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Biomedical politics through time and space: the example of bioinformatics in Brazil

Rising Powers Research

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Abstract

The emergence of a new scientific discipline, as well as the policies aimed to steer its evolution, have geographical implications. In this paper, the relation between scientific evolution, political decisions and geographical configuration is studied. As empirical example, the recent formation of bioinformatics in Brazil is focused on.

After an initial period of geographical concentration (from 1997 to 2006), a new period can be identified (from 2007 to 2014), in which political choices have made diffusion and equality be the main national target. As a consequence, different actors have been involved in a debate, some defending the existence of few specialized research units whereas others have tended to welcome the constitution of a scientific scenario based on decentralized research platforms.
Keywords: bioinformatics; Brazil; decision-making; spatial inequalities

1. Introduction

Scientific and political processes become more meaningful when analyzed together, and even more so when the analysis includes geographical phenomena. Such analyses can be particularly interesting when new a science domain is constituted and the national state is called upon to steer its evolution.

As claimed by Salter and Faulkner (2011, p. 3), "[…] choices about the science have much to do with the creation and husbanding of the resources necessary for the enterprise to have an explicit domestic platform". It is important to consider that such platform takes shape not only institutionally and financially but also geographically.

In this paper, it is claimed that three processes occur in tandem: first, the scientific advances leading to the creation of new disciplinary domains; second, the national state's choices of policies ruling such disciplinary emersion; and third, the consequent spatial phenomena expressing a country's particular geographical configuration. As claimed by Milton Santos (2000), geography, i.e. the study of space as it is produced by society, can only benefit from both the study of scientific activity (one of its main

contents in contemporary globalization) and the consideration of the national state (which continues to be a pivotal social actor). To deal with such issues, we shall focus on bioinformatics in Brazil.

There are two ways of defining bioinformatics. First, it can broadly described as the use of computational tools to handle biological information (Chow & Fernandez, 2003; Gopalan, 2009; Suárez-Díaz, 2010). In this approach, bioinformatics belongs to the historical process of "the computerization of biology" (Suárez-Díaz, 2010, p. 76 note 10). Second, there is a narrow definition in which bioinformatics is the usage of computational resources to process information produced in molecular biology studies (Araújo et al., 2008; Howard, 2000; Ouzonis & Valencia, 2003). Thus bioinformaticians organize DNA sequences, analyze protein structures, design databases and so on. This second, narrow, definition is the one adopted here.

The situation of Brazil is focused on because of the recent emersion of bioinformatics in the country. It can be considered that in Brazil the discipline "[…] was utilized in a systematic way for the first time in 1997 […]" (Conselho de Informações sobre Biotecnologia, 2004, p. 4). Therefore, the relatively new formation of Brazilian bioinformatics facilitates an analysis aimed to show how a discipline evolves not only socially (the mobilization of different social actors around it) but also geographically (the distribution of activities in a territory and its consequent political issues). Furthermore, by focusing on Brazil, we are dealing with a Latin American economic and scientific hub, often pointed to as a promising economy at the global scale as well.

My analysis begins with a description of the methods used in my study. We move on to undertaking a space-time analysis, scrutinizing the historical and geographical evolution of bioinformatics in Brazil. Subsequently, we focus on a debate currently being realized in the country: the dilemma between concentration and diffusion of research infrastructures. Finally, some closing ideas are presented.

2. Methods

This study belongs to the research project called *Rising powers: state strategies of governance in global biomedical innovation,* conducted from 2012 to 2015 and coordinated by Brian Salter (King's College London) and Alex Faulkner (University of Sussex).

The information I present derives from two sources. First, I consulted the website of CNPq, a funding agency attached to the Brazilian Ministry of Science and Technology. One of its resources is the "Research Groups Directory" in which groups register their activities and features. In this database I looked for groups dedicated to, or hosting some, bioinformatics activities. In order to run the queries, I used the word "bioinformatics". For the outcomes, I considered both the field "research line's name" and "research line's keyword". I counted in the groups that described all or some of their activities by using the following expressions: "bioinformatics", "computational biology", "computational analysis of genes", "analysis of data from new-generation sequencers", "applied bioinformatics", "structural bioinformatics", "algorithms in computational biology", "transcriptomics bioinformatics", "functional bioinformatics", and "biomedical informatics".

I also counted in those groups that maintain databases. Some clarification is needed here. According to Chang and Zhu (2010), "primary databases" contain raw information such as contents of DNA and protein sequence whereas "secondary databases" are constructed by processing the data found in primary databases. Therefore: "In secondary databases, the data from the primary database is reprocessed using bioinformatics software" (Chang & Zhu, 2010, p. 451). In my analysis, then, I only counted in the groups whose description suggested the existence of a "secondary database".

The 140 groups I identified are very diverse. Some are specialized in bioinformatics whereas others are biology groups with bioinformatics as a tiny fraction of their activities. In size, they are also varied, with 16 groups being actually composed by only one investigator. The biggest group has 26 people, including investigators and students.

My database query was conducted in December 2014. I also verified the year in which groups were founded. This does not mean that my analysis includes all the research groups that have ever existed in Brazil. It contains only the groups that were created and could subsist until December 2014. This limits my study because I am excluding groups that were created and terminated before that date. However, this

fragility might rather be seen as an advantage, as we are looking at only research groups with enough scientific and institutional force to have had long life.

Second, I present information deriving from fieldwork conducted in Brazil from November 2014 to July 2015. I conducted 18 interviews with bioinformatics lecturers and researchers. This was done in four cities: Campinas and Sao Paulo (state of Sao Paulo), Belo Horizonte (state of Minas Gerais) and Recife (state of Pernambuco). The interviews were semi-structured with open questions. All interviews but one were recorded with permission from the interviewee. The study was reviewed by the ethics committee of King's College London.

In the following part, we begin our analysis by focusing on the geographical distribution of bioinformatics in Brazil. We consider not only spatial aspects, but also the ways in which these aspects have evolved throughout the years.

3. Space-time evolution of Brazilian bioinformatics

3.1. First period (1900 to 1996): biological studies

As explained by Hagen (2000, p. 231), "[…] computers emerged as important tools in molecular biology during the early 1960s". This is when bioinformatics began to be constituted, as a result of the idea that proteins and nucleic acids, because they carry information, can be analyzed as if they were information (Hagen, 2000; Suárez-Díaz, 2010).

Brazil did not join the group of countries that pioneered molecular biology (not to speak of automated DNA sequencing and bioinformatics), even though biological research is quite old in the country. For example, the Foundation Oswaldo Cruz, which conducts biological and sanitary studies, began to operate in 1900, a year that can be symbolic pointed to as the beginning of our first historical period. At that time, Brazil was unable to assimilate the bioinformatics evolution of other countries, because of two limitations. First, most Brazilian universities were created from the 1950s to the 1970s. In their initial decades, they focused on basic domains (especially medicine, engineering and

law) instead of investing resources in cutting-edge areas such as bioinformatics. Second, Brazilian companies were too small to hold research activities. The multinational companies operating in the country, such as the European and American pharmaceutical companies, had no research unit in Brazil, restricting themselves to importing final products and selling them in the Brazilian market (Bicudo, 2009; Palmério, 1942).

Some more elaborate biological and agriculture studies began to be carried out in the 1970s. For example, there were those conducted by the federal company for agrarian and livestock research Embrapa, which was created in 1973. By this time, some university research groups had already appeared which focused on practical and commercial dimensions of agriculture, as was the case of those created at the University of Campinas, founded in 1966. It is worth noting that most of these universities and institutions were located in the southern portion of Brazil (especially the states of Sao Paulo and Rio de Janeiro), which held and continue to hold the main economic forces in the Brazilian economy.

In the 1980s, outside Brazil, bioinformatics reached a new phase of its development due to achievements such as the formation of international biological databases (Lewis & Bartlett, 2013; Ouzonis & Valencia, 2003), the institutionalization of the field in key institutions (Ouzonis & Valencia, 2003) and the formulation of new and more sophisticated algorithms as a result of improved DNA sequencing technologies (Suárez-Díaz, 2010)[1]. At the same time, Brazilian biological and agriculture research scaled up its ambitions and techniques, getting ready for future breakthroughs.

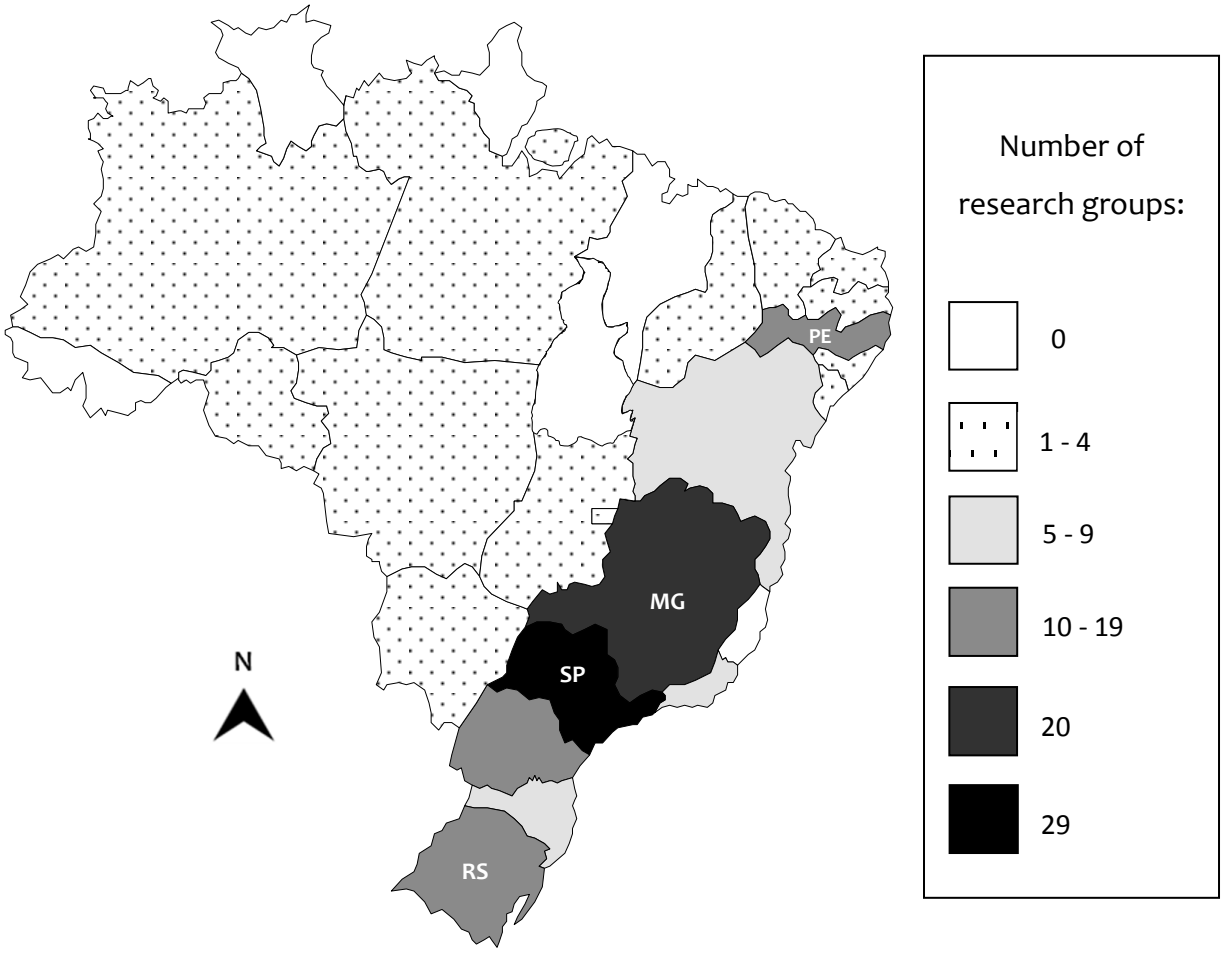
Therefore, even though bioinformatics was absent in this first historical period, many Brazilian research groups were constituted, acquiring expertise to subsequently explore bioinformatics and genomics studies. When bioinformatics eventually was inaugurated in the country, it was these groups that established themselves as pioneers.

3.2. Second period (1997 to 2006): scientific pioneerism and geographical concentration

[1] I am speaking of three historical periods in Brazil. When dealing with bioinformatics internationally, though, four periods can be identified, the first one beginning in the 1960s and the second one in the 1980s.

The following map depicts the distribution of bioinformatics groups in Brazil:

Map 1 – Bioinformatics research groups in Brazil: December 2014



source: elaborated by the author with data from CNPq, Research Groups Directory (http://lattes.cnpq.br/web/dgp)

The prominent role played by the state of Sao Paulo (SP) with its 29 groups is numerically indisputable. It is closely followed by its neighbour state, Minas Gerais (MG), with 20 groups. Another clear feature is the minor role played by the northern states, which have historically been disadvantaged in terms of both economic dynamics and scientific development. The exception is the state of Pernambuco (PE) with its 10 groups.

The reasons for such spatial configuration lie in the historical evolution of bioinformatics since its emersion in 1997. In that year, after much negotiation and preparation, the so-called *Xylella* project was launched. Its purpose was the sequencing of the DNA of *Xylella fastidiosa*, a bacterium that infects and kills orange crops. For project coordination, the University of Campinas (state of Sao Paulo), was chosen, not only because of its expertise in biological and agriculture research but also because at that time, two Brazilian bioinformatics pioneers were based there: professors Joao Meidanis and Joao Carlos Setubal. They had completed their PhDs in the United States and returned to Brazil to found the Bioinformatics Laboratory, the first of its type in Brazil (ComCiência, 2003).

Meidanis' and Setubal's knowledge was not the only factor allowing Sao Paulo to lead the Brazilian bioinformatics adventure. Another important element was the presence of Fundecitrus, a private association composed by orange cultivators and companies of the juice industry. In the *Xylella* project, the main funder was Sao Paulo research funding agency, Fapesp, whereas Fundecitrus made additional research investment. This was so because citrus variegated chlorosis, the disease caused by the targeted bacterium, was provoking huge financial losses for Sao Paulo citrus industry (Dal Poz, 2000; Harvey & McMeekin, 2005; Simpson & Perez, 1998). Thanks to this project, Sao Paulo built up an initial infrastructure for bioinformatics research. Twenty-five laboratories and over 100 researchers joined the project.

> By the end of April 1998, 35 automatic sequencers had been purchased, imported, and installed across Sao Paulo, all the sequencing groups had received basic training, culture of the organism had been mastered, and sufficient DNA had been produced to permit the project to proceed. Moreover, individual researchers had undertaken short training visits to major laboratories around the world [...] (Simpson & Perez, 1998, p. 796).

The model of laboratories operating in network was actually imported from Europe. In the pioneering Brazilian endeavour, it proved very successful, as is testified by the relatively rapid completion of the *Xylella* project in 2000. This world's first sequencing of a plant pathogen deserved publication in the front cover of a 2000 issue of *Nature.*

Following to this achievement, other projects were initiated with similar features. We then leap into a period when Brazilian bioinformatics was strongly impelled by large genome projects, most of them aiming to sequence plant or animal pathogens, or to harness agriculture production. In 2006, Bongiolo (2006) listed all the ten bioinformatics research networks in operation in Brazil; of them, seven were consecrated to plant or livestock issues.

These scientific and political decisions had geographical implications. The major one was the concentration of large projects in the southern part of Brazil, especially the state of Sao Paulo, where the main universities and the most powerful economic players are found. Gradually, Sao Paulo turned into a national bioinformatics hub, until the point in which its researchers could act as national advisors. For example, in 2000 a research network was constituted in the state of Bahia, in order to sequence a pathogen of cacao crops; since its beginning and until its completion in 2005, the project was coordinated from the University of Campinas (state of Sao Paulo) (Dias, 2006).

In Minas Gerais and Rio Grande do Sul, considerable advancement was also achieved in this phase, thanks to both the presence of dynamic agriculture activities and important universities and federal research institutes. For instance, the PIGS network united ten laboratories of the three southernmost Brazilian states in order to sequence a bacterium that causes swine pneumonia. Even though no private money was invested here, the disease had important commercial implications, as it was imposing serious financial losses in a region that holds 30% of the national herd of pigs (Bongiolo, 2006; ComCiência, 2003).

Therefore, this first phase of Brazilian bioinformatics had two main characteristics. On the one hand, even though most genome projects were fully funded by federal institutions, studies focused on agriculture issues with economic import. In 2005 Harvey and McMeekin (2005, p. 649) affirmed that one of the main features of Brazilian genomics was "its association with the principal sectors of Brazilian agriculture". On the other hand, there was an important concentration of major projects in the southern part of Brazil, the main bioinformatics forces being the states of Sao Paulo, Minas Gerais and Rio Grande do Sul. In 2001, the Ministry of Science and Technology launched a call for proposals on bioinformatics; of the 28 projects approved,

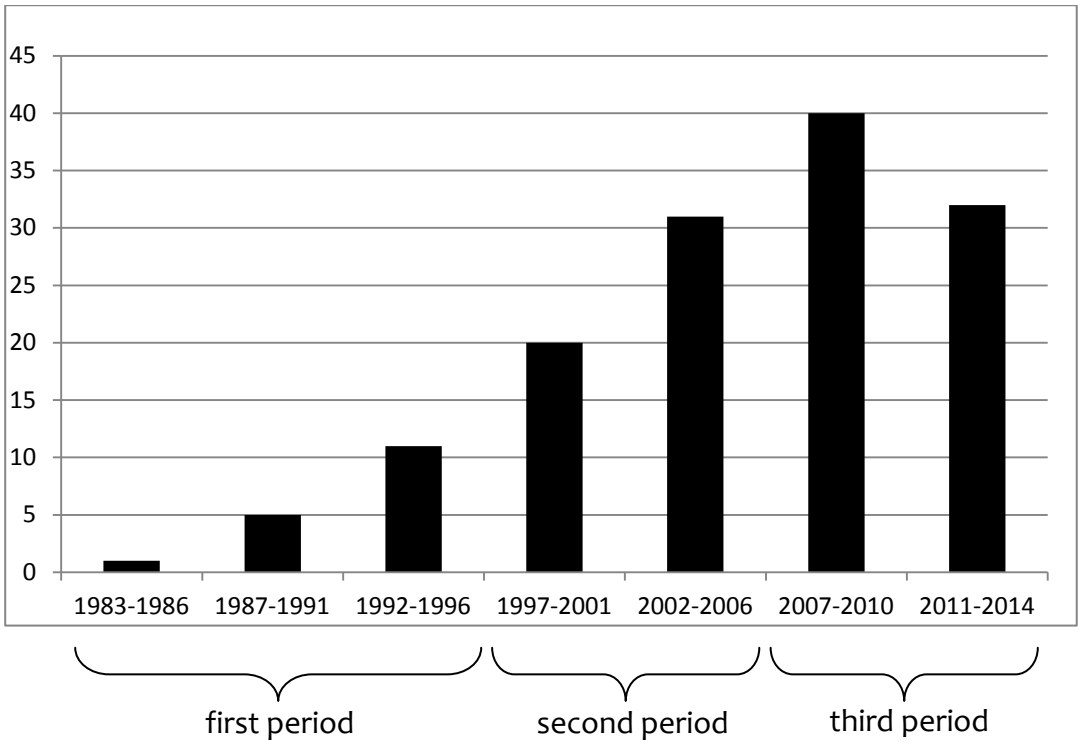
23 had been submitted from either the south-eastern or southern part of Brazil (ComCiência, 2003).

Meanwhile, some states had either institutionally weak bioinformatics groups (thus being precariously integrated to the rest of the country) or no bioinformatics groups at all (thus being kept apart from the new scientific enterprise). This geographical configuration confirms Santos' (2000) explanation: the possibility to deeply know and even anticipate natural phenomena, as well the ownership of equipments enabling this knowledge, draws hierarchies between actors and regions. As we shall see in the following section, this tendency began to be reverted around 2007, as a consequence of political changes.

3.3. Third period (2007 to 2014): scientific consolidation and geographical diffusion

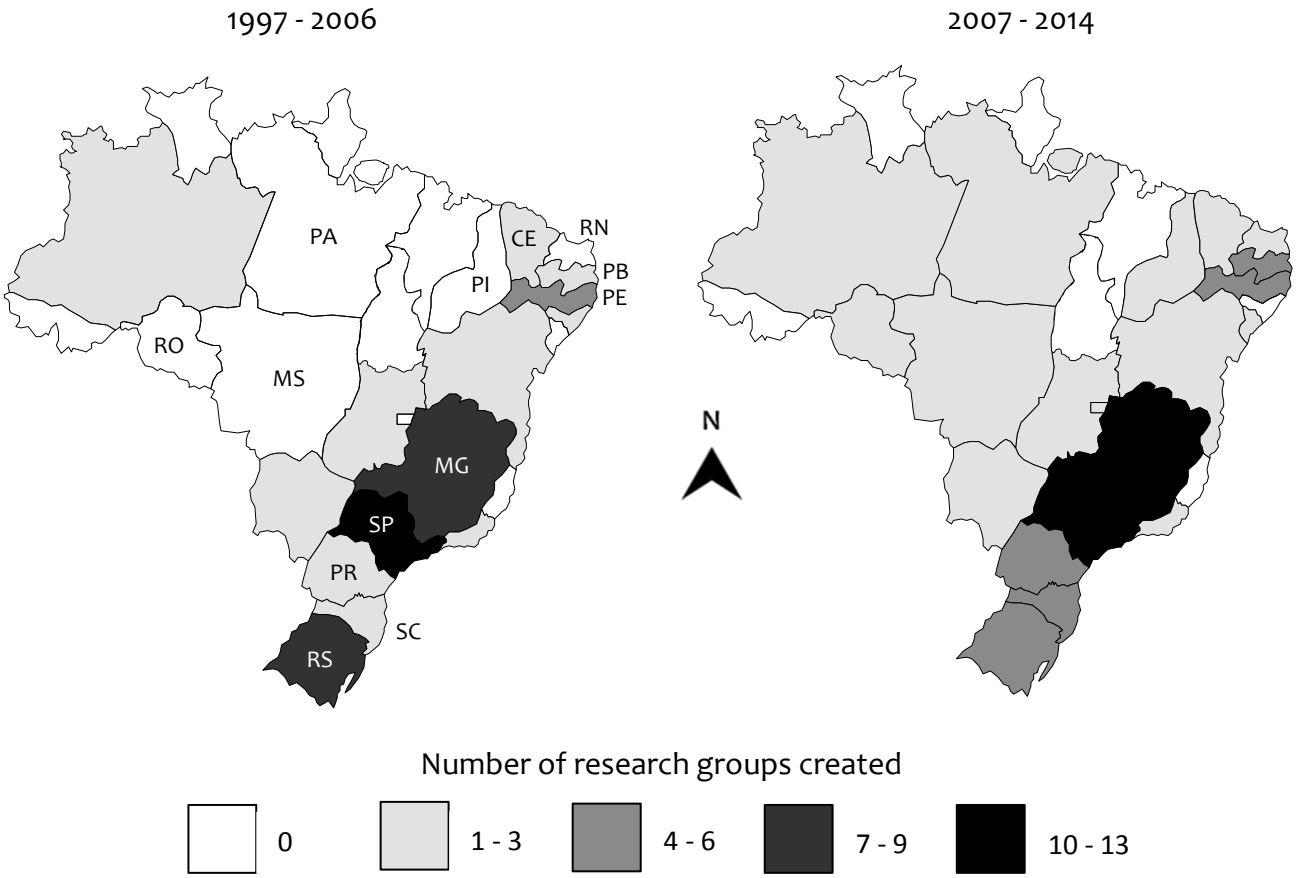
The following map depicts the creation of bioinformatics groups.

Graphic 1 – Foundation of extant bioinformatics research groups: December 2014



At first sight, there is an undifferentiated evolution from the first to third period. The rise has been constant with a small drop in the last part of the current period. Graphic 1 could then suggest the absence of remarkable historical shifts. However, let us consider how this evolution was realized in the geographical space by means of the following map.

Map 2 – Foundation of extant bioinformatics research groups according to Brazilian states: December 2014



source: elaborated by the author with data from CNPq, Research Groups Directory (http://lattes.cnpq.br/web/dgp)

It is worth remembering that in Map 2, we are not dealing with all the groups created in each period. We are only considering the date of creation of groups existing in December 2014. Thus we are not including research groups that may have been created and subsequently terminated before this date. However, Map 2 gives us a good idea of what happened at those moments in geographical terms.

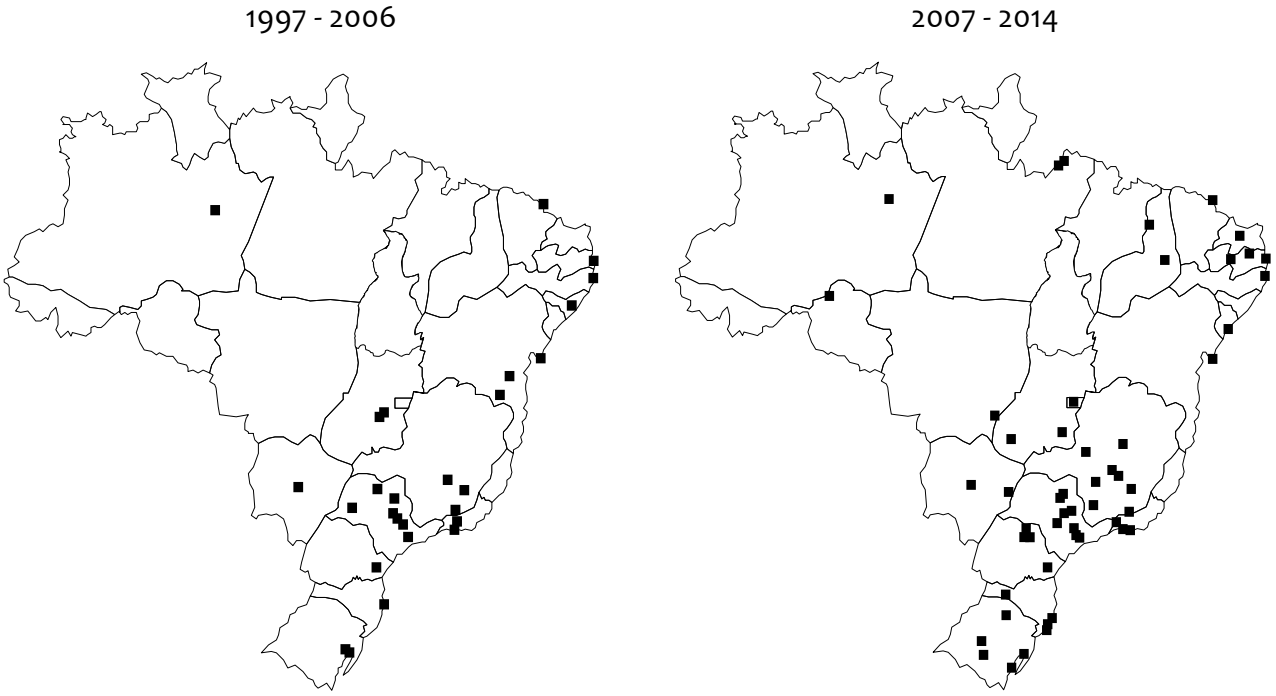
In the 1997-2006 period, groups were concentrated on the coastal part of Brazil, in a line extending from Ceara (CE) to Rio Grande do Sul (RS). Sao Paulo (SP) figured as

the leading bioinformatics force and, along with Minas Gerais (MG) and Rio Grande do Sul, turned the southern part of the country into a bioinformatics hub.

In the 2007-2014 period, geographical dispersion has occurred, as is expressed by four phenomena. First, Minas Gerais attained the level of group formation displayed by Sao Paulo. Second, other regions have known this same process whereby a local bioinformatics hub is matched by the emergence of other forces; this is what happened in the south where Rio Grande do Sul was equalled by Santa Catarina (SC) and Parana (PR), as well as in the north-east where Pernambuco (PE) was equalled by Paraiba (PB). Third, at the closing of the 1997-2006 period, no extant research group was present in five pivotal states: Rondonia (RO), Mato Grosso do Sul (MS), Para (PA), Piaui (PI) and Rio Grande do Norte (RN); in the 2007-2014 period, these geographical voids were filled. In this way, bioinformatics has been reaching the Brazilian hinterlands.

These developments reflect choices taken by the Brazilian government, which has created higher education institutions, especially in the hinterlands, in cities deprived of universities. In order to scrutinize this process of geographical internalization, let us consider the following map.

Map 3 – Cities where at least one extant bioinformatics research group was created: December 2014



Source: elaborated by the author with data from CNPq, Research Groups Directory (http://lattes.cnpq.br/web/dgp)

From one period to the other, it is possible to see the small black squares multiplying and going westwards. This internalization is more evident in the southern and north-eastern parts of the Brazilian territory. This is the outcome of choices that have been made by the Brazilian government since the turn of the century.

In 2001, the Ministry of Science and Technology established the Brazilian Genome Project, which consisted of a network of 25 laboratories scattered throughout Brazil. By the end of its first year, the network had already completed the sequencing of *Chromobacterium violaceum* (Harvey & McMeekin, 2005), a bacterium with potentially beneficial properties for human health and agriculture. However, actual collaboration was feeble in this network, because the different laboratories worked separately and data were subsequently centralized and analyzed in Sao Paulo. Moreover, the project

began with quite limited technological resources. The network could only gain actual momentum in 2008, when one of the participating laboratories, located in Rio de Janeiro, acquired a last-generation sequencing device, thus intensifying the work that could be done within the network.

The dispersive trend initiated by the Brazilian Genome Project was only consolidated and turned into a lasting federal policy with the launching of the 2003 Programme for the Expansion of Public Higher Education (*Programa de Expansão da Educação Superior Pública*), subsequently reinforced by the 2007 Reuni, an acronym for Program for Supporting Plans of Reorganization and Expansion of Federal Brazilian Universities (*Programa de Apoio a Planos de Reestruturação e Expansão das Universidades Federais Brasileiras*). The main focus of Reuni was the Brazilian hinterlands, where cities with no universities abounded.

> Thus between 2003 and 2009, 236 cities which were not served by higher education institutions inaugurated federal campuses through either the creation of new universities or the expansion of units of institutions located in capital cities or cities of large size (Marques & Cepêda, 2012, p. 184).

Thus, in Map 3 above, the multiplication of black squares in the 2007-2014 period is not simply due to its being more recent and therefore holding research groups that have not had the time to fade out yet. Many of the cities marked in this period were actually selected to receive new universities. This is the case of Sao Bernardo (state of Sao Paulo), a city that received, in 2005, the Federal University of ABC, in which a bioinformatics group was created in 2012; and also the city of Alfenas (state of Minas Gerais), which received the Federal University of Alfenas, a school which was transformed into university in 2005 and received a bioinformatics group in 2014. The creation of universities, as well as the transformation of research centres into universities, makes the consolidation of bioinformatics groups more likely. For universities are not only lasting institutions but also have access to special types of funding like the ones provided by federal agencies.

Therefore, due to policies adopted by the federal government, the formation of research groups, in the current historical period, expresses a geographical pattern that is

more balanced, and potentially more geographically democratic, than that which prevailed previously. This distributive concern is in line with a new political attitude that Marques and Cepêda (2012) classify as "neo-developmentalist". This state's political stance "[…] takes as its 'developmental' core the resurgence of purposes of deep social transformation operated via state policies (the *developmental* feature) but changing the strategic axis of this transformation. Now it is redistribution – and no longer (or not only) production – that is the biggest novelty" (Marques & Cepêda, 2012, p. 169).

What needs to be stressed is that the Brazilian state's new posture may be hidden by facts and figures highlighting phenomena of short term, while its is revealed by geographical analyses focusing on the long term evolution of the geographical space. In this way, three pivotal elements appear entangled: first, the policies adopted by decision-makers based in high spheres of the state; second, the configuration of the national territory; and third, the evolution of new scientific domains such as bioinformatics.

Nevertheless, the choices made by the Brazilian state do not go without considerable controversy. As show in the following section, they have triggered much discussion among Brazilian bioinformaticians.

4. Brazilian bioinformatics between concentration and diffusion

In the 1930s and 40s, the south-eastern part of Brazil, and especially Sao Paulo, became the country's economic centre. Consequently, many types of concentration, including scientific ones, tend to occur. Things are not different for the bioinformatics domain, within which the South-east, and mainly Sao Paulo, has early taken the lead (Araújo et al., 2008; ComCiência, 2003).

As explained by a geneticist interviewed in my fieldwork, this region holds the biggest number of geneticists operating in Brazil. This medical workforce underpins the formation of some genetic companies that have emerged over the last two decades. That is why another interviewee, a biochemist who runs a genetic company in Minas Gerais, wish he could be located in Sao Paulo, a city where the middle classes, potential consumers of genetic services, are large and consolidated.

Not surprisingly, then, the issue of geographical concentration rapidly became a scientific and political concern. I interviewed a bioinformatician who joined the group of academics that created, in 2004, the Brazilian Association for Bioinformatics and Computational Biology (AB3C), a scientific association aimed at fostering research and collaboration. He explained to me that one of the ideas presiding AB3C's foundation was the establishment of relations of mutual support in Brazil, giving special attention to research groups based in Brazilian states with no tradition in bioinformatics. The concern has been kept throughout the years. As explained by a university lecturer I interviewed in Minas Gerais, there is partnership between the University of Minas Gerais and AB3C aiming at creating a multicentre post-graduate bioinformatics programme involving several states, so that expertise can flow from places with more research experience to states trying to catch up.

These concerns have also been present within the national state's agencies. According to Goujon (cited by Harvey & McMeekin, 2005), the network model, which Brazil imported from Europe, was aimed to both reduce financial costs and disseminate technologies and skills. "Here, at its origin, the model was seen as a competitive alternative to centralized 'big science'" (Harvey & McMeekin, 2005, p. 640). High degrees of centralization were verified, for instance, in the US and Japanese models.

The infrastructure required to conduct bioinformatics work *per se* is neither heavy nor too costly. Basically, bioinformaticians need computers, more or less specialized software (some of which they can design themselves) and data storage systems. As for these latter, costs have dropped, especially after the advent of the optical era. Some scientists are familiar with the so-called Butter's Law according to which "the cost of sending a bit of information over optical networks halves every 9 months" (Stein, 2010). Even when researchers work with last-generation sequencing devices, which generate floods of information, storage problems can be solved by recurring to cheap cloud computing systems (Jaeger et al., 2009; Schatz et al., 2010; Stein, 2010) or installing relatively cheap computer clusters. My fieldwork did confirm that storage has not been a major issue as Brazilian universities have provided researchers with sufficient storage support. Moreover, some research groups with small-scale work can have their needs easily met by means of tiny computer clusters made of two or three computers installed in their offices.

Things are less straightforward, and more controversial, in terms of access to and generation of data to be analyzed. There is no problem for some groups that have decided to work with free-access data available in international databases (Chang & Zhu, 2010). Nevertheless, many groups, especially when conducting more cutting-edge studies, need to generate new sequencing information. At this moment, a crucial question has to be answered: how can those researchers produce the new information needed? In other words: what are the sequencing devices to be used and (equally importantly) where are they?

If we come back to the historical periods previously defined, a shift can be identified. In the second period (1997-2006), the tendency was for sequencing devices to be concentrated in big Brazilian cities, especially the states' capital cities, and even more especially in the Southern part of the country. In the third period (2007-2014), this trend has been gradually reverted. Here the watershed was the creation, in 2007, of the Pro-Equipment (*Pró-Equipamentos*) program, launched by Capes, the funding agency attached to the Ministry of Education. The program's objective is to improve research infrastructure in all the Brazilian public universities having post-graduate courses.

As Pro-Equipment covers a vast range of scientific devices, infrastructure have been installed that may eventually benefit groups with bioinformatics lines. For example, the Federal Rural University of Semi-Arid (state of Rio Grande do Norte), thanks to the program, installed a computer cluster in 2003. The Federal University of Sao Carlos (state of Sao Paulo) obtained resources to install a new computer cluster in 2012. Some researchers disapprove these funding efforts, arguing that it would be better to concentrate computer capacity geographically. One of my interviewees, a renowned bioinformatician based in Minas Gerais, claimed:

> "[…] I think it could perhaps be interesting to have a national network whereby you have some specific access points for the scientific community, in a professional way, and not as amateurs like we see it today […]".

Pro-Equipment has led to an even more controversial phenomenon: the dispersion of DNA sequencing platforms. In 2010, the Federal University of Jequitinhonha and Mucuri Valleys (state of Minas Gerais) obtained resources to buy a sequencer. In the

following year, the Bioinformatics Program of the Federal University of Parana (state of Parana) obtained resources for the same purpose.

I say these initiatives are controversial because many Brazilian scientists do not agree that the national state should support the diffusion of DNA sequencing platforms. The interviewee quoted above put it as follows: "These platforms should be concentrated in some two or three places in Brazil so that researchers could have access to them in a swift way". The main argument is that most research groups have small-scale work, which does not justify the acquisition of last-generation sequencers capable of generating huge amounts of data. He estimates that 70% of sequencers installed in Brazil are actually turned off most of the time. Another interviewee, a university lecturer who is also based in Minas Gerais, is less pessimist, claiming that this percentage is of 50%. According to this type of thought (which expresses an economic rationale), Brazil is making ineffective investments by funding the purchase of equipments destined to lie idle.

This argument is to a considerable extent valid and worth taking into account. Indeed, some researchers, instead of sharing devices and sequencing facilities, have even preferred to keep their "own" device, in their "own" laboratory, thus being able to proudly possess a sequencing fetish. However, as it seems to me, the argument goes too far into economic considerations, concealing geo-political issues. Here, I would like to highlight two phenomena pointed out by two of my interviewees[2].

First, the diffusion of sequencing platforms has its importance in terms of teaching and academic formation. Some bioinformaticians claim that, in addition to analyzing data, it is important to have some contact with data generation, thus strengthening the researchers' expertise. If sequencing platforms are lacking, teaching and learning are thus curtailed. As explained by a lecturer based at the University of Pernambuco:

> "We've got [...] a problem in the fact that we're far away from centres where data are produced. If we think about the training factor, for example, we lose a bit

[2] Interestingly, both of these interviewees are based in Pernambuco, a state that is slowly acquiring the position of regional bioinformatics hub in the northern part of Brazil, thus offsetting the weight of the South.

of this dynamics. We cannot guarantee that students will understand all the steps necessary to generate NGS [next generation sequencing] data, for example".

Second, it can be said that underutilized devices are not the result of a group's modest workload but of a group's negligence or lack of planning. In Pernambuco, I interviewed the head of a bioinformatics group nested in a research institution that had recently acquired a last-generation sequencer. He outlined the timetable he had conceived in order for the device to be fully explored. After one year in the institution, it had sequenced over 50 genomes of bacteria, over 10 genomes of leishmania and over 10 genomes of plasmodia. Moreover, the group was about to open the platform for researchers based in other federal institutions and other Brazilian states to use it. By the way, since its first call for proposals, the funding agency responsible for the Pro-Equipment program stressed that one of its key goals was to "prioritize investments in goods to be shared and commonly used to develop research projects within one institution and/or by neighbour institutions".

Thus a middle way seems to be the best option here. On the one hand, the "big science" referred to by Harvey and Mckmeekin (2005, p. 640), whereby a handful of sequencing platforms are highly concentrated, does not seem viable. For many places would then be deprived of research dynamics and other privileges such as scientific status, teaching resources and contacts with foreign players. On the other hand, "small science", with one sequencing device per group, is not a reasonable solution either. For this would make Brazil's investments fall prey to some group's negligence or lack of planning. In a huge country like Brazil, setting up regional platforms dispersed across the territory is likely to prove more fruitful.

Last words

Over the last decades, many analysts have focused on the emergence of new science disciplines, highlighting their political, social and axiological implications. However, the geographical dimensions of these processes tend to be disregarded. In this

paper, we drew attention precisely to those dimensions, stressing the spatial consequences of the emergence of bioinformatics in Brazil.

Obviously, Brazilian bioinformatics had to appear in specific points of the national territory, defining an initial concentration of infrastructure and expertise. Due to its historical evolution, the Brazilian territory tends to consolidate concentrations, some states' and cities' dynamics possessing the capacity to slow down or even forestall the development of other places. Thus until the third historical period identified here (i.e. until around 2006), the southern part of Brazil had acquired such a massive relevance that projects undertaken in the northern part seemed destined to remain ancillary or even unviable.

Due to choices taken and policies implemented by the national state since the beginning of the 21st century, a shift was verified. The pace of growth in bioinformatics activities was not impressively accelerated and has even been somewhat reduced in the last four years. Thus one could feel tempted to conclude that no important change has been verified. The novelty, however, has not been purely quantitative (and expressed by numbers) but qualitative (and expressed by the territory via the formation and or consolidation of research groups in new places). In this way, diffusion rather than concentration has marked the recent bioinformatics development in the country, thus reverting long historical tendencies.

Therefore, it is not always sufficient to look at abstract figures in order to understand the processes in course in a country. Frequently, it is also pivotal to consider geographical processes and analyse spatial evolution. For in the understanding of a national situation, the geographical space is as revealing as scientific and political factors. Moreover, science and politics are frequently meaningless and ineffective without being realized through geographical phenomena.

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