WORKING PAPER 49

Globalization and the formation of biomedical markets: the example of bioinformatics in Brazil

Rising Powers Research

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May 2015

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Summary

This paper aims to analyze the situation of bioinformatics in Brazil. I adopt a narrow definition in which bioinformatics is seen as the usage of computational resources to handle large sets of information derived from molecular biology studies. The example of Brazilian bioinformatics is politically and sociologically interesting because of its recent constitution, allowing us to understand how different actors start exploring the field according to their projects and expectations.

It is claimed that we can identify a process of *academic marketization* (as I name the phenomenon). Four manifestations of this process are analyzed. First, academic research has played a major role in the definition of research areas to be explored, at the expense of private companies. Second, these academic choices have prioritized the area of human health studies at the expense of agrarian studies. Third, academic demands have expanded the importation of DNA sequencers devices to Brazil. Fourth, these demands have led Brazil to an increasing involvement in a new global market of DNA sequencing services. As a result, both the constitution of the domestic market and Brazil's engagement in global markets have depended on choices made by professionals accustomed to academic life. Hence the idea of academic marketization.

Even though this phenomenon brings about politically beneficial effects, the national state should play a bigger role in order to steer relations in the domestic market, speed up the internal pace of business formation, and improve Brazil's position in the global market.

Keywords: bioinformatics; Brazil; DNA sequencing; business formation; global markets

Bioinformatics and emergent markets

Continuing research efforts, along with reiterated investments, have led to the emergence of new scientific domains, as well as the possibility of delving into knowledge fields that could not be fully explored in the past. In life sciences, these shifts bring about hopes of cure for resistant diseases, the knowledge of life processes that had remained hidden or barely understood, the capacity to modify the basic genetic information, and so on. How do these changes, which happen at the global scale by means of international research protocols, affect the national state and its institutions? How can so-called developing countries, which are frequently at the margins of scientific advances, assimilate innovations and participate in the markets made possible by them? This paper explores these questions by highlighting a relatively new scientific domain (bioinformatics) and the situation of Brazil.

Bioinformatics can be described as the usage of computational resources in order to handle biological information (Chow and Fernandez, 2003, Gopalan, 2009), thus belonging to the process of "computerization of biology" (Suárez-Díaz, 2010, p. 76 note 10). In this paper, however, I use a narrower definition according to which bioinformatics derives from the needs of molecular biology, in which the study of DNA sequences and protein structures produces huge amounts of data whose proper and quick analysis requires computational tools. Thus bioinformatics' tasks include genome sequence analysis, studies on protein structure and function, cell modelling, comprehension of the relation between genes and diseases, construction of databases, and so on (Bayat, 2002, Howard, 2000, Chang and Zhu, 2010, Conselho de Informações sobre Biotecnologia, 2004). Therefore, the discipline became particularly crucial after the launching of international genome projects, mainly the Human Genome Project, in which the torrential volume of genetic information would have taken many decades to be analyzed without the mobilization of computational resources (Araújo et al., 2008).

Nowadays the relevance of bioinformatics is indisputable. Multinational pharma companies have either hired specialized bioinformatics companies (Chow and Fernandez, 2003) or internalized the knowledge field to speed up drug discovery (Bayat, 2002); bioinformatics patents have been filed (Chow and Fernandez, 2003); the demand for

bioinformaticians has risen globally, allowing us to identify a dearth of professionals in some countries (Dal Poz, 2000); bioinformatics projects have been funded by various institutions, including those such as the Bill Gates Foundation (Faulkner, 2013); and in 2013 a World Health Organization working group concluded that bioinformatics should be "[…] considered a top priority, in light of opportunities this new field provides for disease-endemic country researchers and institutions" (Faulkner, 2013, p. 12).

The emergence of the field is relatively recent, especially in countries like Brazil. By the way, this is one of the major reasons leading me to look at the Brazilian case: I am interested in the constitution of a life science research field, as well as the ways in which different social actors and political institutions engage in the markets derived from it. Whereas bioinformatics started to be constituted in the mid-1960s (Hagen, 2000, Suárez-Díaz, 2010), in Brazil it "[…] was utilized in a systematic way for the first time in 1997 […]" (Conselho de Informações sobre Biotecnologia, 2004, p. 4). Hence we are dealing with an activity less than twenty years old. Therefore, studying Brazilian bioinformatics allows us to surprise a scientific domain in its initial phase in which institutions assimilate it, social actors start exploring it, financial funds begin to be allocated towards it, and society gets accustomed to its deeds.

Much is known about the constitution of scientific fields in so-called developed countries, which usually pioneer them. However, there is much to be known about this constitution process in so-called developing countries, especially in the current phase of globalization when science breakthroughs usually entail the formation of new capitalist markets. Does a research field appear in these countries by means of particular processes that somehow challenge our understanding of science advancement and economic relations? Do these countries simply need to catch up with advanced countries or can they somehow seek particular science pathways?

Brazil represents a good example, because as part of the BRICS group (Brazil, Russia, India, China and South Africa), it is frequently point to as one of the most promising economies in the world. The country has played a relevant global role in biology and medical domains such as medical tourism (Edmonds, 2011), plastic surgery (Edmonds, 2009) and clinical trials (Petryna, 2009, Bicudo, 2014). By studying the emergence of Brazilian bioinformatics, it is possible to scrutinize the ways in which universities institutionalize a research field and companies begin to explore it, but also

these players' attitude towards global trends. It will be argued that Brazil constitutes an extreme example of *academic marketization* (as I name the process) in which the country's engagement in global markets, as well as the formation of its domestic market, depends, to a large extent, on solutions conceived or even improvised by academic researchers.

This study was carried out as part of a 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). In addition to the texts and documents consulted, I draw on information from fieldwork carried out in Brazil from November 2014 to May 2015. I conducted 14 interviews with professionals involved with bioinformatics, 9 of whom were lecturers based in academic departments and 5 were representatives of genetic or bioinformatics companies[1]. The research project was approved by the ethics committee of King's College London.

Our analysis is organized in two parts. In the first part, the national scale will be focused on. We shall highlight the difficult formation of a domestic market due to historical changes facilitated by the national government. The constitution of a Brazilian genetic market has become increasingly dependent on choices taken within universities. As a result, the area of human health gradually overshadowed studies on plant genomics. This trend signalizes the construction of a large genetic market but business potentialities have been attenuated by economic and geographical processes. In the second part, we shall focus on global processes. It will be stressed that the role played by Brazil in the global genetic market has also been shaped by strategies and choices derived from universities. On the one hand, the country has become more and more dependent on DNA sequencing technologies it does not master. On the other, some actors have learnt to use global sequencing services that defy the current steering capacities of state institutions.

[1] My interviews involved five cities: 3 were conducted in Sao Paulo (SP), 3 in Campinas (SP), 4 en Belo Horizonte (MG) and 4 in Recife (PE). These were semi-structured interviews with open questions. All interviews but one were recorded with permission from the interviewee.

First part – The slow formation of a national market

Even though bioinformatics deserves to be treated as a specific knowledge field, it is very frequently exercised as part of genomics projects. Especially within the narrow approach adopted in this paper, it is quite hard to disentangle three overlapped fields. First, there is DNA sequencing, which amounts to the use of devices called sequencers, responsible for a torrential production of four letters (A, C, G and T) with which the basic life code is represented. Second, there is bioinformatics, which by means of computational resources, organizes this information into biologically meaningful data groups. Third, there is genomics, the discipline that interprets these data groups and eventually adds something to the human knowledge of life.

In private companies, the genomics field is frequently lacking, as they are generally interested in solving practical issues[2]. To be sure, Brazil has already a couple of huge national companies exploring bioinformatics, as is the case of its company for agriculture research (Embrapa). Its multinational public/private mining company (Vale do Rio Doce) is also becoming increasingly interested in the knowledge field. However, in terms of middle and small companies, much remains to be done in order for an actual Brazilian genetic market to emerge. Even the country's economic hub, the city of Sao Paulo, holds only a handful of companies exploring those fields.

Actually, there are two types of small genetic companies in Brazil. First, some of them deal with agriculture and livestock, aiming at improving agriculture productivity, fighting animal and plant diseases, and so on. Second, some companies work with human health, generally receiving patients with rare genetic diseases, dealing with reproductive problems or conducting paternity tests. This second group of companies is the one which interests us in this paper. For the most part, these are very small companies with less than ten employees. People working for them seem to be unaware of their market counterparts and, as my fieldwork revealed, often claim to be the only ones offering genetic services in Brazil.

Over the last years, those companies have thriven in spite of the persistently small size of the market. In this first part, we analyze some reasons dictating such a market

[2] In this paper, the word "genetic" refers to the association between DNA sequencing and bioinformatics, without the genomic field.

configuration. This is not an effort of market analysis. My intention is to understand the current social and political configuration of Brazil through its emerging genetic market. It is worth remembering the old Polanyi's (1944) teaching: as markets are always embedded in social processes, it is possible to study societies by scrutinizing the ways in which certain markets emerge, develop or fade away. This is our purpose in this first part: we shall look at the modest Brazilian genetic market in order to understand how different social actors, including bioinformaticians and the national state, try to grasp the opportunities brought about by new technologies and business relations.

One of the reasons why there are only a few companies in Brazil will be explained in the second part: due to the high price of DNA sequencing devices, it is difficult to build up sequencing platforms in the country. However, there we shall also stress some new possibilities of accessing cheap sequencing services. Thus more convincing explanations should be sought. For so doing, we shall analyze, in the following two sections, two processes that, in their occurrence, are very much intertwined.

1.1. From business promise to academic reality

We can identify two big moments in the history of Brazilian bioinformatics. At a first moment (which lasted roughly nine years, from 1997 to 2006), the field emerged in the state of Sao Paulo by means of genome projects conducted by university networks. The first enterprise, named *Xylella* project, was aimed to sequence the genome of a bacteria that was killing orange crops in Sao Paulo, causing huge losses for producers and industries. Involving 35 laboratories of five universities and one federal research institute, the project was funded by Fapesp (Sao Paulo funding agency) and also by Fundecitrus, a private association of orange cultivators and companies of the juice industry. The project began in 1997 and was successfully completed in 2000 (Castro, 2009, ComCiência, 2003, Conselho de Informações sobre Biotecnologia, 2004, Dal Poz, 2000, Harvey and McMeekin, 2005).

An important feature of Brazilian bioinformatics at this initial phase was the effort made by funding agencies to attract private investment toward genome projects in order to make them not only big but also commercially promising. For example, Fapesp

invested 15 million Brazilian *Reais* in the *Xylella* project whereas 400 million *Reais* came from private companies (Dal Poz, 2000). Additional private funding was also present in another Fapesp project aimed at sequencing sugar cane (Harvey and McMeekin, 2005, Simpson and Perez, 1998), as well as in a project of national scope aimed at sequencing an eucalyptus pathogen (Dias, 2006).

Companies participated in the design of genome projects, sometimes playing a pivotal role like in the Fapesp Cancer Genome project, which had a decisive participation of A.C. Camargo, a Sao Paulo private hospital (Simpson and Perez, 1998). One side effect of this initial development was geographical concentration of major genome projects in the Southern part of Brazil (mainly the state of Sao Paulo) where the biggest companies are located. Another side effect was concentration of academic expertise in a few universities. For example, when a genome project was launched to constitute a university network in the state of Bahia (from 2000 to 2005), project coordination had to be accorded to University of Campinas (state of Sao Paulo) because of its previously acquired expertise (Dias, 2006).

Deriving from the genome projects of this initial phase, three companies were created in the city of Campinas: Alellyx, Canavialis and Scylla. This last company, specialized in bioinformatics, was founded by researchers who were based at University of Campinas, had worked in the *Xylella* project, and were bioinformatics pioneers in Brazil (Castro, 2009, Conselho de Informações sobre Biotecnologia, 2004, Folha de São Paulo, 2002). Still operating today, Scylla develops software for companies that need to handle large sets of information deriving from genomics projects.

Brazilian bioinformatics began to follow new pathways in 2007-2010, as a consequence of policies adopted by the new federal government. In an effort of geographical diffusion, the government supported projects in several parts of the territory, including the constitution of small DNA sequencing platforms. A pivotal role has then been played by two federal funding agencies: CNPq (attached to the Ministry of Science and Technology) and Capes (attached to the Ministry of Education). This funding tactics was coupled with the creation of federal universities, especially in cities lacking higher education institutions. As a consequence, the Brazilian bioinformatics scenario acquired, even more than before, an academic dynamics, as the big genome projects

with additional private funding became less frequent even in the state of Sao Paulo, whose funding agency now prefers to support research via scholarships.

Nowadays, bioinformaticians recently formed have quite scant market opportunities to position themselves. For instance, in 2014 the bioinformatics program of Federal University of Minas Gerais tracked 38 researchers who concluded their PhDs there from 2006 to 2013. Of those people, 27 were working in federal institutions (universities and research centres); only 7 had been hired by private companies; and 4 were engaged in other types of work.

Thus the majority of high-skilled Brazilian bionformaticians have state institutions, and mainly universities, as both their origins and their work destination. Nevertheless, it is on them that depends, to a large extent, the creation of new genetic companies. Of the five companies I visited, three resulted from the initiative of physicians whereas two were created by university lecturers. The fact that the Brazilian market is considerably shaped by professionals deeply accustomed to academic life is one expression of what I name *academic marketization.* Its consequence has been the modest pace of business formation in Brazil.

Here, institutional and even cultural characteristics operate. Launching private initiatives is regarded, by most Brazilian academics, as the utmost adventure. They tend to consider the market as an environment depriving people of the work stability enjoyed within universities, and work stability is one of the pillars of the "Brazilian dream". As pointed out by a lecturer and owner of a company I interviewed, "Brazilian scientists still seem to prefer the academic environment to anything else".

Had it consolidated the features of its initial development (1997-2006), Brazilian bioinformatics would probably have acquired more pronounced business features. As big companies, including foreign ones, were investing in genome projects, some Brazilian companies would probably have captured those opportunities to build up big sequencing and bioinformatics platforms. A national infrastructure and expertise would have been established in this way. However, such political trajectory could have led to fragile outcomes. Arguably, some strong Brazilian genetic companies could have been created which would subsequently have been absorbed by the foreign capital. If we look at the history of pharmaceuticals in Brazil, there are many examples of absorption of Brazilian companies by huge multinational corporations (Bicudo, 2009, Paula, 1991, Pereira, 2002),

leading some analysts to speak of denationalization of pharmaceutical production (Cordeiro, 1980, Giovanni, 1930, Gadelha, 1990). Genetic companies could have retaken this economic path. By the way, of the three companies resulting from the genomics *Xylella* project, two (Allelyx and Canavialis) were indeed acquired by American Monsanto in 2008.

What is certain is that, with the new features acquired by genomics and bioinformatics in 2007-2010, activities became more widespread geographically, losing part of their initial concentration in the Southern part of the country. However, as seen in this section, business formation has been slowed down, as it has depended on the initiative of academic researchers unused to, or even suspicious of, market dynamics. In the following section, we shall see that Brazilian bioinformatics knew another kind of historical change.

1.2. From plant research to human health research

In the first years of the 21st century, the basic features of Brazilian genomics-bionformatics had been sketched. One of these features was the tendency to focus on issues pertaining to agribusiness, an economic sector that, for many decades, has been one of the most profitable sectors in the Brazilian economy. For example, the *Xylella* project, which dealt with a pathogen attacking orange trees, was conducted when the citrus sector was the second source of income for Sao Paulo agribusiness and Brazil was responsible for 80% of the world production of orange juice. Subsequently, similar projects were initiated focusing on other agricultural pathogens, even when they were completely funded by federal institutions, such as the one in which a cacao pathogen was sequenced (Dias, 2006, Freire, 2014). In 2000, of all genome projects in course in Brazil, the majority focused on agrarian sciences (Dal Poz, 2006).

It is not surprising that a country's genomics-bioinformatics history begins with agrarian studies, because the genome of plants and plant pathogens are smaller, easier and cheaper to be sequenced (Dávila et al., 2004). However, agribusiness interests also played a pivotal role at this initial period when genetic sequencing promised to harness crops and increase profits. As claimed by Dal Poz (2000, p. 41), the *Xylella* project was

also an effort to "[…] bring the scientific frontiers close to the commercial ones, as well as to the purpose of keeping the Brazilian citrus sector in its world leading position".

Various genomics and bioinformatics studies carried out at this historical phase had then an "association with the principal sectors of Brazilian agriculture" (Harvey and McMeekin, 2005, p. 649). Thus bioinformatics was slowly turning into an instrument at the disposal of a specific (and tendentially exclusive) economic project. This was possible because, at times, what was claimed by Mackenzie (2003, p. 317) holds true: "[…] bioinformatic research techniques are intensively figured as a new way to produce biological knowledge and generate economic value for some people (and not others)".

As explained before, there was a historical shift in 2007-2010, when new federal initiatives facilitated the diffusion of research projects across the national territory. In this way, Brazilian bioinformatics experienced a significant change of emphasis. Gradually, agrarian genomics, which had so far been the main research area, became overshadowed by studies on human health. The following table depicts the outcome of the process initiated around 2007.

Table 1 – Bioinformatics research in Brazilian universities:
number of research groups and researchers in the main research areas – December 2014

Research area	Research groups	%	Researchers	%
Basic	72	51.4	239	48.8
Animal	5	3.6	10	2.0
Plant	15	10.7	59	12.0
Human	48	34.3	182	37.1
TOTAL	140	100.0	490	100.0

source: research on CNPq's Directory for Research Groups in Brazil (http://lattes.cnpq.br/web/dgp)

Not surprisingly, most groups and researchers work in the basic area, which consists of developing software and algorithms to be applied in other knowledge fields and other bioinformatics research areas. Considering these other, more "applied" areas, Table 1 clearly shows the current relevance of bioinformatics studies on human health. Even if we take animal and plant studies together, they do not surpass the number of

both research groups and researchers dealing with human health[3]. So how could this change occur?

The geographical diffusion facilitated by the national state was not accompanied by the definition of priority research areas. In this way, researchers took the new funding and infrastructure resources as an opportunity to study diseases of regional or national occurrence which had not yet been the object of genomics analysis. They would then be pioneering some studies, in addition to being morally rewarded by the hopes of contributing to the solution of domestic health problems. In fact, many today's bioinformatics groups focus on so-called neglected conditions such as malaria and Chagas disease.

Therefore, the Brazilian bioinformatics scenario tends to be crowded by professionals with expertise in human health studies. This characteristic could certainly trigger a business trend whereby some genetic companies would be created in order to offer specialized services. The moment seems to be adequate, as income inequalities have been reduced. From 2001 to 2011, the richest groups' income increased 16% whereas the poorest groups' income expanded 91% (IPEA, 2012). Some genetic companies have been created, over the last decade, as a result of this new economic dynamics and the enlargement of the middle classes.

Nevertheless, companies have still been formed at a rather slow rate because of two main factors. On the one hand, genetic services are still too expensive considering the income level of most Brazilians. For example, in a Sao Paulo company I visited, a genetic test never costs less than 6 thousand Brazilian *Reais* while almost 60% of the Brazilian population has a monthly income of 788 *Reais* or less[4]. On the other hand, companies have been scarcely created due to an important geographical factor. In Brazil, economic markets tend to draw on regional dynamics, as is the case, for instance, of the pharmaceutical market (Bicudo, 2009). So far, this regional segmentation cannot be noticed in the genetic market. The rare companies operating in the country are actually engaged in a sole, national competition. All the companies I visited but one (in Recife) have their wealthy clients distributed across the territory, taking advantage of the fact

[3] The modest figures in the animal research area is arguably due to the concentration of this type of study at Embrapa, the federal company for agrarian and farming studies.
[4] It is worth noting that genetic tests are excluded from the public health service. Nor are they covered by private health insurance schemes.

that genetic samples (usually blood or saliva) do not require special transport conditions and can be simply sent via normal post.

To summarize, Brazilian bioinformatics has experienced a major change through which its initial preferred research area has lost space. This could occur because of a process of *academic marketisation* whereby private companies have played a decreasing role in the definition of research priorities whereas academic researchers have used current opportunities to change the emphasis of bioinformatics, preferring to pioneer studies on human health and, potentially, help tackle Brazil's health needs. This shift can eventually lead to the formation of a scientific workforce capable to offer genetic services. However, business formation has been hampered by some persistent economic and geographical factors.

In this first part, we analyzed the modest Brazilian market, pointing to the process of *academic marketisation.* The second part aims to show that this process is in course not only at the national scale but also when we consider the position of Brazil in the global genetic market.

Second part – Bioinformatics and global DNA sequencing markets

In the first part, it was explained that bioinformatics is by definition dependent on data input. Across the world, many bioinformatics research groups have used some free-access biological databases whose constitution is generally the outcome of international projects (Chang and Zhu, 2010). Nevertheless, some biological questions demand the generation of totally new information. Researchers are then challenged by a need for data generation which threatens to stall their activities.

There are two ways to solve the problem. First, researchers may somehow have access to the needed DNA sequencers. Second, they can hire sequencing services through which their target genomes will be sequenced in institutions or companies they are not based in. In both cases, it is necessary to engage in markets that have already gained a global reach.

Many analysts have failed to give enough attention to recent international market relations entailed by the need for DNA sequencing. Such an analysis is nevertheless

paramount, especially for countries like Brazil where a great proportion of research demands cannot be satisfied by relying exclusively on domestic technologies and expertise. In the following two sections, we analyze the ways in which Brazil has positioned itself into two global DNA sequencing markets of relatively recent formation. Like we did in the first part, this is not an exercise of market analysis. My purpose is to comprehend current trends in Brazilian social and political life by looking at the ways in which different Brazilian actors participate, either directly or indirectly, in global genetic markets.

2.1. Sequencing devices and the myth of decreasing costs

The first DNA sequencing devices, obviously quite rudimentary, were developed in the 1960s and improved in the 1970s (Suárez-Díaz, 2010). In the beginning of the 1990s, it was already possible to sequence DNA around 1,000 times faster than in the end of the 1970s (Hood, 1990). This was also when the development of DNA sequencers, until then a scientific enterprise, started being fully explored by private companies. Rapidly, investments in sequencing development became more and more productive. By 2003, the costs entailed by DNA sequencing were halving every five months (Stein, 2010).

However, there is no need to echo here the ecstatic discourse of some analysts marvelled at the advancement of sequencing technologies. What needs to be pointed out is that these technologies opened up much leeway for the emergence of global markets.

> One of the key features of the revolution in biological science has undoubtedly been the emergence of markets for knowledge [...] For biology, this was most evident as soon as data contained in biodatabases became a separate and novel form of biological knowledge, partly as a consequence of new technologies of data production, such as high-throughput sequencing (Harvey and McMeekin, 2010, p. 487-488).

Nowadays every new round of investment in DNA sequencing leads to greater sequencing capacity. Nevertheless, if investments have become thus productive, they also need to be very big. In other words, in order to buy these new generation devices, initial investment is now too heavy for some institutions to bear it, especially in non-central countries. As a renowned researcher based in a Sao Paulo university explained to me:

> "There is no [...] Brazilian company producing sequencers. That would be crazy [...] Because sequencing technology is advancing in a dazzling rhythm. So the capital you would need to build up a company capable of competing would be... This capital doesn't exist here in Brazil [...] Neither in Brazil nor in 99% of countries [...]".

This is not to say that Brazil occupies a backward position in the global genomics-bioinformatics scenario. It is still possible to affirm what Dávila, Steindel and Grisard (2004, p. 44) stated in 2004: Brazil is placed "[...] in the forefront of genomics and bioinformatics research in the South American region". Moreover, Brazilian scientists have come to important achievements at the global scale as well. For example, the first world's sequencing of a plant pathogen was the outcome of the *Xylella* project (Dávila et al., 2004, Harvey and McMeekin, 2005). In 2000, the project deserved publication in the cover page of *Nature* (Dal Poz, 2000, Harvey and McMeekin, 2005). As a result, Brazilian bioinformaticians received invitations to collaborate with the United States Department of Agriculture, the American Vineyard Association, the University of Washington, among other institutions (Harvey and McMeekin, 2005). Across the decades, Brazilian researchers have had other high impact publications, such as the ones by a research group based at University of Campinas in the prestigious journals *New phytologist* (in 2012) and *The plant cell* (2014).

On the one hand, Brazilian researchers need to keep carrying out high quality studies and maintain their international partnerships. On the other hand, this necessity frequently asks for access to cutting-edge DNA sequencers that are not produced domestically. As Brazilian funding agencies have become more willing to fund the acquisition of sequencers, the purchase and selling of these devices have thriven.

Two American companies struggle to dominate the expanding Brazilian market. One of them is Thermo Fisher, which has operated in the country since the beginning of the 21st century (first as Applied Biosciences and then as Life Technologies). The other company is Illumina, which controls 60% of the world market and installed an office in Sao Paulo in 2011.

The recent arrival of Illumina at Brazil signalizes the favourable state of its market, as scientists' demands trigger the importation of last generation sequencing devices. For example, I visited a Recife bioinformatics group which by means of Capes (the funding agency attached to the Ministry of Education), acquired an Illumina sequencer that was lacking in the whole North-eastern region of Brazil. In this way, new lines of study were opened up at the institution. Moreover, the device will also be available to other public institutions and universities willing to use it.

In Sao Paulo, I visited a company offering genetic counselling and diagnostics services. It is a modern laboratory possessing a vast range of last generation sequencers, a very rare assemblage of devices in Brazil. The company owner claimed that it is often difficult to negotiate with multinational companies selling sequencers.

> "They import and deliver them to you here. But as I told you, for them the dollar… They multiply the dollar's exchange rate by three at least, not to speak of taxes and other associated things […] Of course, trivial devices, you get to have them quite easily, but these rarer things, it is indeed very difficult […]".

As a result, there appears a spontaneous chain of commercial and academic relations whereby those which possess sequencers sell sequencing services to those which do not, or simply provide these services for free. In Belo Horizonte, for example, I visited a bioinformatics group of a federal institution that does not hold last generation devices. In order to conduct more sophisticated studies, the group has decided to buy sequencing services from a Brazilian private company. At times, sequencers can also be accessed without payment, as is the case of a genetic company I visited in Sao Paulo. Research partnerships can be established between the company and a university, so that researchers use the company's devices during their projects. In this case, the researcher may work with a scholarship from a funding agency. For the company, the arrangement

is interesting because on completion of the project, a genetic test may be developed which will subsequently be sold as part of its portfolio.

So far, there have been no systematic attempts by the Brazilian state in order to steer or foster these market-university relationships. Thus the academic researchers themselves (who sometimes are also entrepreneurs) frequently create and improvise arrangements. (For instance, a lecturer-entrepreneur may use, in his or her genetic company, bioinformatics software developed in his or her university laboratory, after its publication as free online resource.) The existence of such creative solutions is another reason why I speak of *academic marketization.*

However, it is worth considering that access to sequencing devices is not the only aspect to be considered. There are at least five other aspects. First, there must be technical personnel who will operate the sequencers. Second, there must be adequate rooms and installations in order for these devices to work properly. Third, investment must be economically justifiable; in other words, the research group must have a significant amount of studies running so as to avoid moments at which sequencers are turned off. Fourth, last generation sequencers have high capacity of generating data but for so doing, they need to function with expensive chemical reagents; if simpler types of reagents are used, their throughput is reduced significantly. Five, samples to be sequenced can be prepared either manually or by using some other expensive devices; manually, sample preparation may take up to one day and half whereas it can take only 30 minutes when scientists use preparation devices.

Considering all these five aspects, it is quite easy to perceive the need for tempering the excited discourses about the miracles of sequencing technologies. It may be true that "The cost of genome sequencing is now decreasing several times faster than the cost of [data] storage [...]" (Stein, 2010, p. 2). However, this reduction seems to be more probable for institutions where all the needed resources (laboratories, technical personnel, storage systems, devices and reagents) are already in place and working than for those which strive to establish their basic infrastructure, as is the case of many institutions in countries like Brazil. In other words, if the costs of DNA sequencing have dropped, the reduction is faster and more significant in some institutions and countries than others.

Milton Santos (2000) is then right to claim that every technological advancement has particular impacts depending on the national context. In Brazil, some choices made by the national state have led to significant changes, but they still lack coherence to be considered as an actual national policy. As a result, researchers' capacity to identify market opportunities and even legal loopholes has been responsible for involving Brazil in the global sequencing market. Over the last decade, the importation of sequencers has depended, to a considerable extent, on academic researchers who respond to calls for proposals as a way to voice their need for devices to be used in either personal projects or research collaborations. Thus the process of *academic marketization* expresses itself at the global scale. Hopefully, this process will become more evident in the following section, in which we shall consider a sequencing market of recent constitution.

2.2. Global sequencing services and the hidden flows of genetic samples

Instead of buying new devices, universities and companies may prefer to hire sequencing services located abroad. Although all-important and full of implications, this phenomenon has been unnoticed by analysts. As I have just claimed, the costs of DNA sequencing have dropped less in Brazil than in some other countries, even when the very same sequencer is utilized. Thus Brazilian researchers may feel tempted to hire the cheap sequencing services of some foreign players. For example, in a Belo Horizonte genetic company I visited, last generation sequencers are lacking. When more sophisticated tests are in need, a Canadian company, which works with a large scale of service and is completely updated in terms of technology, is hired.

Interestingly, the practice has become usual also in universities. In Belo Horizonte, I interviewed a researcher who had previously been a university lecturer in Brasilia, the country's capital city. Even though the university possessed a modern sequencing platform, he frequently hired foreign services.

> "Sometimes I sent samples abroad instead of doing it next to my office, because this is cheaper [...] Frequently, if I had to do many sequencing runs with the device I had, that would be more expensive than doing it with a company or sending it abroad".

The United States, Germany, France and the UK hold some of these global sequencing companies. Over the last ten years, though, a few Asian companies have managed to capture a big proportion of the Brazilian market because of their small prices. In my fieldwork, interviewees cited particularly the Beijing Genomics Institute (a Chinese private/public institution) and Macrogen (a Korean company). Recurring to these players is relatively simple because, as explained before, genetic samples do not require special transport conditions. Often, they are sent via normal post, results can be received via email and payments are made with credit cards. Researchers have learnt to reserve some funds for this type of service in the budget of their academic projects. In this unexpected way, they have included a new type of need into the list of global demands of Brazil. This is another expression of *academic marketization.*

Some interviewees disapprove the practice, like the owner of a Sao Paulo genetic company, for whom the Brazilian government should regulate the field more clearly and control this new market. "Those companies are coming along, offering tests, taking dollars abroad [...] So you're taking money abroad without paying taxes [...]". Indeed, the practice happens because companies and researchers have found an economic and regulatory loophole to operate. For most of my interviewees, though, the phenomenon does not seem to pose problems. As bioinformaticians, they see DNA sequencing as a menial job that only prepares the ground for the real intellectual work (bioinformatics) to happen. For example, a Belo Horizonte university lecturer told me:

> "[...] they do the sequencing and give it to me. But in genome analysis, 95% of the work is the analysis itself. You need to have the sequence, but the most important thing, the part where you do your particular job, is intellectual [...], which is bioinformatics and is what I do."

Most of my interviewees would agree with this statement. However, from a socio-political standpoint, the process is rather problematic. As explained by a geneticist I interviewed in Sao Paulo, researchers sometimes lack the knowledge to properly interpret the overwhelming amounts of data regurgitated by new generation devices. Bioinformatics is sometimes described as an outcome of the so-called "big data" problem[5]. It is important to consider that data is generated which may end up proving obscure or futile. Moreover, data may be produced as a side effect of a device production that, at the end of the day, is only reflecting science fashions. These are the dangers in the process of *academic marketization* through which Brazil, whose national state is still considerably blind to the new global phenomena described here, ends up having its market insertion defined, to a large extent, by the academic needs of some groups that, although guided by sound scientific purposes, fail to consider all the political implications of their choices. Thus the academic definition of the Brazilian participation in the global market threatens to become a market definition of the Brazilian academic landscape.

At the same time, the lack of powerful sequencing platforms in Brazil reinforces old global scientific hierarchies. To be sure, the simple generation of data through the use of sequencing devices is not a highly advanced scientific activity. However, the capacity to develop sequencers (which is lacking is Brazil) does express the existence of a sophisticated scientific know-how. In order to produce and improve a sequencing device, it is necessary to gather excellent researchers from different fields such as engineering, chemistry, biology and so on. When Brazil relinquishes the production of sequencers and uses them as mere service, it is in fact giving up a strategic dimension of the global genomics work. Differently said: "When Brazil invests in Genome Projects and deposits data in those banks [free global data banks] without completing, at the national scale, all the generation and appropriation cycle pertaining to GABs [genomic agrobiotechnologies], it may be creating a new type of technological dependence [...]" (Dal Poz, 2006, p. 283).

[5] On its website, a German genetic company describes itself as follows: "Centogene is one of the leading laboratories focusing on genetic testing for rare hereditary disorders. We now offer more than 2200 routine genetic and biochemical tests".

Last words

In this paper I analyzed four expressions of academic marketization in Brazil. First, a political shift has diminished the relative role played by companies in the Brazilian genomics-bioinformatics scene, enhancing the role played by academic researchers and consequently slowing down the pace of business formation. Second, due to academic choices, the area of human health research has gained weight at the expense of agrarian studies. Third, academic needs have enhanced the role of Brazil as importer of sequencing devices. Fourth, these very same needs have also expanded the Brazilian participation in the market of sequencing services, augmenting the global flows of genetic samples.

Since the 1990s, analysts say, globalization has assumed a more flexible structure. Thus markets have emerged whose future configuration is frequently unclear. This fluid nature of globalization asks for new modes of government whereby the state fulfils regulatory and financing functions, transferring responsibilities to private companies, instead of playing a stringent role as direct manager and decision maker. Analysts have identified the emergence of this *adaptive state* not only for Asia (Kim, 1999, Salter, 2009, Wu, 2004) but also for Latin America (Eakin and Lemos, 2006).

Nevertheless, the model of adaptive state seems to be scarcely applicable when we look at the Brazilian bioinformatics example. For instead of enlarging the responsibilities of private players, the state has transferred decisive choices to the academic domain. In addition, it continues to be rather oblivious to trends and relations that are shaping the bioinformatics scenario both domestically and globally. For example, there have been no regulations devoted to the sequencing agreements taking place in Brazil. Nor there appears to be any knowledge of the relations between academic researchers and global companies offering sequencing services. In face of these regulatory voids, companies but especially researchers continue to improvise and shape the genomics-bioinformatics landscape in an indirect manner.

This process of academic marketization brings about good social and political tendencies. For example, as we have seen, researchers have been attentive to Brazil's health needs, which have inspired many research projects. Eventually, a scientific model could emerge in which national demands, instead of global ones, would conduct the Brazilian genomics-bioinformatics development. However, academic marketization also brings about some dangers. For example, scientists may fall prey to market strategies and be lured into acquiring devices of powerful data throughput but minimal scientific import.

As claimed by Salter and Faulkner (2011, p. 9): "The fluid patchwork of regulation interacts with the negotiation of technological zones, driven by various interests and actors". The Brazilian state needs to become more aware of the technological zones, interests and actors present in the bioinformatics scenario. Academic marketization does constitute a politically beneficial (and potentially democratic) process but it is not sufficient. The state's participation in the process also needs to be enhanced. At the national scale, this would generate initiatives speeding up business formation and regulating the manifold relations between different actors. At the global scale, it would lead to policies improving the fragile country's position in genetic and sequencing markets. In this way, Brazil could turn (and nowadays it seems to be the only country capable to turn) into a model of good balance between global relevance and national justice.

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