher (which means that the less productive states within the 'quartet' decreased the scientific productivity gap).

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