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WINDOWS OF OPPORTUNITIES AND KNOWLEDGE NETWORKS: IMPLICATIONS FOR THE CATCH-UP IN DEVELOPING COUNTRIES

TESE APRESENTADA À ESCOLA BRASILEIRA DE ADMINISTRAÇÃO PÚBLICA E DE EMPRESAS PARA OBTENÇÃO DO GRAU DE *DOUTOR*

MARNE SANTOS DE MELO
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WINDOWS OF OPPORTUNITIES AND KNOWLEDGE NETWORKS: IMPLICATIONS FOR THE CATCH-UP IN DEVELOPING COUNTRIES

Thesis submitted to the Brazilian School of Public and Business Administration (EBAPE) of the Getulio Vargas Foundation (FGV) as partial requirement for the title of PhD in Administration.

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MARNE SANTOS DE MELO

"WINDOWS OF OPPORTUNITIES AND KNOWLEDGE NETWORKS: IMPLICATIONS FOR THE CATCH-UP IN DEVELOPING COUNTRIES"

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To my dear son Vítor, by being the greatest incentive to my search for becoming a person better every time, I dedicate this thesis.

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“As soon as we are shown something old in the new, we are calmed”.

Friedrich Nietzsche

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OVERALL PRESENTATION

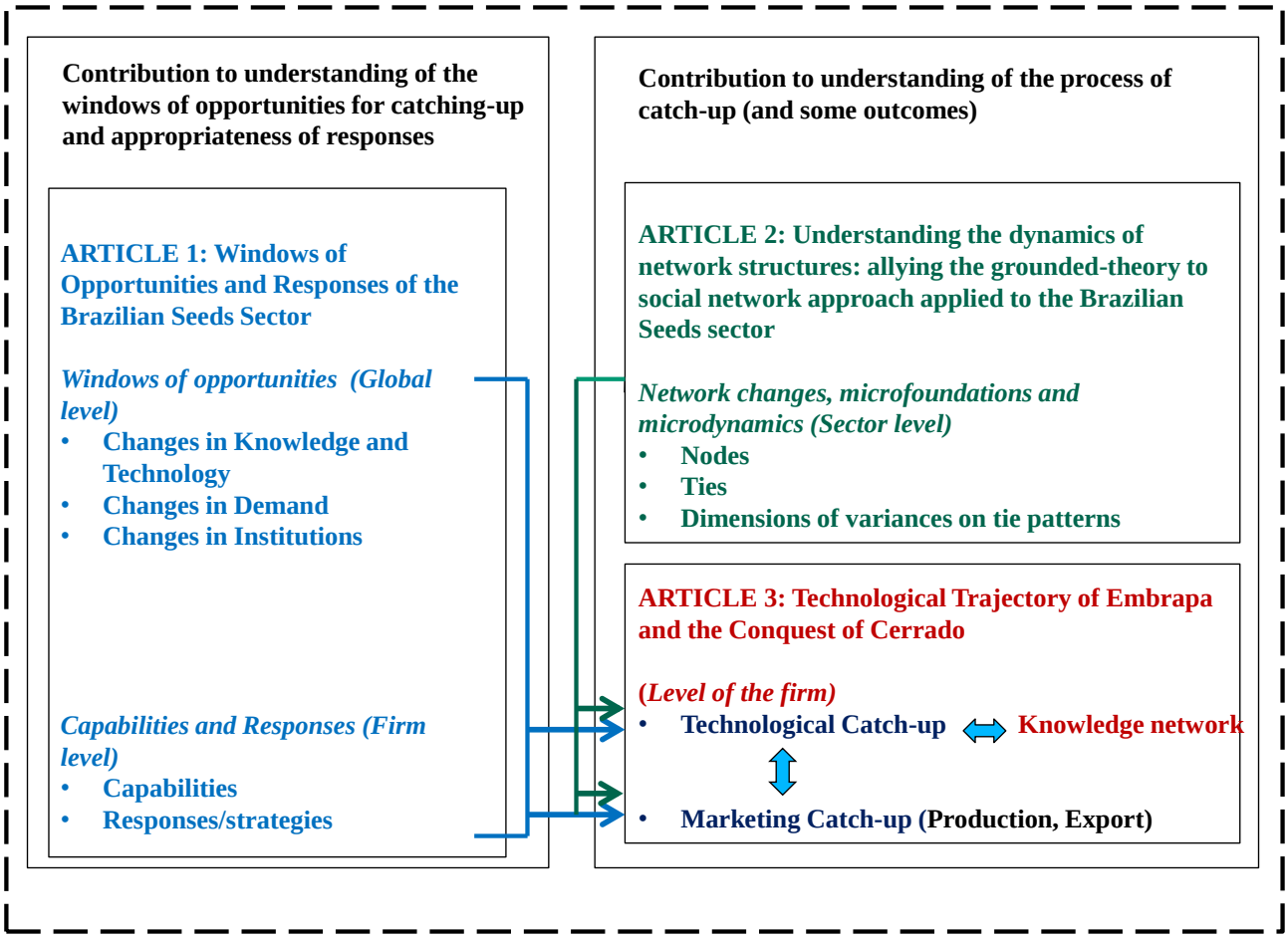
This document represents a doctoral thesis held under the Brazilian School of Public and Business Administration of Getulio Vargas Foundation (EBAPE/FGV), developed through the elaboration of three articles. The research that resulted in the articles is within the scope of the project entitled "Windows of opportunities and knowledge networks: implications for catch-up in developing countries", funded by Support Programme for Research and Academic Production of Faculty (ProPesquisa) of Brazilian School of Public and Business Administration (EBAPE) of Getulio Vargas Foundation.

In general lines, the project aims to: (i) provide important inputs that can contribute to the improvement of public policies and business strategies in developing countries; (ii) expand knowledge about how firms and sectors of developing countries may take advantage of opportunities and catch-up.

All the three articles of the thesis are concerned with technological innovation and catch-up, but each one explores different aspects. We have chosen the Brazilian seeds sector as locus of investigation, since it involves a wide range of activities with high level of complexity and therefore it is intrinsically linked to technological innovation. Moreover, it has been facing great dynamism, especially from the 2000s. Due the diversity of the activities involved in diverse processes of the sector, we decided to delimit the scope of the research to one of the most important process of the industry: the plant breeding process. As there are also considerable differences in plant breeding activities depending on the culture, we chose the soybean to be examined, since it is the most important crop for the country in economic terms.

To address the research questions of the articles, we have drawn on empirical evidences mostly obtained through the carry out of in-depth interviews in different types of organizations, but in Brazilian Agricultural Research Corporation (Embrapa) and Embrapa Soybean mainly. Beyond these companies, we collected data from associations/foundations/cooperatives of the sector and a company specialized in strategic information to agribusiness. The Figure 1 presents the framework of the thesis.

Figure 1: framework of the thesis



Source: developed by the author

The first article addresses the theme of changes in industrial leadership and catch-up by latecomer firms during the long run evolution of a sectoral system. In this article, we examine the argument defended in Lee and Malerba (2014) that these changes and catch-up are determined by the capabilities and the appropriateness of responses/strategies taken in the face of the arising windows of opportunity. These windows would be related to different dimensions of a sectoral system: changes in knowledge and technology, changes in demand and changes in institutions and public policy. Specifically, we first investigated the major changes that took place during the period between 1973 and 2015 related to knowledge and technology, demand and institutions in global level that somehow could affect the seeds sector. Next, we examined the capabilities of Embrapa (and of the Brazilian seeds sector) and its strategies facing these changes.

We found out that, during the given period, different forces had a major influence on the changes of the sector. At first, capabilities and appropriateness of responses/strategies of Embrapa were enough to move the company from a follower position to a leader position. After the Plant Variety Protection Law (PVPL), the marketing strategies of the transnational companies, allied with intellectual property protection mechanisms have hindered the presence of smaller companies in the seeds market, despite its capabilities. Nevertheless, Embrapa was able to position itself over time and continue to fulfill its structural role in the sector and in regulation of the market. Regarding the latter, a strategic decision of Embrapa was to continue investing in some areas of R&D so that the company be ready to quickly supply and meet the demand of the Brazilian producer if necessary, avoiding big verticalization and excessive prices. Through the research findings, we believe we have achieved two major contributions. The first one is that, in addition to confirming the Lee and Malerba (2014) hypothesis, we evidenced the major forces that influenced the industry and how and in which extension this happened. The second is that it was possible to shed light on how differences concerning the firm´s capabilities and strategies could contribute to catch up of the companies and the sector.

The second article of the thesis addresses the network structure and public-private partnerships (PPP) themes. In this article, we sought for understanding a gap previously identified in Powell et al. (2005) and later exploited in Ahuja, Soda and Zaheer (2012): the origins and evolution of alternative types of network structures; in other words, their dynamics. In addition, we intended to put light on the reasons for the emergence and rise of new organizational forms in the context of public-private partnerships. Specifically, this research examined how and why networks centered at a public R&D firm of a developing country have evolved to take the forms they do. In addressing this question, special attention was given to the reasons why both private and public companies establish partnerships. We used as underlying logic to conduct the research the grounded-theory and as research design a longitudinal single-case. In addition, we made use of the social networks approach both as a methodological tool and as a theoretical lens.

As result of the research, we presented a theoretical framework, which included seven propositions. We observed that the determinants of the rise of novel organizational forms have changed over time. For example, we found out different interests among the companies in making partnerships in different periods. We also found out different effects for each kind of network. Although both

universities and private companies have played important roles, their relevance was bigger or smaller depending on the phase of Embrapa's life. We also noticed that Embrapa, during the entire investigated period, had a high degree of centrality, which theoretically should mean that the company had access to diverse information or high status or prestige. Our findings showed, notwithstanding, a slight different conclusion. It is evident that Embrapa has high status or prestige in a general way. However, at least in relation to its plant breeding process, it seems that the high degree of centrality of Embrapa has not been able to supplant the lack of access to some insider information. Moreover, the high status or prestige did not necessarily have reflected in balance of power in relation to the transnational companies, being the industry dominated by them.

The third and last article aimed to elucidate the trajectory followed by Embrapa Soybean1 to conquest the Cerrado and become one of the most important cases of success in Brazil, whose outcomes remain until today. We specifically examined the relation between the process of innovative technological capability accumulation of Embrapa Soybean and the knowledge networks centered on the firm. Moreover, we investigated the evolution of some indicators of marketing and technological catching-up (production, export and yields) and the influence of the conquest of cerrado in this evolution. The relation 'technological capabilities - knowledge networks' is considered by many authors one of the most important interaction. Despite its relevance, this relationship has been not only poorly explained, but even little described until now. In order to delimitate the scope of the research, we focused on the main phases of the soybean breeding programs.

Through an inductive and qualitative research strategy, allied with concepts of the knowledge network approach, it was possible to clarify how Embrapa in a short time has moved away from a stage of follower and reached the level of global leadership and to verify some important outputs until 2015. We believe we are offering important insights into how a company in a developing country was able to reach the level of global leadership.

Together, we believe the three articles bring contributions to: (i) the understanding of windows of opportunities and the appropriateness of firm's responses aimed to catch-up while facing these

[1] A Research Unit of Embrapa which has as one of its main attributions to enable solutions for sustainability of production chains of soybeans for the benefit of the Brazilian society

windows; (ii) the bigger understanding of the process of catch-up in developing countries and the influence of it in important outcomes.

Moreover, they present a picture at the same time comprehensive and deep about the Brazilian seeds sector. As a company that has always played a structuring role in the industry with much success, the strategies adopted by Embrapa – e.g., strong investment in R&D (participation in global value chains supported by a solid base of R&D) and in building strong (knowledge) networks during its entire life - seem to have been much effective. Although Embrapa makes part of a sector related to natural resources, its example actually could inspire, for instance, firms of the industrial sector, being reference for new attempts of public companies.

ARTICLE 1: WINDOWS OF OPPORTUNITIES AND RESPONSES OF BRAZILIAN SEEDS SECTOR

ABSTRACT

This study aims to investigate the theory of catch-up cycles in the setting of developing countries. We chose the Brazilian seeds sector as the *locus* of investigation. In order to explain catching up and industrial leadership, as suggested by the authors, we confront changes at the global level and windows of opportunities that emerged with responses from the main company of the sector - Embrapa. In our empirical study, we made use of in-depth interviews with historical and longitudinal analysis. We found evidence that changes in key dimensions alter in importance over time, but that institutions/public policy seem to be the forces that most contribute to strong dominance of transnational companies nowadays. Moreover, differently than suggested by some authors (although they are mainly focused in the Argentinean seeds sector), we find evidence that transnational companies – particularly the Gene Giants – do are driven the process of seeds innovation in the industry. In addition, the highest amount of launching of new varieties each year is not synonymous of more (or bigger) innovation; dominant positions in the market is not directly associated with higher levels of technological innovation. In fact, market innovation – e. g., commercial approach of transnational companies, which includes financing of producers and sales distribution - seems to be, at least, as relevant as technological innovation in the setting of seeds industry.

Key words: Theory of catch-up cycles. Windows of opportunity. Strategies. Catch-up. Latecomers. Seeds sector. Embrapa. Developing countries.

RESUMO

Esse estudo busca investigar a teoria de ciclos de "*catch-up*" no contexto de países em desenvolvimento. O setor de sementes agrícolas brasileiro foi escolhido como locus de investigação. A fim de explicar catching up e lideranças na indústria, foram confrontadas mudanças e janelas de oportunidades ocorridas no nível global com as respostas da principal empresa do setor – Embrapa. No estudo empírico, fizemos uso de entrevistas em profundidade e análise histórica e longitudinal. Foram encontradas evidências de que mudanças em dimensões-chave alteram em importância ao longo do tempo, mas que instituições/políticas públicas parecem ser as forças que mais tem contribuído para a forte dominância das empresas transnacionais atualmente. Além disso, diferentemente do que tem sido sugerido por alguns autores (embora eles estivessem focados principalmente no setor de sementes da Argentina), encontramos evidências de que as empresas transnacionais - em particular as "*Gene Giants*" - realmente tem direcionado o processo de inovação na indústria de sementes. Além disso, a maior quantidade de lançamento de novas variedades a cada ano não é sinónimo de mais (ou de maior) inovação; posições dominantes no mercado também não estão diretamente associadas a níveis mais elevados de inovação tecnológica. Na verdade, a inovação no mercado - e. g, abordagem comercial das empresas transnacionais, o que inclui o financiamento de produtores e de distribuição de vendas - parecem ser, pelo menos, tão relevantes quanto a inovação tecnológica no cenário da indústria de sementes.

Palavras-chave: Teoria dos ciclos de *catch-up.* Janelas de oportunidade. Estratégias. *Catch-up*. Teoria dos Ciclos de *Catch-up*. *Latecomers*. Incumbentes. Setor de sementes. Embrapa. Países em desenvolvimento.

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INTRODUCTION

For the last few decades, the agricultural seeds sector has been facing dynamism of major proportions, having significant impact on companies from emerging countries and requiring, as a result, new positioning to face changes of different natures. In this sense, Lee and Malerba (2014) argue that during the long run evolution of a sectoral system, three windows related to different dimensions of a sectoral system may emerge: one related to changes in knowledge and technology; a second related to changes in demand and a third related to changes in institutions and public policy. The authors advocate that it is the combination of these windows of opportunity, with the presence of capabilities and the appropriateness of responses/strategies, which determine industrial leardership changes and catch-up by latecomer firms.

Following this idea, Andersen et al. (2015) use the case of Argentina to investigate how the main forces have opened new opportunities for innovation in the Argentinean seeds sector and how some companies in Argentina have received these opportunities. The authors, however, do not accurately collate every important event about the three dimensions investigated with the firms' responses. Thus, it was not possible to observe in detail how the responses/strategies of the companies contributed to catch-up and innovation.

In this paper we propose to examine the argument defended in Lee and Malerba (2014[2]) applied to the Brazilian seeds sector. Through the confrontation of the main events that happened in the sector at a global level – changes in knowledge and technology, demand and institutions/public policy - with responses of the main company of the sector, we believe it was possible to test the theory (forthcoming), bring robustness to its arguments. We hope in this way, it was possible to understand how the main forces has driven the innovation over time and nowadays; in addition, we believe it was possible to shed light in how differences concerning the capabilities of the firm and its strategies contributed to catch-up.

Because there are considerable differences in breeding activities depending on the culture being developed, we chose the culture that has the most important economic relevance to Brazil: soy. We

[2] Previous versions of the paper (forthcoming) were presented at the Bocconi University Milan Workshop (2012), Seoul Workshop (2013) and at 2013 Globelics Conference. The paper was developed for the special issue on Catch-up Cycles of Research Policy and the date of its latest revision is May 2015.

decided to investigate Embrapa, as it is the main representative of the sector in Brazil and because, in addition to regulating the market, interacts closely with private companies, complementing their services and offering alternatives to producers.

Thus, specifically, we will investigate the main changes related to knowledge and technology, demand and institutions in the global context that have somehow impacted the Brazilian seeds sector and the catch-up of Embrapa related to soy plant breeding process facing these changes, considering its capabilities and strategies. The period of investigation is the entire life of Embrapa, from 1973 to 2015.

2. SECTORAL SYSTEM, WINDOWS OF OPPORTUNITIES AND FIRMS' STRATEGIC RESPONSES: the theory of catch-up cycles

When discussing about formation of value networks, Perez (2010) introducted the concept of windows of opportunities. The author advocated that the growing interdependence, currently noted, which arose from globalization associated with the huge capacity of diffusion of information – and made possible by the revolution in information and communication technology (ICT) - offers an important window of opportunity for developing countries. The contribution that each component of the network delivers to the network as a whole is what going to set its value (or relevance) and participation. Therefore, such an opportunity could be used by developing countries through the network to add value in the form of innovative technological capacity.

In seeking to explain what gives entrants or latecomers an opportunity to catch-up and take industrial leadership, what explains successive changes in industry leadership and why they take place in some sectors and not in others, Lee and Malerba (2014), based on some empirical observations, proposed the theory of catch-up cycles. The authors argue that previous theories, including those more recent ones, are not able to explain these questions.

According Lee and Malerba (2014), the product life cycle theory (Posner, 1961; Vernon, 1966) – the focus of which is mainly on the movement of production from advanced to developing countries – is not sufficient to explain "why innovative products and production processes can be developed by firms in developing countries" (Lee & Malerba, 2014, p. 6). Other weakness of the product life cycle theory is that it cannot be applied very well to industries (especially those that generate multiple technologies), it is not oriented to the historical development of industries and it fails in

considering other important explanatory factors, such as institutions. More recent theories – macro variables (such as labor costs and exchange rates) (Katz, 1995), firms capabilities (Bell & Pavitt, 1993; Kim, 1997; Lall, 2001), and national innovation systems (NIS) (Freeman, 1987; Lundvall, 1992; Nelson, 1993) – help explain catch-up, but fail in other aspects (Lee & Malerba, 2014).

Lee and Malerba (2014, p. 7) advocate that "what we need is not a firm-level but an industry-level theory that takes into account various broad variables": (i) knowledge and technology; (ii) demand and (iii) institutions and public policy. Concerning this latter, Mazzoleni e Nelson (2007) highlight the relevance of the effectivity of the public research system and higher education, which has become an increasingly important part of the institutional structure needed to catch-up.

The sectoral innovation system approach - analytical derivation of the national innovation system – places the sector at the analytical level. A sector may be defined broadly as "a set of activities that are unified by some product groups related to a particular demand or to an emerging demand and that share some common knowledge" (Malerba, 2006, p. 7). Changes in each of these variables – or combination of them - represent 'windows of opportunity' that may emerge during the long run evolution of a sectoral system. Depending on the timing of entry, the level of capabilities and the appropriateness of responses/strategies in facing these changes, the firms and countries will be more or less successful in their catching-up trajectories. Of course, the responses of incumbents also influence latecomers' results (Lee & Malerba, 2014).

In this study, technological capabilities may be understand as the organization's resources to generate and manage technological changes, including skills, knowledge and experience, institutional structures and connections networks, as suggested by Bell and Pavitt (1993, 1995). By accumulating capabilities, the latecomer firms narrow the technological gap with the developed countries; in other words, they catch-up.

3. RESEARCH METHOD

In this section, we discuss about the research setting, the research design and data collection and sources.

3.1 Research setting

We choose the Brazilian Agricultural Research Agency (Embrapa) as research setting for many reasons. One of the most important is that the company is responsible for coordinating the National Agricultural Research System (NARS), which consists of about approximately 122 organizations related to research in agricultural sciences, among federal public institutions, state universities, private companies and foundations. In addition, Embrapa interact closely with farmers, transfering technologies for the productive sector (Embrapa, 2016).

3.2 Research design

Following directives from Pettigrew (1990; 1997), Davis and Eisenhardt (2011) and Yin (1984), we used a longitudinal single-case, inductive study design. A longitudinal study was necessary, since we intended to examine changes over time.

3.3 Data collection and sources

We gathered data mainly from Embrapa and Embrapa Soybean through semi-structured interviews. However, in order to ensure greater robustness to our research findings, we also interviewed professionals from other organizations that interact with Embrapa and Embrapa Soybean. The interviewed organizations were the Brazilian Association of Seeds and Seedlings (Abrasem), the Agronomy Institute (IAC), the Meriodional Foundation, the Integrated Agroindustrial Cooperative, the MT Foundation, the Agribusiness Center at the Getulio Vargas Foundation, the Center of Management and Strategic Studies (CGEE) and the Kleffmann Group. Altogether, we conducted 37 interviews over a year with around 40 people, which generated 488 pages of transcribed primary source material.

First, we visit Embrapa headquarters in Brasília, since this would made possible to get a broader vision about the company and its strategies. Next, we visited Embrapa Soybean in order to understand in detail the decisions and actions of the company. Then, we went to the other organizations to get evidence from other sources. Finally, we came back to Embrapa and Embrapa Soybean to confirm our evidences and to solve some doubts.

We selected the interviewees initially through the confrontation between the research goals and the functions exerted by the Embrapa professionals in areas previously selected. Both professionals from the directive board, managers from middle level and supervisors, analysts, engineers, assistants, technicians, experts and researchers made part of our sample. Next, we used the snowball strategy to select other professionals to be interviewed.

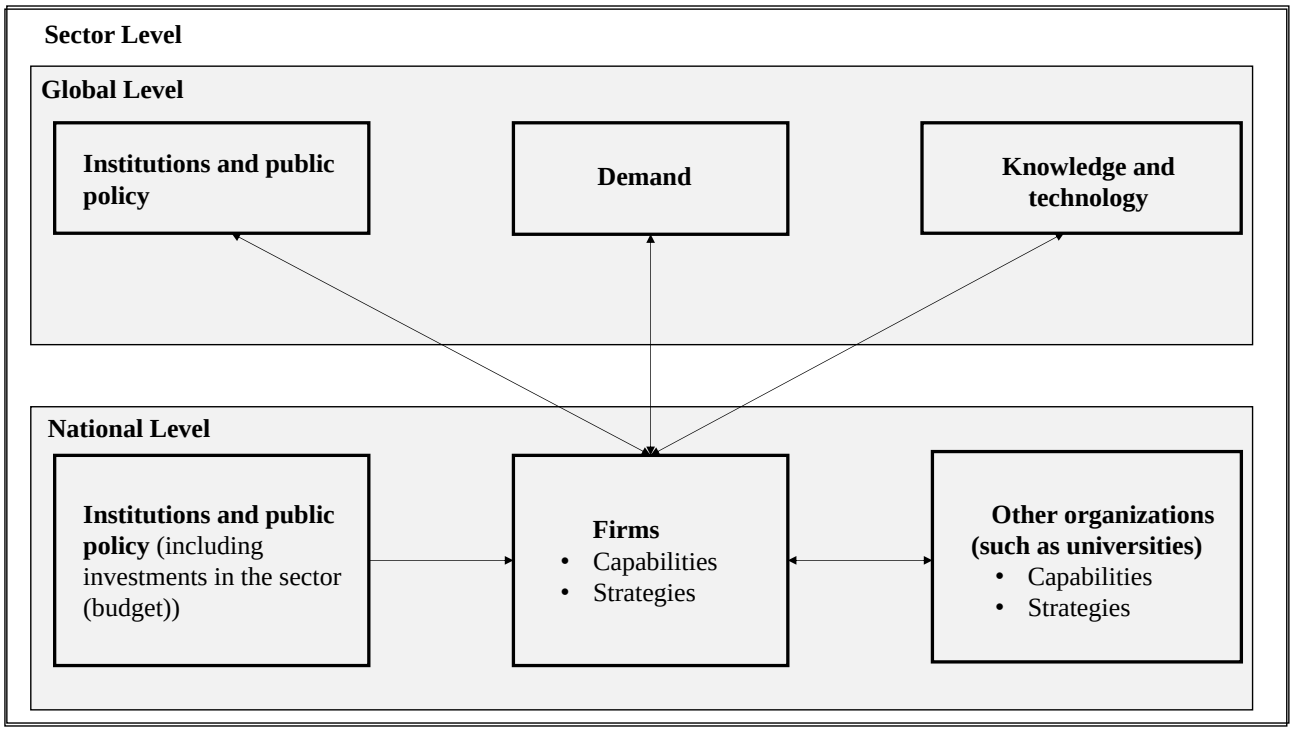
In addition, we made use of secondary data, both from the literature and from internal reports of the companies.

3.4 Procedures for the analysis of the collected empirical evidence of research

For the analysis of empirical evidence collected, we follow the steps suggested by Miles and Huberman (1994). Initially, we carried out the data cleaning activity, when the data collected are transcribed, coded and prepared in a common format in defined categories. Then we performed the data reduction, ie selection, simplification, abstraction and transformation of the original data. Later, the data were organized in narrative texts, matrices, charts, etc. schemes to allow conclusions and decision making. Finally, we seek to identify patterns of answers, explanations and possible relations of cause and effect between the variables investigated (data interpretation). The evidence of the review process covered the entire field research period, and one should always turn to the theoretical and conceptual basis - as well as the analysis of estrtuturas - in order to compare them with data empirical collected, always focused on finding answers to research questions.

Figure 1 presents the analytical research model.

Figure 1 – Framework of the article: sectoral innovation system of the Brazilian seeds industry



Source: Elaborated by the author, based on the theory of catch-up cycles

We applied the framework to analyse the processes of plant breeding which includes two main routes nowadays: 'conventional route' and other one that we are calling as 'transgenic route'.

4. PLANT BREEDING PROGRAMS AND THE USE OF MODERN BIOTECHNOLOGIES TECHNIQUES

The focus of the plant-breeding program is always to increase productivity. However, besides quality of the seeds, which drives high yields and economic sustainability, we must taken into account issues related to agricultural, social and environmental sustainability, beyond health safety.

Until the 20th century and the advent of modern biotechnology, a conventional process of plant breeding, the *so-called crossbreeding* process, was used almost exclusively. *Crossbreeding* is carried out between plants of the same species or, when possible, between plants of genetically close species. In line with our interviews, Andersen et al. (2015) mentioned that at that time, the

process of seed improvements was mostly developed based on a ‘trial-and-error’ process, which features tacit knowledge.

The advent of modern biotechnology carried different techniques that have contributed enormously to plant breeding programs. Some of them - such as the molecular markers technique - can be used both in conventional breeding programs and to develop genetically modified organisms (GMOs). The molecular markers technique, which is advancing greatly, accounts for a major innovation in plant breeding programs: molecular markers-assisted selection (Andersen et al., 2015), which has increased the speed of generating cultivars enormously.

Other tools made a mix between conventional cultivar and transgenic events possible. When a good commercial non-gm cultivar is available, it is possible to insert specific transgenic trait through transformation methods.

Other techniques are specific to the transgenic route. A great advantage of the genetic engineering is the enlargement of the gene pool available to the breeder, since it is not restricted to intraspecific sexual compatibility or compatibility between related species. In this way, new possibilities for genetic improvement emerge (Faleiro et al., 2011). However, although some of the benefits of the transgeny are already reality, the potential of transgeny is not being fully utilized in some countries, such as Brazil. Beyond greater resistance to biotic (pests, diseases, weeds), other some benefits of the transgeny are abiotic (high temperatures, drought) stresses; an increase in nutritional value through increasing the concentration of vitamins, minerals and proteins; and the generation of bioplants, which are plants for the production of vaccines and therapeutic proteins (Nass, 2011). Therefore, it is seems to be more the future possibilities than real successes achieved so far by the ‘transgeny’ that most motivate the huge investiments in R&D.

The fact is that we have to consider new technologies as ‘auxiliary’ tools in plant breeding programs. “They will never replace the essential practices of breeding, such as the phenotypic analysis of plants, accounting for the environmental effects and interactions genotype x environment” (Faleiro et al., 2011, p. 564). In other words, the conventional and modern biotechnology routes should be perceived as complementary and not competing. It would not be possible to use the transgenic techniques with their full potential if there were no good genetic seeds. Moreover, the genetic potential will be expressed only if other conditions, such as soil and climate, are ideal.

5. ANALYSIS OF DATA AT GLOBAL LEVEL: CHANGES IN THE WORLD AND WINDOWS OF OPPORTUNITIES FOR THE BRAZILIAN SEEDS SECTOR

Many authors, including Andersen (2011), consider demand one of the most relevant drivers of innovation, especially in developing countries.

5.1 Changes in the demand and orientantion of market

Next, we will discuss the changes related to the window 'demand', both in quantitative and qualitative terms, which happened in the two periods: 1973-1997 and 1998-2015.

5.1.1 From 1973 to 1997

A very important event in the industry was the burst of the soybean price in the stock market in 1973, which increased the price from US$ 150 to US$ 400 a tonne, as explained by an interviewee. While the price 'boom' influenced the world's soybean sector, it mainly affected countries that had great extensions of land, especially in developing countries. As Brazil had huge land extensions, the demand for soybeans and the increasing prices stimulated soybean production in the country and, in consequence, stimulated the Brazilian seeds sector.

The exchange rate is another important component in the decision-making process of farmers that focuses on agricultural commodities for export (Conab, 2015b).

5.1.2 From 1998 to 2015

The world's demand for food continues to grow. Two main factors – a growing population and an increasing demand for energy – explain the predicted future growing demand for agricultural products for the next decades (OECD-FAO, 2015; Andersen et al., 2015). In fact, developing countries are accountable for the growing population and their income growth is a determinant of demand in world commodity markets. Within the scope of developing countries, "according to estimates, almost all of the land expansion in developing countries would take place in sub-Saharan Africa and Latin America" (Andersen et al., 2015, p. 69). This is also true for the soybean; its demand is increasing due the higher consumption of protein, mainly as food and animal feed.

According to the World Bank, Brazil is the country with the greatest potential area for soybean expansion in the world. Thus, with regard to restrictions on supply, the country is an important actor, which may reduce the problem of food safety. In addition to expanding the area under cultivation, it is expected that productivity will be increased. However, it is important to emphasize the relevance of the domestic soybean market in Brazil.

Andersen et al. (2015, p. 70) mentioned two key qualitative changes in the demand - one by the farmers and the other by the final consumers - for some important crops such as soybeans, that had opened new opportunities for innovation in the Argentine seed industries. Concerning the first one, demanded by the farmers, the authors affirmed that "they do not only demand higher-yield seeds but also seeds that match specific services (i.e. herbicide or insect resistance) that facilitate the management of agricultural production and allow them to reduce costs." The other change in demand refers to "...the increasing demand for more environmentally friendly and healthy products" by consumers who would be willing to pay more for organic and non-GM products. These changes are consistent with our findings; thus, they also represent new opportunities for innovation in the Brazilian seeds sector.

Next, we will discuss the changes related to the window 'institutions', both in 1973-1997 and 1998-2015 periods.

5.2 Changes in the institutions and governmental incentives

Institutions are important drivers of innovation, as argued by North (1990), Williamson (1996), Zylbersztajn (2014) and many others. According to some authors, lobby groups often take advantage of weak governments. Brazil is not an exception.

In its origin, the seed industry's main characteristic was the presence of specialized companies limited to their home countries. Globalization, allied with intellectual property rights (IPR) has changed this.

The regulatory framework of the sector is complex and includes laws related to production and trade, intelectual property and biosafety and biotechnology. In the first group, there is the Seeds and Seedlings Law (Law 10,711 of 08/05/03) and the Decree of Seeds and Seedlings (5,153 07/23/04). In the second group, there is the Patent Law (9,279 of 05/14/96) and the Plant Variety Protection

Act (9,456 of 04/25/97). And in the third group, there is the Biosafety Law (11,105 of 03/24/2005) and the Law on Access to Genetic Resources (Law 13,123, of 05/20/2015). We will now explore how the regulatory framework evolved over time both in global and national levels.

5.2.1 From 1973 to 2015

Since the innovation efforts in the seed industry act on living organisms, we observed additional difficulties for the regulatory framework focused on the appropriation of these efforts. In fact, even in countries that already had a specific law regarding plants, as in the case of the U.S. Plant Patent Act of 1930 (which had significant gaps), the problem of appropriation of innovation efforts in seeds persisted (Carvalho & Pessanha, 2001).

5.2.1.1 The Union for the Protection of New Varieties of Plants (UPOV) and the protection certificates

The Union for the Protection of New Varieties of Plants (UPOV, its acronym in French, as it is known) – founded in 1961 and enacted in 1968 – arose as a result of the search for a law that met the specificities of plant breeding, since the cultivars obtainers encountered great difficulties in meeting the requirements for patentability (Guerrante, 2003). UPOV was the conceptual mark for national legislation on intellectual property rights to plant breeders (Greengrass, 1993). The signatories to UPOV would ensure that the rights of breeders of new cultivars would be respected by other countries that have acceded to the Agreement and, conversely, would agree to respect the rights of other countries.

From 1973 to 1997, UPOV underwent three revisions: in 1972, 1978, and 1991. Brazil – and most developing countries – adopted the 1978 Convention, which is still in force. Highlights of the 1978 Convention were: (i) the breeder's right to use any protected material as initial resource of variation to create new varieties – known as the "breeder's exception"; and (ii) the farms' privilege to use part of its own production (crop) obtained from protected varieties as seed/seedlings for own use (replanting) – known as the "farmer's exception" (Fuck et al., 2007). Moreover, the Convention prohibited double protection, that is, simultaneous protection by rights of plant breeders/obtainers (obtentores) and by patents. The 1991 Convention introduces the concept of essentially derived variety, expanding the scope of protection granted to the holders of varieties (which are commercially successful) where there is use of their material as a source of genetic variation. Thus,

since the improved variety has a minimum number of characteristics defined by law and it maintains the essential characteristics of the initial variety, the Convention required anyone who wanted to use it to get permission from the copyright holder and pay him/her royalties (Carvalho et al., 2007). Since there is no mention of dual protection in the 1991 review, it subtended the possibility of protection by both breeder's rights (based on *sui generis* protection mechanisms) and through patenting.

In 1980, there was a major change in U.S. law. It allowed living organisms (or at least certain parts, such as the genetic construction) found in nature to be patented. The patenting of biotechnological products and processes began in the U.S. and quickly spread among developed countries (Carvalho & Pessanha, 2001). The argument used by the United States and other developed countries to ensure the patenting of organisms found in nature is that "there is inventive activity in the identification process of the material" (Carvalho, 2003, p. 18). Microorganisms, plants, animals, and even human DNA fragments are being patented. In Brazil, differently, it is not allowed patenting of life forms and/or genomes (genes) as found in nature, but the use of genes for specific genetic buildings only.

Hence, the agricultural seeds sector coexists with the use of two main instruments for the protection of investments and innovations: (i) the plant variety (cultivars) protection certificates, a *sui generis* system introduced in the 1960s (Fuck et al., 2008) and (ii) patents. Certificates are used to protect new varieties of seeds, genetically modified or not, as recommended in Article 2 of Plant Variety Protection Act (PVPA)[3] of Brazil. Such certificates guarantee rights to the breeder during the guard time and prevents others from selling the variety, offering it for sale, importing or exporting it, conditioning it, storing it, or using it in the production of a hybrid variety or a different form of it (UPOV, 2016). Patents, however, are used to protect new genes or new genetic constructs. The plant variety protection differs from patents not only in scope, but also due to exceptions or limitations to the rights holder: the farmer and the breeder (Carvalho, 2003; Fuck et al., 2007).

However, even after passing laws aimed to ensure appropriation of innovation efforts, serious problems persisted, especially those concerning international trade. The emphasis in international

[3] Art. 2 of the LCP (1997): The protection of rights to intellectual property related to plant varieties is performed through the granting of a Plant Variety Protection Certificate, considered a movable property for all legal purposes and only form of plant variety protection and law that could stop free use of plants or its parts of reproduction or vegetative propagation, in the country.

trade changed the *locus* of the discussion. From the first international conventions that sought to regulate and harmonize laws and treaties on specific fields of intellectual property, it began to create a link between the participating organizations, which eventually ended up in the World Intellectual Property Organization (WIPO). In the field of plant variety protection, this articulation took place in UPOV. These two organizations have always been leaders in the intellectual property protection field, as they were the mediation locus of disputes until the Uruguay Round of the General Agreement on Tariffs and Trade (GATT), which began in 1986 and ended in 1994 with the signature of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS).

5.2.1.2 Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS)

The TRIPS agreement is another important milestone in the industry, since it promoted crucial changes: (i) shifting the scope first based on the protection of national technological development, to emphasize protection and international trade, and (ii) recognition of protection for pharmaceuticals, food, and, particularly, plants (Carvalho et al., 2007; Carvalho, 2003). TRIPS explicitly allows dual protection, i.e., the *sui generis* system, the patents, or even a combination of both. When enacted in 1995, countries tried to adjust their national legislation to the terms of TRIPS with regard to intellectual property (Fuck et al., 2007), which implied an institutional redefinition (Carvalho et al., 2007). Since IPR legislation was not common in developing countries until the 1990s (Andersen et al., 2015), TRIPS had a great impact and induced changes in national legislation.

Thus, at the international level, UPOV and TRIPS are considered the most relevant treaties regarding intellectual property in plant breeding. The possibility of a country to join the 1978 Act ended in 1999 and, therefore, the countries that accede to UPOV will have to adhere to the Act of 1991. There is some pressure on UPOV member countries – especially developing countries that adhered to the 1978 Act (including Brazil) – to base their legislation on the recommendations of the 1991 Act (Fuck et al., 2007). As mentioned by Andersen et al. (2015, p. 72), “the argument is that this system, by promoting stronger degrees of appropriability, will favor innovation”.

5.2.1.3 Convention on Biological Diversity (CBD)

Regulatory issues in the seed industry have become even more significant since the advent of genetic engineering. The government has had to invest in regulatory issues (ISF, 2013) such as

intellectual property and trade rules, specific technological aspects, and sustainable agriculture. The unpredictability of long-term effects arising from non-natural recombination of genes for food production and the social and cultural issues related to it seems to contribute to this phenomenon. Coupled with the increasing adoption and use of genetically modified varieties, the global nature of the sector means movement of seeds across national borders, leading to a much more complex regulatory framework.

In this sense, the Convention on Biological Diversity (CBD) is a treaty of the United Nations (UN) and is one of the most important international instruments related to the environment. Established during the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992 (ECO-92), the Convention was enacted in December 1993. Currently, there are more than 160 signatories to the agreement. The Ministry of Environment (MMA) is the focal point for the implementation of the Convention in Brazil (Brazil, 2016b). The CBD is the world's leading forum for questions related to the subject, covering all that relates directly or indirectly to biodiversity and functioning as a kind of legal and political framework for several other conventions and more specific environmental agreements. Among these, we can mention the Cartagena Protocol on Biosafety; the International Treaty on Plant Genetic Resources for Food and Agriculture; the Bonn Guidelines; the Guidelines for Sustainable Tourism and Biodiversity; the Addis Ababa Principles for the Sustainable Use of Biodiversity; the Guidelines for the Prevention, Control, and Eradication of Invasive Alien Species; and the Principles and Guidelines of the Ecosystem Approach for Biodiversity Management (Brazil, 2016b). Based on three main principles (the conservation of biological diversity, the sustainable use of biodiversity, and the fair and equitable sharing of benefits arising from the utilization of genetic resources), the Convention refers to biodiversity at three levels: ecosystems, species, and genetic resources (Brazil, 2016b). The marketing of GM products is also being discussed in the context of the Biosafety Protocol, provided by the Biodiversity Convention. The Protocol has as its objective the disciplinary transboundary flow of products containing GMOs. This is relevant because the vast majority of countries do not have laws and technical-scientific criteria about the safety of these products (Brazil, 2016a).

5.2.1.4 Consumer attitudes

Andersen et al. (2015) examined consumer attitudes toward GM technologies as informal institutions. In fact, consumers differ in relation to acceptance of genetically modified products,

influencing both decisions from the government and private companies. In general, consumers are not in favor of genetically modified products. However, there are differences of opinions across countries. For example, Europe and Japan are clearly more interested in non-GM seeds, creating a niche market for those who are interested in investing in it. At this point, it is important to highlight the opposing interests of the farmers and the consumers.

Next, we analyzed the third and last window of opportunity: science and technology.

5.3 Changes in the science and technology

Science and technology is another driver of innovation, whose strength is considered even greater in developed countries.

5.3.1 From 1973 to 2015

The information and communication technology (ICT) revolution was perhaps the main change related to science and technology that happened during this period. In the opinion of Perez (2010) and others, the new scenario arising from the huge diffusion capacity of the information afforded by ICT associated with globalization started offering an important window of opportunity for developing countries. Through networking, these countries could exploit such an opportunity, adding value in the form of innovative technological capacity. The revolution in ICT has enabled the possibility of working with Bigdata. Combined with other technological advances, such as bioinformatics, such changes have been particularly important for the seed sector.

Many researchers (such as Andersen et al., 2015) considered advances in biotechnology (including molecular biology), nanotechnology, and bioinformatics the main new knowledge bases that contributed to improvements in the seeds sector. Their new knowledge – about the genome, genetic structure, relationship between genes, generation of protein from the gene – contributed enormously to advances in genetic engineering technology, allowing the manipulation and transfer of the sequence of genes of interest.

From these advances, large companies seem to have grabbed onto two main opportunities. The first opportunity concerns the complementarities between the development of agrochemicals and the result of genetic improvement, that is, tolerance developed and marketed by chemical pesticide

companies and the development of varieties adapted to chemical fertilizers (Carvalho & Pessanha, 2001). As mentioned by an interviewee from Embrapa's Department of Business, "Large companies saw a way to capture value on top of the transgenic event, and the way to lead this transgenic event to the farmer is through seed. Then there was a very large investment of these large companies, such as Monsanto, in plant breeding to be a vector of transgenic events. Thus, these big companies are entering heavily in genetic programs (conventional plant breeding programs) for an array of transgenic events." The second opportunity is the potential expansion of economies of scope in biotechnology research due to their multi-sectoral characteristics and the diversification of these companies toward the seeds industry (Carvalho & Pessanha, 2001).

The seed sector's characteristics are directly associated to edaphoclimatic conditions – both land expansion and changes of nature (such as being prone to extreme events like droughts and storms) – and, therefore, constant technological innovation is required in the industry. A great challenge the seed sector is facing nowadays, for example, is the development of seeds resistant to drought. Moreover, due to countries' cross-border trade of seeds, it is necessary to invest in seeds tolerant to diseases, plagues, and potentially damaging insects, not just tolerant to nematodes, which would justify even investment in preventive breeding.

Although plant breeding is one of the most important technologies of a genetic companys, as advocated by a respondent from the Embrapa Soybean' Directive Board, soil managment, crop rotation and forest-crop-livestock integration are perhaps the main factors of productivity.

Figure 2 resumes the main changes in the windows of opportunities in the investigated periods.

Figure 2 - Main changes concerned demand, institution and technology from 1973 to 2015

		1973 – 1997	1998-2015
DEMAND	(in quantitative terms)	Growing	Growing
	(in qualitative terms)	Increase of yields	- Increase of yields - Resistence to herbicide or insects (producers) - Social and environmental sustaintability (consumers) - Health safety (consumers)
INSTITUTIONS		Emphasis on the protection of national technological development Globalization of Brazil since 90s	- Emphasis on international trade - Principles of: •conservation of biological diversity • sustainable use of biodiversity • fair and equitable sharing of benefits
TECHNOLOGY		Revolution of ICT	- Biotechnology - Bioinformatics - Nanotechnology

Source: elaborated by the author

6 ANALYSYS OF DATA AT NATIONAL LEVEL: THE BRAZILIAN SEEDS SECTOR AND APPROPRIATENESS OF EMBRAPA'S RESPONSES

6.1 From 1973 to 1997

As mentioned by Alves (1980), Brazil needed desperately to increase agricultural productivity to get the domestically balance between supply and demand for food, and still be able to export more. Meanwhile, the attractive soybean prices in the international market in 1973 (see section 2.1.1) opened the eyes of local producers of Brazil to the possibility to take advantage of the great land extension of the country. The idea was to transform 'barren land', as Cerrado, in productive land.

6.1.1 Responses at National Level

The main responses at national level involve changes related to the three windows. Regarding the institutional window, after the market opening of Brazil, we observed, beyond the creation of Embrapa and its units – Embrapa Soybean and Embrapa Cerrados – the creation of special programs, specially the POLOCENTRO and Japanese-Brazilian cooperation program for the agricultural development of the Cerrado (Prodecer). Later, it was enacted the Plant Variety Protection Law. Concerning the technological window, we highlight changes in the way Embrapa

(and the industry) responded to the emergence of the modern biotechnology, which also resulted in changes in how they answered to the demand. Let us explain such changes.

6.1.1.1 Creation of Embrapa, Embrapa Soybean and Embrapa Cerrados

With the main objective of promoting agricultural development in Brazil, Embrapa was created in 1973. The financial resources for Embrapa stemmed, basically, from "the National Treasury through the Ministry of Agriculture appropriations, special programs of the Federal Government and development poles" (Alves, 1980, p. 8). The company also counted with Financier of Studies and Projects (FINEP)'s and National Bank for Economic and Social Development (BNDES)'s loans, and international loans from the Interamerican Bank of Development (IDB) and the International Bank for Reconstruction and Development (World Bank - IBRD). In addition to these resources, there were also resources coming from agreements, arrangements and from Embrapa itself (Alves, 1980).

The high prices of soybean, allied with the possibility of using great extension of not yet arable lands encouraged the creation of Embrapa Soybean and Embrapa Cerrados at the same year, in 1975. Soybean, as one of the most important products chosen to be developed, gave rise to the creation of the National Soybean Research Center. In the first period, the R&D program of Embrapa Soybean was funded almost exclusively with public resources and partnerships with public institutions, notably the State Companies of Agricultural Research. The partnerships had technical nature, such as to make cultivars assessment trials and involved the free movement of plant material between the institutions and conducting evaluation tests on cultivars nationwide. The ecoregional research center "Embrapa Cerrado" was created in order to develop agriculture in the Cerrado sustainably (Embrapa, 2015).

6.1.1.2 Creation of Special Programs: POLOCENTRO and Japanese-Brazilian cooperation program for the agricultural development of the Cerrado (PRODECER)

Encouraged by the great possibility of historically unprecedented increase in food supply due to the conquest of the Cerrado (Alves, 1980), the government invested in the creation of special programs. These programs, such as POLOCENTRO, established in 1975, were considered the main driving force of the development of agriculture in the Cerrado. POLOCENTRO aimed at "the development and modernization of agricultural activities in the Midwest Region and the western state of Minas

Gerais, through the rational occupation of areas with characteristics of Cerrado and their exploitation in enterprise scale". Its main instrument of incentive was the favored credit to whom wished to invest in agricultural business operating in selected areas (Roessing & Guedes, 1993), as confirmed in our interviewees.

It is also noteworthy the actions of Embrapa Cerrado, especially the partnership with Japan International Research Center for Agriculture Sciences (JIRCAS) in 1974, which aimed to agricultural development of cerrados. At the core of cooperation, it was established in 1979 the 'Japanese-Brazilian Cooperation Program for Agricultural Development of the Cerrado (PRODECER)'. Under joint administration of both countries, the program developed 345 000 hectares (1.5 times the size of Tokyo), representing investments of 68.4 billion Yen (US$ 684 million). PRODECER acted as a project pilot of agriculture of Cerrado and as 'basic development' of the vast agricultural frontier. The program contributed not only to the establishment of improving of techniques of production of the Cerrado, but also to the development of sustainable agriculture (JICA, 2011; Hosono et al., 2016).

6.1.1.3 Market Opening, Plant Variety Protection Law and Modern Biotechnology

During the 90s, Brazilian agriculture has undergone profound changes because of market opening through which the country was going through. Different impacts occurred in family farming - geared predominantly to supplying the domestic market - and in export agriculture (Duclós, 2014). An interviewee from the Directory Board commented about the role of the State at that time:

> Then, in the mid-90s with the rise of plant variety protection law in 97, the setting began to change. The soybean crop also started to have some greater prominence and began to economically attract the private sector. With that stronger presence of the private sector, the public agencies somewhat stopped participating in public research, technical assistance, and mainly in technology transfer. Then, as Emateres - the State Institutes for Rural Extension - started to get weaker, the cooperatives started a close relationship with the private sector and grew apart from public institutions.

It is important to remember that the first adhesion of Brazil to international agreements took place in 1995, its agreement to TRIPS. Only in 1997, after the country becoming a member of OMC (in 1995) and in compliance with the TRIPS, the country enacted the Law No. 9456 or "Plant Variety Protection Law" (PVPL), which established the mechanism *sui generis* of plant variety protection.

Thus, before this, due to the lack of regulatory framework in Brazil that ensures the rights of breeders of new plant varieties in Brazil, there was no interest from private companies to invest in the developing of new and improved seed varieties adapted to the domestic market. This situation completely changed after the promulgation of the LPC. Another important law of this period was the Law No. 8,974, of 01.05.1995, the Biosafety Law.

After we explained the changes at the national level, let us see the actions of Embrapa when facing these changes.

6.1.2 Responses of Embrapa: Conquest of Cerrado and increase of soybean production

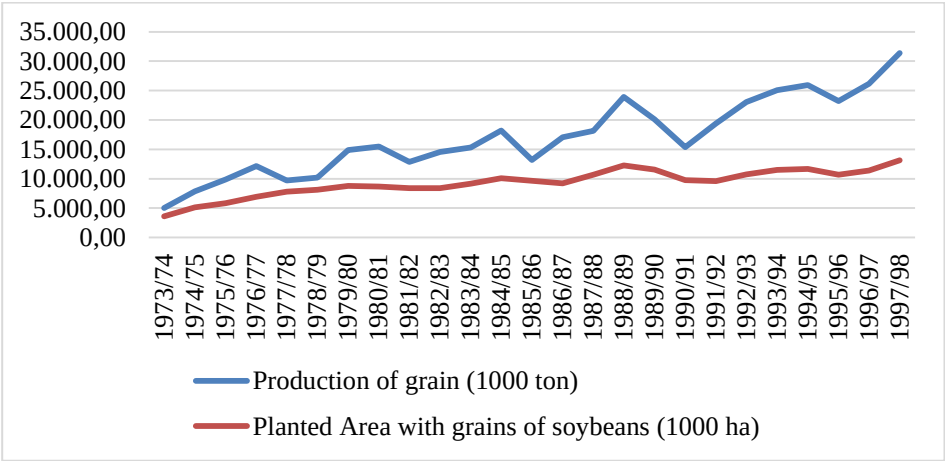
At first, Embrapa Soybean made a strong partnership with american institutions - mainly universities and the Agricultural Research Service (ARS) of U.S. Department of Agriculture (USDA), since the culture was already advanced in the USA. These companies brought the knowledge base, allowing the early evolution of the soybean crop in Brazil more significantly. As mentioned by a respondent, “Big consultants, great american researchers, came here basically to introduce the soybean crop in the most economical way in Brazil. They brought selected cultivars, adapted to our condition as well as soil and crop management practices that have allowed us to take the first step”. The next step of Embrapa Soybean was to invest strongly in capacitation, abroad mainly. The number of researchers between 1975 and 1981 jumped from 14 to 51. Considering just researchers with master or PhD degree, the increase was of 8 to 47 in the same period. As result of the investiment on these learning mechanisms, Embrapa Soybean was able, at first, to adapt the american seeds hitherto developed for some regions of Brazil. Next, the company itself develops its own cultivars.

However, in order to expand significantly the production of soybean, the country would have to make use of new planting areas, such as the Cerrado, which makes Embrapa faces important technological chalenges. Perhaps the biggest one was the problem of nitrogen fixing, since nitrogen is the most required nutrient by soybeans (Embrapa, 1984) and, therefore, a main element for high productivity. Nevertheless, the characteristics of the soil (microflora) of Cerrado – e.g. traces of elements, very high aluminum – brought additional difficulties for liming and fertilization and, in consequence, to fix nitrogen. As mentioned by a respondent, Embrapa and its associates was able to solve the problem through biological nitrogen fixation, which allowed producing soybean in new edaphoclimatic conditions not only of Cerrado, but in other areas. Some authors strengthen the

relevance of this finding by saying that "Embrapa converted our bigger passive into an asset" (Delfim Netto, 2015). As a result, it was possible to increase the Brazilian production of soybean, as well as the yield, as can be seen in Figures 3 and 4, respectively.

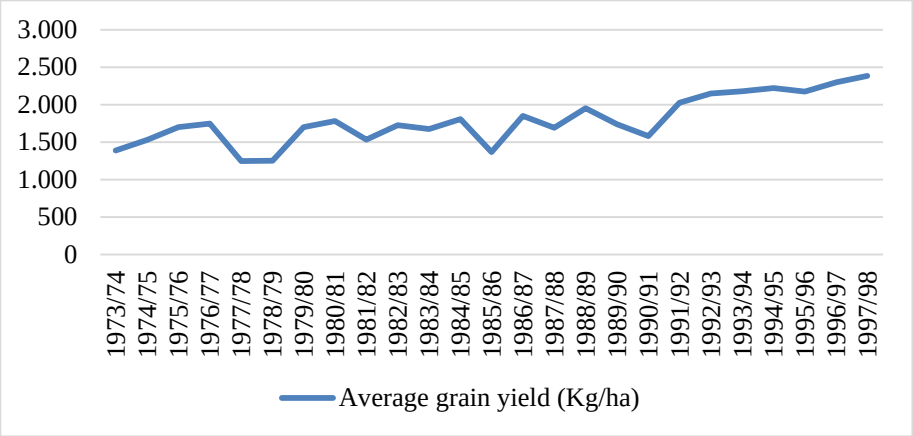
Therefore, regarding the technological trajectory followed by Embrapa, it moved from a 'path-following' to 'path-creating'. First, Embrapa just adapted the american cultivars to edaphoclimatic conditions of the South of Brazil. Later, beyond developing its own cultivars with similar quality compared with the best cultivars in the world, Embrapa made feasible the biological nitrogen fixation that led to the conquest of the Cerrado and forwarded the country to become a major producer and one of the major world's soybean exporters.

Figure 3 - Evolution of soybean production and planted area with the grain in Brazil (1973-1997)



Source: Own elaboration based on data from Conab and IBGE (Annual Technical Report of the National Soybean Research Center - 1973, 1974 and 1975). Acess in 10/30/2015.

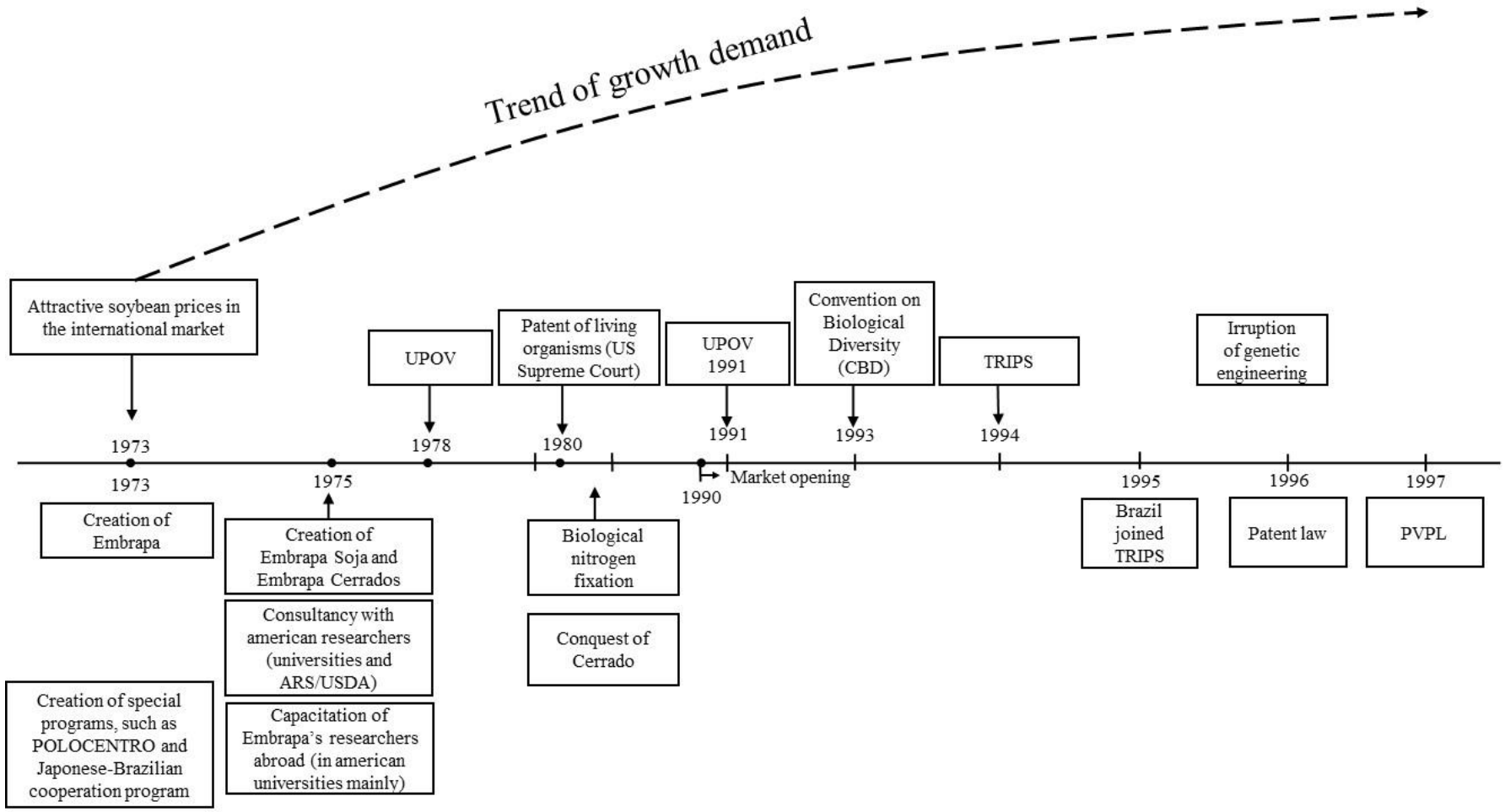
Figure 4 - Evolution of average soybean yield (Kg/ha) from 1973 to 1997



Source: Own elaboration based on data from Conab and IBGE (Annual Technical Report of the National Soybean Research Center - 1973, 1974 and 1975). Acess in 30/10/2015.

The Figure 5 presents the main events happened between 1973 and 1997.

Figure 5 -Timeline of changes in the industry from 1973 to 1997



Source: elaborated by the author based on the literature and interviews.

6.2 From 1998 to 2015

The period between 1998 and 2015 presents a completely different industry history. Let us first see the responses at national level in the investigated period concerned the three windows: institutional, of demand and technological.

6.2.1 Responses at National Level

From 1998 to 2015, we observed important responses of the State with regard to institutions aspects.

6.2.1.1 Institutions

Brazil has signed the Act of the UPOV Convention 1978 in 1999, becoming member of UPOV from this year. The first Brazilian Plant Varieties Protection Law (PVPL) entered into force in 1997. It was based on the 1978 convention, but having incorporated elements of the 1991 Convention (Fuck et al., 2007), including the concept of essentially derived varieties. Other important national laws for the sector enacted in the period (and that are into force nowadays) are: the Law No. 10.711 of 05/08/2003 that regulates the National System of Seeds and Seedlings (which replaced and revoke the old Seed Law - Law No. 6,507, of 12/19/1977), and the Law No. 11.105, of 3/24/2005, the so-called Biosafety Law (which also replaced and revoke the old Law No. 8.974, of 01/05/1995). Beyond this, it can be mentioned the Convention on Biological Diversity, promulgated by Decree No. 2519 of March 16, 1998, and that regulates about the access to genetic resources, the protection and access to associated traditional knowledge and the sharing of benefits for conservation and sustainable use of biodiversity.

6.2.1.1.1 Restrictive Characteristic of National Laws

The government has been lagging in elaborating important laws for the Brazilian seeds sector. Moreover, the Brazilian legislations in general are considered little modern and restrictive, which have affect the development of the sector negatively. As mentioned by the Coordinator of the Agribusiness Center Getulio Vargas Foundation and former Agriculture Minister Roberto Rodrigues, “it is not just a problem of official government policy, but of changing laws that are obsolete and, above all, society’s acceptance” (EBC Brazil Agency, 2015). Rodrigues still noted

that logistics infrastructure and transport, income policy and policy trade are the major bottlenecks to further expansion of Brazilian agribusiness, which does not depend of the Ministry of Agriculture (MAPA).

An example of slowness that affected strongly the Brazilian seeds sector was due the legal restrictions in accepting genetically modified seeds. Around 2001 or 2002 smuggled seeds coming from Argentina to the South stormed the country. The irruption of these genetic seeds changed the demand in qualitative terms in the Brazilian seeds sector (see section 6.2.2.1). At that time, a number of other companies had engaged with biotechnology, and had done their networks in a strong way. Meanwhile, as pointed our research findings, the orientation from the government to the company headquarters of Embrapa was in the sense of not investing in modern biotechnology and in the development of GMOs. According a respondent from the Products and Market area of Embrapa, at that period, Embrapa had perhaps the best technicians in biotechnology in comparison to any company both in national and international levels. However, a stand-by of three of four years was enough to had brought difficulties to Embrapa to be part of this segment in a competitive way.

The Law of Access to Genetic Resources, even after the review she passed through, is another national law also considered by a respondent from the Directive Board of Embrapa very restrictive. According him, “the country will not be able to compete with other countries, and this is one of the main obstacles to research in Brazil”. Other criticism observed coming from some economists of Brazil was the decision of the federal government to invest in multilateral agreements such as Mercosur and the non-realization of bilateral agreements, which occurred in many countries.

6.2.1.1.2 The problem of pirate seeds

A huge problem faced by the Brazilian seeds sector – perhaps the most critical nowadays - has been the use of pirate seeds. The Brazilian legislation (based on the UPOV Convention of 1978, which Brazil is part of) allows the so-called “farmer’s privilege”, that is, that the farmer saves an amount of seeds for their own use in the following year and does not require permission from the rights holder on the farm. Therefore, the farmers do not pay royalties on its use. However, the “farmer’s privilegie” has been misused. As explained by an interviewee from the Technology Transfer of Embrapa Soybean: “Some farmers do not only supply itself illegally (amount greater than allowed by law), but also supplies the other”. This practice has gained such proportions – and since the fuel of the breeding program are the royalties - that has been cited as a problem that can potentially

leave out of the sector the only company outside Embrapa, essentially Brazilian that is developing varieties. In fact, in harvest 2014/15 in Brazil, the percentage of saved seeds was 13% (7% in North and 20% in South). The State with bigger percentage of saved seeds is Rio Grande do Sul, reaching 40% while 60% is of certificated seeds (Kleffmann Group, 2015).

At this point, it is important to observe the huge unbalance between the IPR based on patents (transgenic events) and the IPR based on sui generis mechanisms (genetic breeding). While companies of conventional plant breeding face great difficult to be successful in appropriating its technological innovations, the companies that invest in transgeny are rewarded through technological rate. As explained by an interviewee from the Seed Technology area of Embrapa Soybean, if the producer does not prove that had paid at the time of purchase of seeds, upon delivery of seed for export ('moega'), exporting firms (e. g., Bunge, DM, Cargil) do a test for genetic modification. If the result is positive, the producer has to pay 7% for the company that had developed the transgenic event, Monsanto usually.

6.2.1.1.3 Outlay of Embrapa

Beyond the restrictive laws, other relevant decision in the level of Federal Government that affected the sector greatly was about the outlay of Embrapa. Alves and Oliveira (2005, p. 75) examined the outlay (dispêndio) of Embrapa between 1975 and 2003 and, based on calculation of rates of return, found out that "investing in Embrapa is a great deal for the government, compared to other options". Nevertheless, the author noted that investments at Embrapa have been reduced since the 1990s, which did not occur with other areas that have had their budgets very enlarged. The fall of investment in Embrapa relative to the agricultural GDP was detailed in this way:

> In 1978, five years after (Embrapa have been) deployed, this ratio equated to 0.77% and jumped to about 1% in 1981 and 1982. Between 1983-89, the relationship remained in the range 0.65 to 0.84. In the period 1990-1993, the relation expenditure (dispêndio)-GDP agricultural exceeded the 1% mark. It is close to 1% in 1996-1998, when it comes into freefall and reaches the level of 0.55% in 2003, a level which is lower than that achieved in 1978, 0.77%, when the EMBRAPA had five years of life (Alves & Oliveira, 2005, p. 76).

After we examine the changes at national level, let us investigate what happened at the level of Embrapa.

6.2.2 Responses at the level of Embrapa

Many changes affected directly Embrapa and therefore required changes in the way Embrapa acted.

6.2.2.1 Institutions

At the level of Embrapa, its internal regulations are also old and restrictive. As mentioned by an interviewee from the Directive Board of Embrapa Soybean, “The rules of Embrapa are from 2000 or a little earlier, as soon as it was promulgated the Intellectual Property Law. However, the context of that time was very different and today these regulations no longer allow competing fairly in the market that is very competitive”. According to the interviewee, the company is discussing several proposals in order to get more flexibility, especially in its partnerships. For example, to work with private companies in the development of genetic material in early phases of the breeding program, be charged decreasing royalties due to the seed purchase volume.

In fact, for Embrapa, to be flexible is urgent. As mentioned before, the strategy of transnational companies includes swallowing everyone. It also includes the influence on the composition of Foundations and participation of its members. Despite the decrease in the number of Foundations is not necessarily bad - since Embrapa together with other Foundations may encompass other members and therefore meet the demand of other states -, the model of partnerships with foundations do not seem to be enough to compete in the current context of great competitiveness.

6.2.2.2 Demand in qualitative terms

In qualitative terms, important changes related to demand also happened.

6.2.2.2.1 Smuggled Seeds from Argentina

As mentioned before, one of the most relevant event that is worthy of note is the smuggled seeds from Argentina. A respondent from the Department of Business of Embrapa explained that, besides the fact of being transgenic, other technological characteristics of the seeds seemed to please the local producers: its precocity and its growth habit - that was indeterminated - that adapted well in the region. As mentioned by one respondent from the Technology Transfer area of Embrapa Soybean: “... now the new varieties that are coming out meets the preference of the farmer; they are plants with different architecture with indeterminate habit”.

At this point, we consider crucial to clarify that, despite the existence of two separate markets - genetics and transgenic events (or 'traits'), they are closely related. Companies of genetics, such as Don Mario (and more recently Embrapa), for instance, make partnerships with companies of 'traits' in order to insert them into their seeds. Since the smuggled seeds from Argentina were transgenic when came to Brazil (when GMOs was forbidden in Brazil), at that time Argentinean companies had already established partnerships with biotech companies and built their networks. This very relevant aspect contributed quite a lot to the reduction of the market share of Embrapa in the Genetic market.

Although the bigger number of companies geared towards developing cultivars to the Brazilian seeds market[4], almost all of them are transnational companies. However, with few exceptions - such as Don Mario, as well as Embrapa and TMG which have conventional program -, large companies no longer produce material other than GM). According a respondent of the Directive Board, TMG, despite continues in this market, is threatening to quit.

Considering the so-called 'germplasm market', nowadays more than 50% of the Brazilian soybean cultivars market is in the hand of GDM group (Brasmax and Don Mario) and Nidera, which are the large companies in the Brazilian seed sector. Next, with relative market share, are Syngenta and Monsanto. According to a respondent from the Directive Board of Embrapa Soybean, Embrapa and TMG are the only eminently Brazilian companies operating in the soybean cultivars development sector. However, its market share is currently small.

Beyond the care about independence and sovereignty of the country (see section 6.2.2.4), Embrapa also consider other risks, such as severe or potential dangerous illnesses, when developing their cultivars. This implies to invest on plant health or preventive improvement against diseases, different from many private companies whose focuses are just on productivity. As mentioned by a respondent, Embrapa question itself whether it should decrease its focus on tolerance to diseases, and put the focus only on productivity, i.e., "forget all the energy expenditure that the plant do to be resistent and put all this expenditure of energy for she be more productive, as everyone is doing". However, even considering the possibility of being badly evaluated due to lower participation in cultivars market, the option of Embrapa was to continue providing sustainable alternatives to producers that ensure profitability, to look after the preservation of the productive system in the

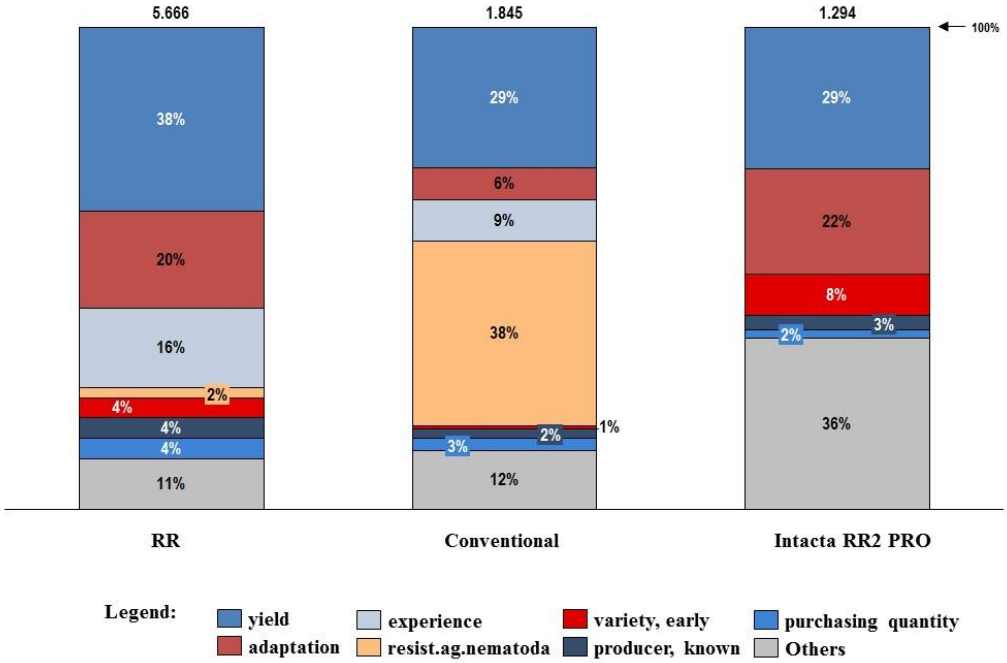
[4] By early 2000, there were 3, 4 companies that developed cultivars. Today we have around 30 or 40 companies.

long term and of the preservation of the environment. This attitude results in confidence in Embrapa by different actors of the sector, as mentioned by a respondent, “interestingly, when there is a problem in the field (even using cultivars of other companies), the farmer comes into contact with Embrapa”. In order to reduce risks, the company has conducted numerous trainings with the participation of large number of private enterprises professionals, including transnational corporations. As mentioned by a respondent from the Seeds Technology, “The staff working for these companies that are our competitors - Syngenta, Pioneer, Bayer, Basf, Monsanto - are already here and we do not close the door for them; this is the function of Embrapa, because what we want is a soy with quality for producers”.

6.2.2.2.2 Prevalence of transgenic seeds in the Brazilian market

In order to know precisely the reasons why producers opt for genetically modified seeds, we sought this information with Kleffmann Group (see Figure 10).The reasons for cultivations of biotech informed by productors are yield, adaptation, previous experience, early variety, known producer and purchasing quantity. Although these reasons are also important for producers that invest on conventional cultivars, the resistence to Nematodes is the number one concern, as can be observed. As can be inferred, beyond technological factors, producers take into account other factors directly related to commercial approaches (see Figure 6). Thus, considering that transgenic events do not increase productivity, we may consider some possibilities to the farmers’ decision: perhaps the producers are misinformed, or they are not believing that other technologies different from transgenic events may give them high productivity or, yet, as we said before, they just want commoditiy and security.

Figure 6 - Reasons for cultivation biotech – Seed Soybean Brazil



Source: Kleffmann Group (2015)

Therefore, we do not fully agree with the statement that "the most innovative ones (firms), which have managed to bring to the market each year improved varieties highly demanded by the domestic farmers, have managed to gain dominant positions in the market..."(Andersen et al., 2015, p. 78-79). In our opinion, these conditionings are necessary, but not sufficient. First, it is important to analyse what exactly means "to launch new varieties each year". According many of our interviewees, often the differences that there is between one cultivar and another is very small, almost nothing. Often they are thrown carelessly, without proper testing and with cycles (of the cultivars) getting increasingly shorter. The dwindling life cycle of products (launch of new products to replace the older ones) is another similarity of the seeds sector with traditional sectors of technological complexity, but this not necessarily imply in higher quality. Our findings revealed that there are much more things involved on the choice of the cultivars than the quality of them. As examples, we may mention the commercial approach of transnational companies, which includes financing of producers and sales distribution (see section 6.2.2.2.3).

Based on two important indicators of innovation in the seeds sector, Andersen et al. (2015, p. 75) questioned the argument that few MNCs (the six Gene Giants) "have been the main seed suppliers,

have driven the process of seed innovation, and benefited from the expansion of the agricultural sector in Argentina". The authors used 'the number of new plant varieties registered' (and sold) and 'the market share of new varieties' to conclude that this argument is not true for the Argentinean seeds sector. Although we did not examine this sector, given the similarities of the two countries, we believe it is safe to come to some conclusions. In our opinion, it is absolutelly truthful that Don Mario has been able to take advantage of the new opportunities opened by the expansion of the Argentina seeds sector and "have done so despite of the massive diffusion of transgenic events controlled by a few MNCs" (Andersen et al., 2015, p. 79-80). It is important to clarify that meanwhile the six Gene Giants also took advantage of the sector's expansion. The same happened in the setting of Brazil when both Embrapa and the six Gene Giants took advantage of the new opportunities opened by the expansion of the Brazilian seeds sector. However, the success of the domestic company (in the case, Don Mario) does not mean that the six Gene Giants - the main suppliers of transgenic events - are not driven the process of seeds innovation. We may surely affirm that in the setting of Brazil these companies do are driving the process of seeds innovation. An important indicator is the rapid development of the use of transgenic seeds in Brazil, which increased from 2% of the total of planted area in 2001/2002 to 93% in the harvest of 2014/2015. In our opinion, even these companies have interest in pursuing partnerships most of time, they are in the control (both in Argentinean and Brazilian seeds markets) and they decide in which market they are interested in, the time to enter into and to go out and also the direction of the sector. For example, perhaps due the problems of appropriation of innovation efforts, it seems reasonable that they could not be so much interested in the genetic seeds market as before.

6.2.2.2.3 Commercial Approach of Transnational Companies of 'Traits'

Another important aspect that has influenced the demand in qualitative terms was the commercial approach of the companies of 'traits', an aspect also quite mentioned by some interviewees and a cause for concern.

The companies of 'traits', beyond offering a 'package' (seeds plus chemical products), finance the crop, getting on with a percentage of it after the harvest. They offer a range of amenities, which "in a way could cause the farmer to become loyal to a particular product or company", as explained by a member of the Department of Business of Embrapa:

> A while ago I got this information, Monsanto had authorization from its board to invest US$ 1 billion to support the marketing process in Brazil, and support the marketing process did not mean only marketing (read up advertising or disclosure), but use negotial and financing mechanisms to facilitate the sale of products and the understanding by the producer that his life could be facilitated.

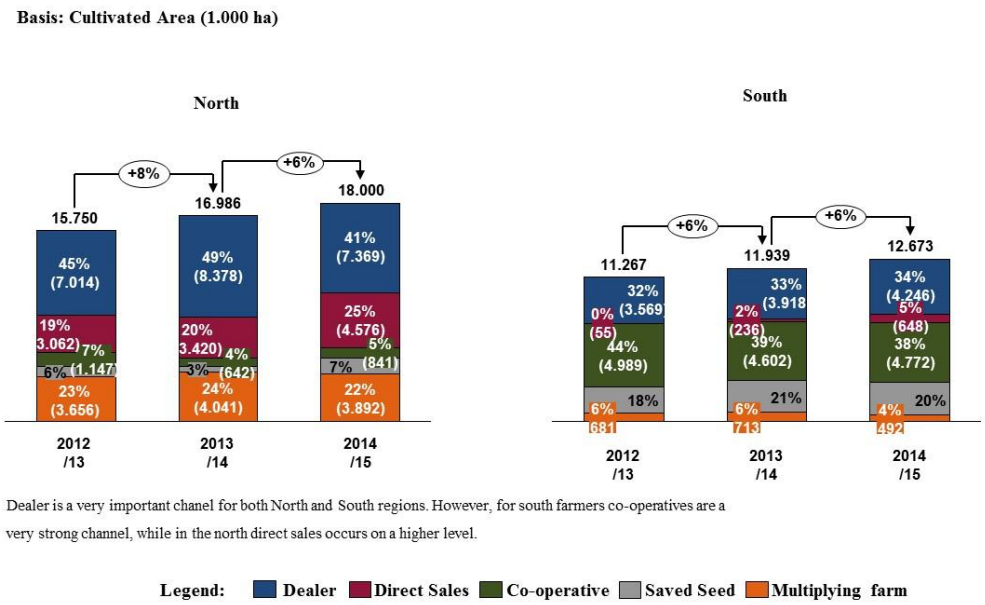
The main reason for concern stems from the 'system of verticalization', as called by a respondent from the Directory Board. "…In the moment that many producers are financed by the companies, it became an employee of that company; sometimes when he realizes, it's late, it has been swallowed".

As sugested by an interviewee from Department of Business of Embrapa, the 'logic of product' has virtually prevented that materials developed by Embrapa can grow in the market. In contraposition with the difficulty of Embrapa to reach the local producers, the strong interaction of the transnational companies with them is another characteristic of the commercial approach used by companies of 'traits'. The trust generated due the proximity between producers and transnational companies allied with deceived information provided by the latter is a complicating factor for Embrapa. Interviewees from the Directive Board of Embrapa Soja explained this fact in this way:

> We can visit, for example, the producer and come up with the information to the producer once every two or three years, and others can reach that same producer, three, four times a month. So, in whom does he trust?

Kleffmann Group highlithed the relevance of sales distribution, drawing attention to the importance of different sales channels in different regions of the country (see Figure 7). According the Kleffmann Group (2015) "dealer is a very important chanel for both North and South regions of Brazil", accounting for about 41% of sales in the North and 34% of sales in the South. "However, for South farmers cooperatives are a very strong channel (having represented in 2014/2015 about 38% of the total of sales distribution in the South), while in the North direct sales occurs on a higher level (having represented in 2014/2015 about 25% of the total of sales distribution in the North".

Figure 7 - Importance of Sales Distribution (North and South)



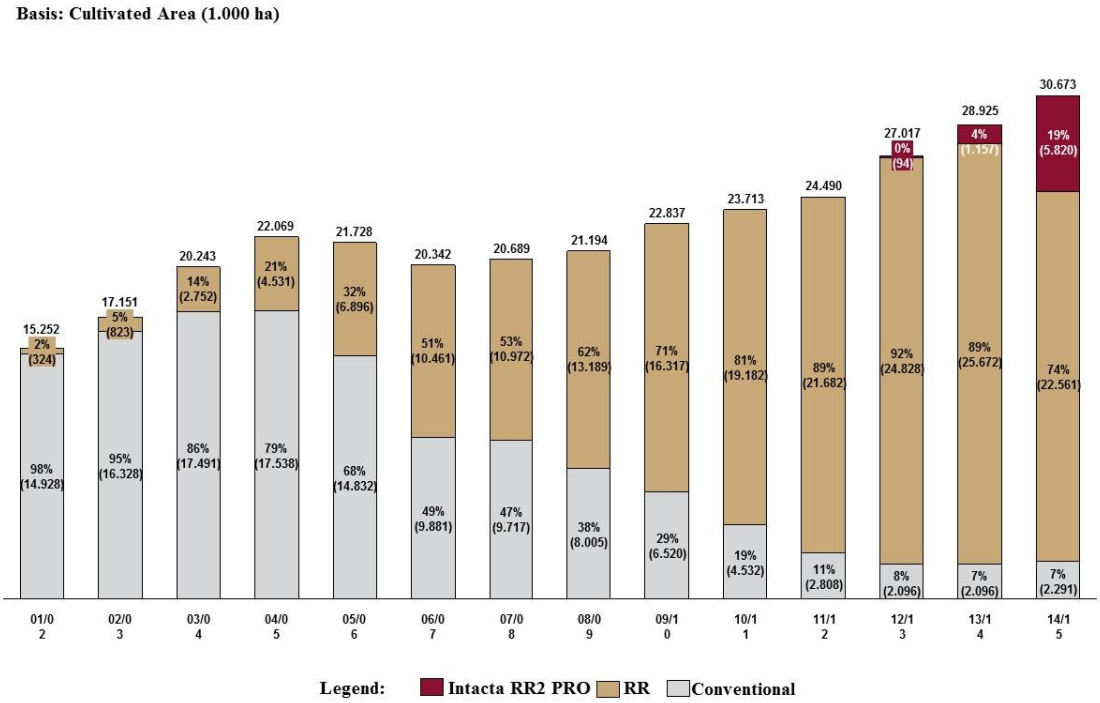
Source: Kleffmann Group (2015)

As mentioned by an interviewee, beyond productivity and susceptibility to disease, these answers are commonly mentioned as reasons of abandonment of variety: “problem with the distributor”, “I did not have availability in my city” and “I bought these varieties in the past, but this year my cooperative did not put it”. Another important industry feature, as mentioned by a respondent is that “the soybeans are very regional, each state has two major brands; and then he (the farmer) seeks a third to test but he can not plant so much, this it is quite evidente”. Thus, there are much more complexity involved on the sector and this is what cause uncertainty about the future of the companies from the developing countries in face of the forces of the transnational companies.

A respondent from the Directive Board of Embrapa Soybean told us that some consultants and producers are faithful to what Embrapa says. “These professionals are getting along, and they do not want to change”. He complemented: “But to gain new adepts is not easy. Based on the nature of our business, we have to have a work ethic, be very faithful to reality, to the truth, tools that others do not use”. Although some parties are starting to become aware of the risks of dependence to transnational companies, the demand for Embrapa’s cultivars nowadays – that is growing slowly – may be considered still reduced.

The fact is that security and amenities brought by the transgenic events to the crop production in point of fact not only pleased farmers, but, as affirmed by a respondent from the Department of Business: “the presence of these events has been a conditioning for acceptance of cultivars by farmers”.

Figure 8 - Evolution of cultivated area with transgenic seeds (2001/2002-2014/2015 harvests)



Source: Kleffmann Group (2015)

As we see, there were only transgenic soybeans tolerant to the herbicide glyphosate with technology Roundup Ready (RR) – both RR and Intact RR2 PRO - developed by Monsanto. This technology occupies in 2015 93% of the soybean market in Brazil. The so-called “big six”(or Gene Giants) - Monsanto, Dupont and Dow (USA), Syngenta (Switzerland) and the German BASF and Bayer – are companies of traits that introduced all authorized GM crops for commercial cultivation in Brazil.

The main response of Embrapa to the predominance of transgenic seeds in the Brazilian seeds market came in form of partnerships with transnational companies of ‘traits’, since Embrapa could not afford to the high costs of producing, identifying and regulating their use within and ouside the country. As mentioned during the interviews from Technology Transfer area of Embrapa Soybean, Embrapa has nowadays four transgenic programs in partnership with transnational companies. In the case of Basf, the transgenic events were developed together (and still are). Thus, the problem of

being not competitive in “package”seems to begin to be solved (or at least minimized) in the moment that the company launches its first transgenic cultivar in partnership with Basf, the “Cultivance”, herbicide resistant. Embrapa receives the gene and incorporate it into their varieties from other companies of ‘traits’.

6.2.2.2.4 Asymmetry of Information

Another relevant factor that hampered the market share of Embrapa is the asymmetry of information. While the transnational companies year after year buy rich information from a world leader consulting company in strategic information to the agribusiness segment[5], Embrapa had bought this kind of information just once or twice. Among others, the company offers information about planted area of agriculturist (current and a forecast for the next harvest); forescast about technology to be used (if conventional or transgenic) and, in case of transgenic, which kind (if Intacta or RR); which culture besides soybeans the agriculturists produced in that year (safrinha, summer corn); about varieties (which varieties the agriculturists planted that season, which technologies, the level of his satisfaction with the varieties, the reason for choice, which varieties the agriculturists bought on the previous harvest and the reason for abandonment); planting density; price paid for seeds and royalties; the amount produced in that harvest or expectactions to produce and also information about the agricultural pesticides market (amount of pesticides used in each variety). This kind of information given to the companies who bought a huge strategic advantage in terms of knowledge related to demand (in both quantitative and qualitative terms) and, in consequence, in terms of which direction its R&D should follow.

6.2.2.3 Demand in quantitative terms

Regardless which actors are being the most successuful in terms of market share, what seems to be most important is to discover which contributions the companies are bringing to the Brazilian seeds sector, to the Brazilian crop productivity and soybean export. Embrapa has always played (and already does) an extremely important role in the Brazilian agricultural seed sector. Even when Embrapa develop its own seeds, the company is thinking in the producer and in the sustentability of the sector (see section 6.2.2.4). As explained by a respondent, “it’s not Embrapa who earn, but the

[5] This information is sold by Kleffmann Consulting firm for leading private sector companies, which account for about 90% of the Brazilian market.

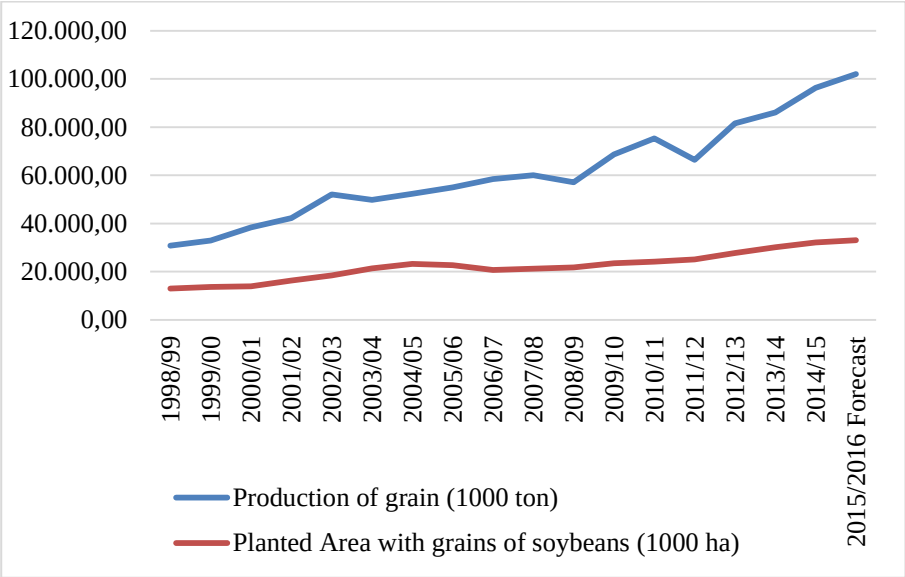
seed producer that is gaining a lot from the seeds of Embrapa due its limited availability but its high quality".

In line with the growing global demand, data about production, planted area (Figure 9) and yields (Figure 10) of soybean in Brazil show significant improvements of all these indicators. The Brazilian production of soybean in 1998, however, was yet mostly directed towards the domestic market. While the production of the 1997/98 harvest was 31,370 (in mil ton), the domestic consumption was 22,400 and the exportation just 9,287.70 (Conab, 2015). The 2014/15 harvest registered very different numbers. The producion in this period was 96,243.3 mil tons and, while the domestic consumption was 44,639, the total exports for the 2014/15 crop were 50,800 (in mil ton) (Conab, 2015). It is important to register that the forecast for 2015/16 harvest surpasses 100,000 mil tons.

According to the Foreign Trade Secretariat (Secex), in June 2015, Brazilian exports reached 9.81 million tons, the highest monthly export value ever (Conab, 2015b; Secex, 2015). In June 2015, the Conab registered the second record of soybean productivity achieved in the country - 3,016 kg / ha, only surpassed in the 2010/11 season that was 3,115 kg / ha. The productivity in 2015 registered a superior percentual variation of 5.7 in relation to 2013/14 harvest.

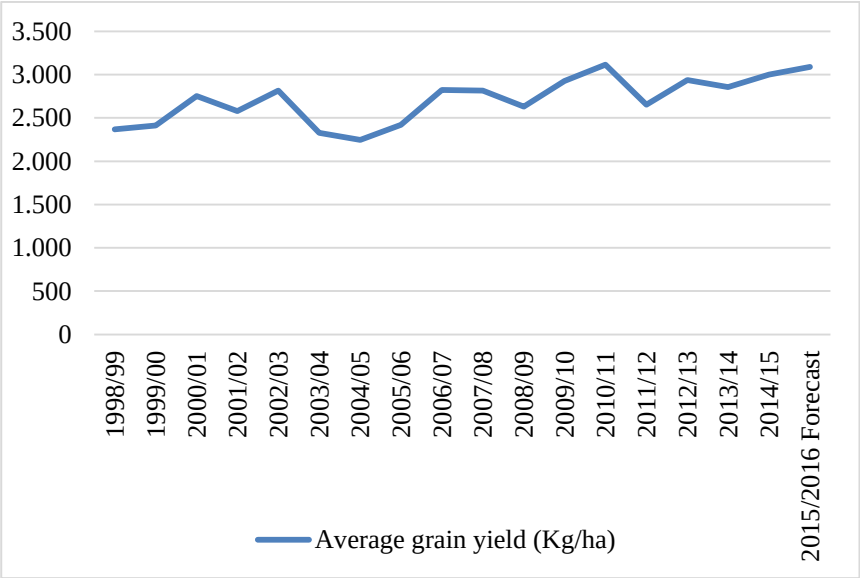
The percentual variation of both production and planted area was also positive in 2014/15 harvest in relation to the previous harvest of 5.8% and 11.7%, respectivelly. Thus, the production achieved 96,222.10 mil ton and planted area 31,908.3 mil ha (Conab, 2015b). As mentioned by a respondent from the Directory Board, "The yield potential is not reached, but the productive potential continues to increase ..."

Figure 9 - Evolution of production and planted area of soybean (1998-2015)



Source: Own elaboration based on data from Conab. Acess in 10/30/2015.

Figure 10 - Evolution of average soybean yield (Kg/ha) from 1998 to 2015



Source: Own elaboration based on data from Conab. Acess in 10/30/2015.

The expectation for the future is also very favorable to Brazil, as can be observed in Table 1.

Table 1 - Largest exporters of soybean in the world - projection for 2024/25

Countries	Exportation (million tons)	Share of world trade
Brazil	69	45.9
USA	50.2	33.4
Argentina	12.4	8.2
Other South American countries	11.2	7.4
World	150.4	100.0

Source: USDA, February 2015

6.2.2.4 Technologies

As can already be inferred, it is important to analyse the contributions of technologies in a broader way, considering both their potentialities and the sustentability of the sector in the long term. Moreover, we must also analyse it from different perspectives, not only from the perspective of productor, but also from the final consumer perspective.

First, it is important to say that Embrapa, as a public company, has different interests of a private company. While private companies focus on activities that give short-term financial returns, Embrapa unfolds in many different activities and technologies[6] to fulfill its role as "regulator" of the sector, as explained by an interviewee from the Directive Board of Embrapa Soybean.

> While we have to do genetics (together with other activities), we spend effort. We do genetics more for the country's security question to prevent suddenly all fall into the hands of a few. So even we do not have a market, because we have not primarily the tools that today the market uses to make material available, we are still investing, investing heavily in genetics. We spent a period in which we had trouble, but today our genetics is as good as or even better than that of the partners, what we lack are other tools to put this genetic in the market, and we see it more as a way to regulate the market... The role of Embrapa we say today is very much a regulatory role, precautionary role to prevent tomorrow or after a very large verticalization problem, this is what we are.

Therefore, the role of regulator in this case was not related to the setting of maximum prices for the market, but leaving Brazil prepared to "in the case of an external action or of creating a monopoly

[6] As example of these technologies, beyond development of cultivars, there are: crop rotation, crop-livestock-forest integration, soil management, integrated pest management, diseases, weeds, crop management, tillage enhancement techniques, fertility correction, seed technology, use of inoculants, biological nitrogen fixation and preventive improvement against diseases.

or an exaggerated verticalization, Brazil has conditions quickly to supply and meet this demand". In other words, "to preserve the sovereignty of the country in sourcing and supplying high quality genetics and competitively".

The case of Helicoverpa armigera clearly illustrates the need to take care for the sector's sustainability, as explained by one respondent from the Directive Board of Embrapa Soybean:

> Recently we had that Helicoverpa problem, everyone came running to apply product, to do emergencial importation, to do emergencial register of product..., importation of products from all that was place. We began researching and found that the Helicoverpa caterpillar was controlled by natural enemies. If put or did any treatment with insecticide, they killed the natural enemy and increased the population of Helicoverpa. Then we started recommend not to apply, but we were seriously and hardly questioned. They stayed on call (chegaram a fazer plantão) in our experimental areas to see if we were not lying that we did not apply anymore. Really, they confessed...

The Embrapa's interest in invest not just on higher productivity – unlike many private companies – reflected in the characteristics of the cultivars Embrapa. For example, they are resistance to major disease and to nematodes, as mentioned in our interviews.

> Our genetic material, our cultivars continue with the same pattern of resistance to major diseases, we also have resistance to nematodes; then it is a differentiated material, the producer knows it. Often he wants to buy, but the 'package' is not there. So it's not easy, it's a tough market, very complicated...If we observe today, especially that material that comes from the US, which goes to Argentina and come here to Brazil, it has no resistance to major diseases. Diseases that had been eradicated in Brazil are beginning to reappear...

We also question the argument present at Andersen et al. (2015, p. 69) that according to studies, "a substantial proportion (that varies from 50 to 90 per cent) of crop' yields increases is explained by improved seed varieties (other are the diffusion of better agronomic practices, or combination of both)". Our findings point in another direction. As mentioned by an interviewee, "...the main factor of great productivity is not genetic, but it is the management, soil management, crop manegement... what makes the difference to industry". The argument of bigger productivity of transgenic seeds (in comparison to conventional seeds), although widespread, also does not convince us. We are convinced that through biotechnology it is possible to reduce losses, but not to aggregate

productivity. In fact, the potential productive is in genetics. As observed by another respondent from the Directive Board of Embrapa Soybean: “Despite the speech that GM gave great productivity leap, in fact everyone who is in the industry nowadays knows that with the conventional material it is possible to produce much more than with GM, but has an entire media ... the other companies have money to make merchandizing”.

Concerning the final consumer perspective, we can see two diferent interests of this group of actors that seems to be obvious, both related to health. The first one is the potentialilty of transgenic seeds to act as a medicine, a vaccine or to have a high nutritional quality, what is already happening in some countries, as mentioned by a respondent from the Department of Business of Embrapa. The second is the benefits for health due to limiting the amount of use of agricultural pesticides. It seems to be obvious that limiting the amount of use of agricultural pesticides would please them, independently if the soybean will be for human or animal consumption. This has been an arduous task for Embrapa. Despite its attempts, the company has achieved only relative success.

In this sense, although the huge potentiality of the modern biotecnology route, especially the transgeny, in practice there are just two strands in the Brazilian seeds market nowadays: mechanisms to control weeds and mechanisms for pest control, as explained by a respondent from the Department of Business of Embrapa.

Moreover, the much-vaunted reducing of use of herbicides and insecticides due to the use of transgenic events did not materialize. In fact, what we see often is an indiscriminated use of both herbicides and insecticides by some producers in order to ensure their production. This practice has cause, at least, two important bad effect. One is the dependence of small (and medium) producers with regard to transnational corporations due the high costs (of insumes) - especially herbicides and insecticides. The other is the inducement of nature to develop resistant species, plants and/or insects. An interviewee from the Department of Business corroborated this idea:

> Considering the condition of the Brazil you have agriculture 365 days a year, the possibility of these things (resistence) happen faster. While in the US you have one crop per year ... here we have three crops in the year ... this means the rate at which these things happen, which is growing plant, that is growing insect, that you are applying product to control, you increase what we call selection pressure. Some individuals will overcome that barrier and that generates a problem. So if you do not have manoeuvre strategies suitable of these biotechnological events, you can lose their efficiency quickly, and the advantage they would have relative to a conventional material is lost ... Early in the application of biotechnology in relation

> to the plant had a preconceived idea that if it were used, their problems be solved ... Actually, it is not so.

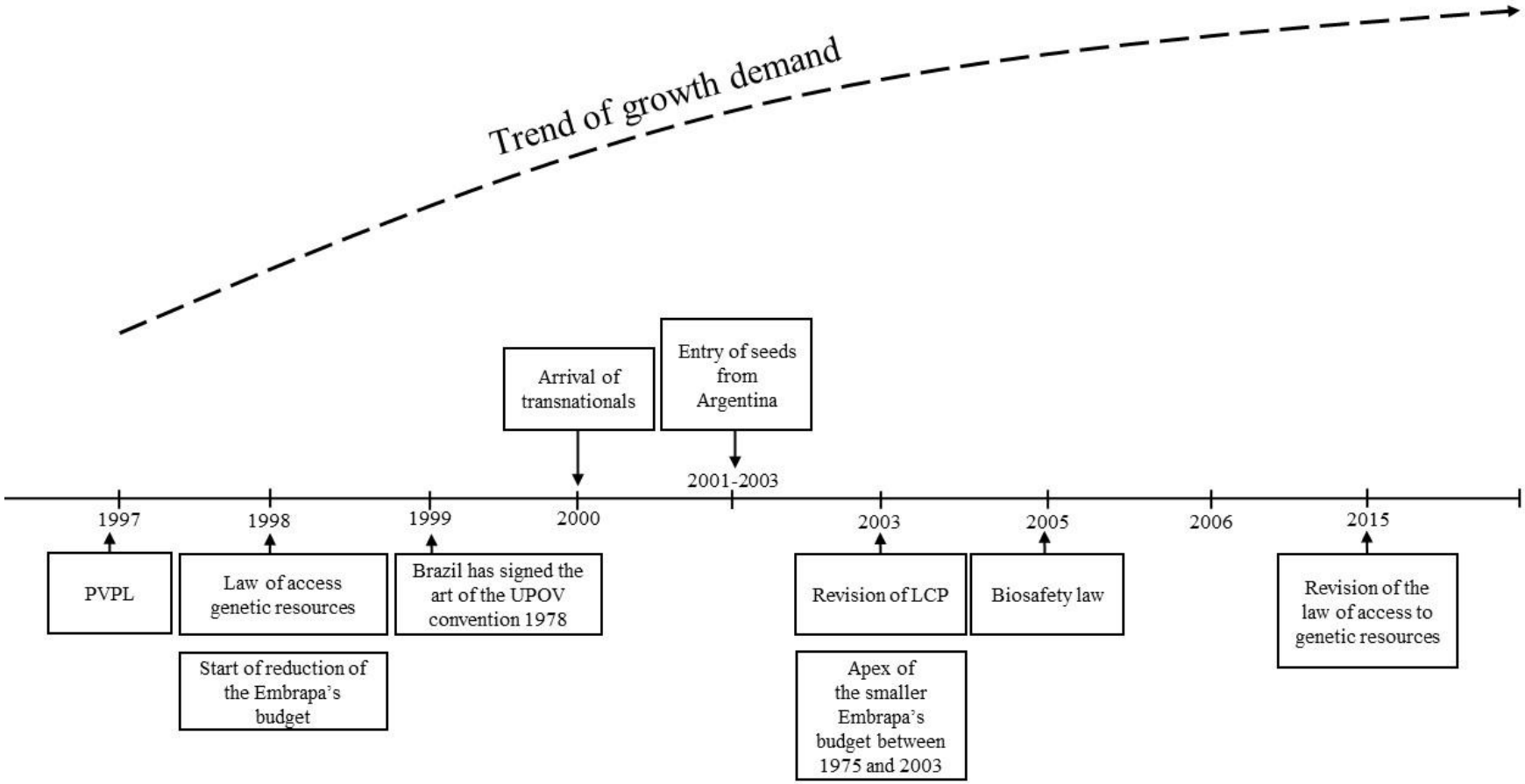
In consequence, we can say that the transgeny in Brazilian seeds sector benefits exclusively or mainly the farmers and not the industry or the final consumers, as found in interviews.

Concerning the technological capabilities of Embrapa, it seems to be evident that Embrapa is on the technological frontier at conventional technological route. Although Embrapa does not have a big market share nowadays, its cultivars have similar levels of productivity and, perhaps, higher levels of protection to disease and nematodes than the most cultivars used in the market. Regarding the modern biotechnology route, Embrapa has some disadvantages, such as the quantity of people involved with biotechnology[7] and of machines and equipment (level of automation and robotization consequently) that is much smaller than the transnational companies. Moreover and more important, the capacity of financial investment of these companies is much bigger than Embrapa. Despite all this, through partnerships established with large private companies of biotechnology, Embrapa has been able to provide also GM seeds of equal quality to the best in the market. Be noteworthy, yet, the high level of knowledge of Embrapa professionals in biotechnology, similar to those of private corporations.

The Figure 11 presents the main events happened between 1998 and 2015.

[7] "Embrapa Soybean has around ten professionals including researchers and support staff currently involved with biotechnology".

Figure 11 – Timeline of changes in the industry from 1997 to 2015



Source: elaborated by the author based on the literature and interviews.

7. DISCUSSIONS

7.1 From 1973 to 1997

As we have seen, between 1973 and 1997 there were major changes in the "demand dimension" (increase in soybean prices in the international market), in the "technological dimension" (as the irruption of genetic engineering) and also in the "institutional dimension" worldwide (important international agreements).

In the level of Brazil, there are many evidences that point to the demand as the main motivating factor of innovation not only of the creation of Embrapa (also Embrapa Soybean and Embrapa Cerrados), but also of its responses/strategies until the creation of the Plant Variety Protection Act in 1997. Initially, it was the large domestic demand and, next, the attractive soybean prices in the international market. From 75 to the early 2000s, the presence of State in Brazil was very strong. At that time, there was quite a strong public investment in agriculture, with extension activities with State research institutes. Embrapa's response to the investments of the government could not have been more appropriate. Embrapa invested mainly in two mechanisms of learning - consulting and capacitation abroad -, which allow that the company moved from a 'path-following' to a 'path-creating' trajectories and to conquer the Cerrado. The achievement led the country to increase its soybean production and reach the status of one of the major producers in the world. This discover also opened a promising avenue for researchers from around the world.

Concerning the regulatory framework at global level, important discussions related to appropriation of innovation efforts has occurred in the period, resulting in relevant agreements. Among the most important are: the 1978 and 1991 UPOV Convention, the authorization from the US Supreme Court to patent living organisms in 1980, the Convention on Biological Diversity (CBD) in 1993 and the TRIPS Agreement in 1994.

In the setting of Brazil, the country's openness to the global market occurred from the 90s. In 1995, Brazil became member of OMC and in the same year the country signed the agreement on TRIPS. Next, Brazil enacted its Patent Law in 1996 and its Plant Variety Protection Law in the next year,

1997. With the possibility of appropriation of innovation efforts in the Brazilian seeds sector, the Brazilian market started attracting the interest of private companies.

Although the irruption of genetic engineering had an effect on Brazil around mid 90, the country did not invest on the area immediately.

7.2 From 1998 to 2015

From 1998 to 2015, the main global changes that affected the Brazilian seeds market were the arrival of the transnational companies (around 2000) and the entry of seeds from Argentina in the South of Brazil (between 2001 and 2003). Beyond the always-growing demand, the irruption of the Genetic Engineering around mid-90 allied with the IPR regulations were the main forces that motivate the entry of the transnational companies, changing completely the context of the Brazilian seeds sector. Thus, demand, technology and institutions (perhaps technology has motivated the IPR regulations) contributed to innovation efforts.

In the level of Brazil, beyond the country has signed in 1999 the Act of the 1978 UPOV Convention, the government invested on its domestic legislations: the Law of Access to Genetic Resource in 1998, the revision of its Plant Variety Protection Law in 2003, the Biosafety Law in 2005 and the revision of the Law of Access to Genetic Resources in 2015. However, in general these laws are considered rather restrictive and not very modern, limiting the actions of Embrapa and other national companies. Other decision of the State that in some way affected the company was the reduction of its budget (investment in Embrapa) since 90s, reaching the lower apex in 2003: 0.55% of agricultural GDP in a crucial moment, when strong transnational companies were arriving to Brazil. Moreover, even though Embrapa gathered a large group of experts in biotechnology at the time, because genetically modified organisms were banned in the country, the guidance was that the company did not invest in biotechnology. Our findings indicate that ideological contours guided this decision. The same have led to our legislation be so restrictive. As somebody say, technology is ideology. The entry of GM smuggled seeds from Argentina in the South of Brazil forced the State to revise its position. However, a stand-by of 3-4 years while transnational companies (both genetic and biotechnology companies) were builting their networks in a strong way were enough to bring difficulties for the company.

Although the advances in legislation both in global and national contexts, the problem of appropriation of IPR in the seeds sector persists, but only in the genetic market. Similarly to Andersen et al. (2015), we advocate that the plant certificates on innovation activities are not being duly effective in appropriating the innovation efforts in plant breeding programs (conventional seeds). The use of pirate seeds, considered by many actors of the sector one of the major problems for the genetic market nowadays, is strong evidence. The unique company essentially Brazilian, apart from Embrapa, that are involved with genetic is threatening to leave the market of conventional seeds (genetics). Thus, a decision taken in the 1st UPOV Convention (and which is in force until now) that should theoretically protect small farmers, in practice appears to make not only the life of breeding companies more difficult, but also the Brazilian genetic market.

However, the opposite surely happen concerning the innovation efforts related to transgenic events. Besides being easy to detect transgenics, there are strong surveillance and proper charging concerning their use. Since it is not possible to carry out tests proving that the producers are making use of pirate seeds and there are much more ways of making enforcement and charge upon event than upon cultivars, companies who work with conventional plant breeding are at extreme disadvantage with regard to the appropriation of technological innovations, since. Moreover, considering the diferences of domestic laws and the high prices of patenting, we can say that if on the one hand IPR contributes to technological innovation, on the other in some extent, in a practical way, it is acting as a protection of market against those who do not have conditions to bear the expense of patenting[8]. Thus, unless small and medium-size companies from developing country make partnerships with transnational companies, they probably would be left out of the transgenic seed market.

We advocate that the transnational companies of traits (The Gene Giants) dominated not only the so-called ‘traits market’, but the whole sector of agricultural seeds. The evolution of the cultivated area with transgenic seeds gives good evidence about this dominance in Brazil. It is important to be noted that the offer of soybean is almost entirely transgenic. The market for conventional seeds, therefore, has become a niche market. In fact, transnational companies dominate the food chain from the production of seeds, fertilizer and pesticides to the logistics, transport an export.

[8] The costs of complying with regulatory biosafety requirements and the costs of patenting can reach levels up to 10 times higher than those connected with developing the new transgenic event (Andersen et al., 2015).

The reasons for the dominance of Gene Giants are many. As examples, we may present a not exaustive list: (i) commercial approach of transnational companies, which includes financing of producers; (ii) asymmetry of information among companies (privileged information obtained through the acquisition of high-priced consulting); (iii) high-prices of complying with regulatory biosafety requirement and the costs of patenting and (iv) influence of lobby groups which often take advantage of weak governments. Furthermore, as can be inferred, although prohibited in Brazil, the practice of combined sale (venda casada) of products is sorely adopted in the Brazilian seeds market, since this rule is circumvented by alternative business practices, for example in the form of discounts. Once local producers are often undercapitalized, it is easy for the companies of 'traits' retain their customers and therefore grow in the Brazilian market. As we said before, although widespread, we strongly do not share the opinion that transgenic seeds are more productive.

If we think objectively, perhaps it is safe to say that, the farmers were not asking specifically for transgenic seeds, at least those that are being used in Brazilian seeds sector aimed only to protect against pests and diseases. What seems that they wanted (and still want) were safety and convenience. Perhaps public policies geared towards minimize the risks of the producers (e.g., if crop insurance was amended in order to be similar to what happens in the US based on income or revenues) could minimize their interests on them. A more real insurance to cover producer deficiency moments could minimize verticalization by transnationals.

The positioning of Embrapa was ever in the sense of helping the producer and preserving long-term sustainability of the sector. Although it is not consensus among all industry stakeholder groups - since there are in the sector different groups of actors and therefore different interests - Embrapa acknowledges that there is an exchange between the public and private sector. To the extent that the private sector will take responsibility for developing soybean cultivars adapted to Brazil leading to greater productivity of Brazilian crops, the public sector tends to turn to other tasks. However, the company must prevent risks and take the market regulator role. This role must be understand in the sense of preserving the country's sovereignty in sourcing and supplying high quality genetics and does not mean control prices though. In other words, Embrapa must keep the country competitive for, if any extreme action, as creating a monopoly or an exaggerated verticalization, Brazil be able to quickly

supply and meet demand of the Brazilian producer. Embrapa, therefore, seeks to provide the producer with a range of alternatives capable of meeting your needs without dependence on any particular company, a single group, or international companies.

Thus, the success of Embrapa must be observed from a broad perspective. If on the one hand Embrapa lost participation in cultivars market, on the other the country continued to expand its soybean production largely because of their actions. According USDA (2015), the tendency is that Brazil in the next years be the world's largest producer of soybean, passing ahead of the United States. The projection with respect to exports is also favorable to Brazil. For 2024/25 it is expected that the country be in the first place, reaching to export 69 million tons, which represents 45.9 of the share of world trade (USDA, 2015).

Concerning the technological capabilities, we argue that Embrapa is on the technological frontier in both routes, since the company develop and offers with its partners both conventional cultivars and transgenic seeds with similar quality of the companies who are the leaders of markets (genetic and 'traits'). Moreover, Embrapa uses advanced bio-technological tools to develop new cultivars, such as crossbreeding relying on molecular markers. Embrapa also rely on a complex network of development and experimentation that spreads all over the regions in Brazil. Therefore, since the demand has maintained an upward trend for several decades, that there seems to not be significant differences in terms of technological capabilities between Embrapa and industry-leading companies, the institutions seems to be the force that both affected the sector in the pass and that have potential to influence the sector in the future.

We argue that because of different reasons - current dynamism of the sector, limitations of financial resources and numerous possibilities that are presented to the company mainly - Embrapa is facing a critical period nowadays, which requires a deep debate among stakeholders, scientific and academic community mainly. Concerning the range of alternatives to Embrapa, we can mention the possibility to act more strongly in partnerships with private companies in the beginning of the process of genetic, or in modern biotechnology or both. Sometimes, even considering that it is impossible to compete in the same condition, it is important to keep up near of the technological frontier. Moreover, there is a need for the company develops its networks to replace the previous model of rural extension and

cooperatives. As appears to have happened earlier, the country does not deserve to take wrong decisions due ideologies. Conversely, they must be based on a scientific basis.

8. FINAL REMARKS

We observed in the seeds sector the phenomenon mentioned by Lee and Malerba (2014), in which new firms and countries emerge in international leadership of a sector and others decline. In the case, the new firms were large transnational private companies from chemical sector mainly which dethroned public companies that usually drove innovations in the sector. The companies that nowadays dominated the sector are from USA, Switzerland and German.

In the long run evolution of the Brazilian seeds system, we witnessed the influence of the three windows of opportunity mentioned by the authors: 'changes in knowledge and technology', 'changes in demand' and 'changes in institutions and public policy'. However, their strengths differed over time. Between 1973 and 1997, changes in demand at domestic level and global level mainly were the primary force that drove innovations both in the global seeds sector and in the Brazilian seeds sector. While there was no commercial interest in the seeds, the theory of Product Life Cycle (CVP) seemed to be enough to explain the first phases of Embrapa. These phases comprised initially adaptation of american varieties to our conditions. Next, Embrapa developed its own varieties.

Later, in a more complex environment, CVP was no longer enough. We argue that in the case of Brazilian seeds sector, population size (related to the food security) and exchange rate (related to the interest in exportation) are very important macro variables that we have to consider. They help to explain demand surely, but they tell little, for example, about the capabilities of the companies that will make them able to take advantages of the windows of opportunities. The firms' capabilities, on the other hand, although helping to explain why one firm does better than another in the same setting, but not always include in their analysis relevant variables, such as institutions or other very relevant influent factors. In the context of the Brazilian seeds sector, institutions had (and already have) a huge influence. Despite criticism about the national innovation systems[9], this theory seems to go forward in

[9] Some criticisms are that: its concept is rather broad; the theory is descriptive rather than explicative; authors use different concepts for institutions; no understanding of dynamics; the action is elsewhere – networks, firms and individuals; does not

the sense of giving explanations on catching up in view of the complexity of today's world. However, an important feature of the national innovation system is that it uses the country as analytical level, that is, the national borders delimited it (Freeman, 1987; Nelson, 1993; Lundvall, 1992). Differently, the sectoral systems approach focuses on the nature, structure, organization and dynamism of production and innovation in sectors (Malerba, 2006). Thus, considering the global nature of the seeds sector, it seems that the variant of the NIS – the 'sectoral innovation systems'- has greatest potential to explain catching-up in the examined industry. Therefore, as mentioned by Lee and Malerba (2014), it is necessary to step forward.

In our opinion, the great advantage of the theory of catch-up cycles is that it allows that events from different levels may be contrasted, especially if they are analyzed longitudinally over a longer period. Although we did not observe in the Brazilian seeds sector successive changes in industry leadership (or catch-up cycles) – at the beginning of Embrapa's life, Embrapa were the leader in the Brazilian seeds sector and next (and now) the leadership seems to be with the transnational companies - the theory fits very well to analyse the sector. We believe that it made possible to explain why changes in industry leadership took place in the Brazilian seeds sector and to shed light on actual opportunities to catch up of domestic companies.

As main conclusion, we can say that developing countries seem increasingly dependent of institutions/public policies in order to catching-up, or even, to keep up near of the technological frontier. Due the sector's complexity and the imbalance of power between key players, it seems to be an urgent need a large debate between governants and scientific and academic community society in order to not only take advantage of opportunities, but to minimize imminent risks (or problems that already are reality). We cannot fail due limited and biased view again.

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includes in its analysis the users most of time; it is not operationalized in a concrete and consistent manner; and it is not not so good as a research tool and limited ability to offer policy advice (DRUID, 2013).

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ARTICLE 2: UNDERSTANDING THE DYNAMICS OF NETWORK STRUCTURES: ALLYING THE GROUNDED-THEORY TO SOCIAL NETWORK APPROACH APPLIED TO THE BRAZILIAN SEEDS SECTOR

ABSTRACT

The proposition of this study is to shed light on a gap previously identified in Powell et al. (2005) and later exploited in Ahuja, Soda and Zaheer (2012): the understanding of the origins and evolution of intensive network structures in knowledge; in other words, their dynamics. Specifically, this research has examined how and why networks centered at an R&D firm of a developing country have evolved to take the forms they do. In the process of addressing the research question, special attention was given to the various reasons why the public and private sectors seek to establish partnerships. The empirical setting chosen was the Brazilian agricultural seeds sector, but we focused specifically in the soybean breeding program at Embrapa, the main representative company of the sector. The underlying logic used to develop our theoretical framework was the grounded theory building. The research design is a longitudinal single-case, inductive study, but we also made use of the social network approach. Based on our research findings, we developed a theoretical framework to understand the dynamics of the networks. We found out different interests among the companies, which were changed over time, and different effects for each kind of network. Moreover, we confirmed the increasing relevance of interaction among organizational actors and important trade-offs between public and private organizations.

Keywords: Intensive network structures in knowledge. Network dynamics. Public-private partnerships. Social value. Seeds sector. Brazil.

RESUMO

O objetivo deste trabalho é lançar luz sobre uma lacuna previamente identificada em Powell et al. (2005) e posteriormente explorada em Ahuja, Soda e Zaheer (2012): a compreensão das origens e evolução das estruturas de rede intensivas em conhecimento; em outras palavras, seu dinamismo. Especificamente, essa pesquisa examinou como e por que redes centradas em uma empresa pública de P&D de um país em desenvolvimento têm evoluído para assumir as formas que elas possuem. No processo de examinar a questão de pesquisa, especial atenção foi dada para as várias razões pelas quais os setores público e privado buscam estabelecer parcerias. O contexto empírico escolhido foi o setor de sementes agrícolas do Brasil, mas nos focamos especificamente no programa de melhoramento de soja da Embrapa, a principal empresa representativa do setor. A lógica subjacente utilizada para desenvolver nosso arcabouço teórico foi a "*grounded theory*". O desenho de pesquisa é um estudo de caso único longitudinal, estudo indutivo, mas também foi feito uso da abordagem de rede social. Com base nos achados de pesquisa, nós desenvolvemos um arcabouço teórico para compreender o dinamismo das redes. Nós constatamos diferentes interesses entre as empresas, que mudaram ao longo do tempo, e diferentes efeitos para cada tipo de rede. Além disso, foi confirmada a crescente relevância da interação entre atores organizacionais e importantes "*trade-offs*" entre organizações públicas e privadas.

Palavras-chave: Estruturas de rede intensivas em conhecimento. Dinamismo da rede. Parcerias público-privadas. Valor Social. Setor de Sementes Agrícolas. Brasil.

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LIST OF ACRONYM

Name of organization	Acronym in Portuguese
Agrinatura Consultancy	AC
American Cyanamid Company	ACC
Agribusiness Technology of the Paulista Agency	APTA
ARC-Grain Crops Institute - Agricultural Research Council	ARC
Agriculture Research Service	ARS
Agriculture Research Service	ARS
Higher Education Personnel Improvement Coordination	CAPES
Education Centre Of Federal Technological Pellets	CEFET/RS
Photosynthetic and Biochemical Studies Center	CEFOB
Technological Center Agropecuario Del Paraguay	CETAPAR
Center Of Strategic Technology Northeast	CETENE
Centre Cooperat Int Rech Agron Development	CIRAD
National Council for Scientific and Technological Development	CNPq
Agricultural Research Center Cooperative	COODETEC
Sugarcane Technology Center	CTC
Technological Center for Research Agropecuarias	CTPA
D & F Armazens Gerais Ltda	D&F
DuPont Brasil	DuPont
Estacion Experimental Agroindustrial Obispo Colombres	EEAOC
Enterprise Technical Assistance and Rural Extension	EMATER
Brazilian Agricultural Research Corporation	EMBRAPA
Agronomy School of Paraguacu Paulista	ESAPP
Araucaria Foundation	FA

Support Foundation of the State of Goiás Search	**FAPEG**
Foundation Educ City Assisi	**FEMA**
State Agricultural Research Foundation	**FEPAGRO**
MS Foundation	**FMS**
MT Foundation	**FMT**
FUNDACEP	**FUNDACEP**
Guangdong Academy of Agricultural Sciences	**GAAS**
Hubei Academy of Agricultural Sciences	**HAAS**
Brazilian Association Action to Weed Resistance to Herbicides	**HRAC BR**
Agronomic Institute Ituto	**IA**
Agronomic Institute of Parana	**IAPAR**
Institute of Biosciences	**IB**
International Crops Research Institute for the Semi-Arid Tropics	**ICRISAT**
Federal Institute South Rio Grande	**IFSUL**
Rosario Agrobiotechnology Institute	**INDEAR**
National Institute of Agricultural Investigaciones	**INIA**
National Institute of Agricultural Technology	**INTA**
Paraguayan Institute of Technology Agraria	**IPTA**
Iowa State University	**ISU**
Jilin Academy of Agricultural Sciences	**JAAS**
Japan International Research Center for Agricultural Science	**JIRCAS**
Kazusa DNA Research Institute	**Kazusa**
LABEX USA Plant Biotechnol	**LABEX USA**
National Laboratory of Science and Technology	**LNCC**
Ministry of Agriculture, Livestock and Supply	**MAPA**

Ministry of Science, Technology and Innovation	**MCT**
Monsanto Brasil	**Monsanto**
National Institute of Crop Science	**NICS**
Nidera Seeds Ltd.	**Nidera**
Pioneer Sementes Syngenta Seeds	**Pioneer Syngenta**
Rothamsted Res	**RR**
Tropical Breeding and Genetics	**TMG**
University of Agricultural Sciences	**UAS**
University of Basel	**UB**
University of Bristol	**UB**
University of Cambridge	**UC**
University of Chiba	**UC**
Catholic University Brasilia	**UCB**
University of Durham	**UD**
Campinas State University	**UEC**
Campinas State University	**UEC**
State University of Londrina	**UEL**
State University Maringa	**UEM**
State University of Minas Gerais	**UEMG**
North Fluminense State University	**UENF**
State University Northern Parana	**UENPR**
Paulista State University	**UEP**
State University Santa Catarina	**UESC**
Union Super Nova Mutum Education	**UESNM**
Philadelphia University	**UF**

University Florida	**UF**
Federal University Alfenas	**UFA**
Universidade Federal Ceara	**UFC**
Federal University of Campina Grande	**UFCG**
Federal University Rio de Janeiro State	**UFERJ**
University Federal Espirito Santo	**UFES**
Federal University Grande Dourados	**UFGD**
Federal University Goias	**UFGO**
Federal University Lavras	**UFL**
Federal University of Minas Gerais	**UFMG**
Federal University of Mato Grosso	**UFMT**
Federal University of Pelotas	**UFP**
Federal University of Paraiba	**UFPB**
Federal University of Pernambuco	**UFPE**
Federal University Piaui	**UFPI**
Parana Federal University	**UFPR**
Federal University of Rio de Janeiro	**UFRJ**
Rural Federal University Pernambuco	**UFRPE**
Rural Federal University of Rio de Janeiro	**UFRRJ**
Federal Rio Grande do Sul University	**UFRS**
Federal Rio Grande do Sul University	**UFRS**
Federal University of Santa Catarina	**UFSC**
Federal University of Santa Maria	**UFSM**
Federal University of Sao Paulo	**UFSP**
Federal University of Uberlandia	**UFU**

Federal University of Viçosa	**UFV**
Federal University of Jequitinhonha and Mucuri Valleys	**UFVJM**
Federal University Valley San Francisco	**UFVSF**
Universidade Georgia	**UG**
Universidade Glasgow	**UGw**
Universidade Illinois	**UI**
University Kentucky	**UK**
University of Mississippi	**UM**
University of Missouri	**Umissouri**
National University of Asunción	**UNA**
University of Brasilia	**UNB**
North Carolina State University	**UNCS**
University Center Philadelphia	**UNIFIL Brazil**
University North Paulista	**UNP**
University North Parana	**UNPR**
University Newcastle Upon Tyne	**UNUT**
Rio Verde University	**UNV**
University of Ottawa	**UO**
University West Parana	**UOP**
Ohio State University	**UOS**
Purdue University	**UP**
University Paranaense	**UPR**
University Paranaense	**UPR**
Queensland University	**UQ**
Rio Verde University	**URV**

University Sevilla	**US**
United States Department of Agriculture	**USDA**
University Sao Paulo	**USP**
Institute Agronomico	**USP IA**
CEU San Pablo University	**USPablo**
Tsukuba University	**UT**
University Federal Tecnol Parana	**UTFPR**
Tokyo University	**UTk**
Wageningen University	**UW**
Waters Corp	**WC UNB UEC**

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INTRODUCTION

This study sought to help to fill the research gap on the understanding of dynamics of network structures. Specifically, this research has examined how and why networks centered at an R&D firm of a developing country have evolved to take the forms they do.

Beyond a greater understanding of network results (Ahuja et al., 2012), the relevance of the research stems from the need of understanding new organizational designs, as well as novel forms of public private interaction. Thus, in the process of addressing the research question, we examined the main reasons why, on the one hand public companies trying to generate social value to its society and on the other hand, private companies focused mainly on economic profits seek to establish partnerships among them. Particularly, we recognized the value mechanisms that were present on public private partnerships (PPPs) over time and how these mechanisms affected the changes in their designs and outcomes.

We developed our theoretical framework (including our propositions) based on the literatures of network and networks institutions - including the concept of "institutional complexity" developed by Greenwood et al. (2010) – and PPP. The underlying logic for this was grounded theory building. In order to get answers to our research question, we used as research design a longitudinal single-case, inductive study, allied with the social network approach and a framework developed in Ahuja, Soda and Zaheer (2012).

The empirical setting is the Brazilian seeds sector, which is very dynamic, both from a technological and institutional point of view and dominated by transnational private companies nowadays. We chose Embrapa as our research object, since the company combines multiple logics and is the main representative company of this industry. Beyond being responsible for coordinating the National Agricultural Research System (NARS), the company also offers its own seeds to the local market. It is important to be noted that the study's scope is delimited to the soybean-breeding program at Embrapa. Therefore, the networks and PPP presented in the research reflect this delimitation.

2 CONCEPTUAL BACKGROUND AND LITERATURE REVIEW

In this section, we discuss the conceptual background that were used in the research and make a short literature review.

2.1 Network, Public Private Partnerships (PPPs) and Institutions

There are two main research streams in network research, one examining the origns and consequences (Zaheer & Soda, 2009) of the overall network structure and the other investigating the particular influence of individual ties (Lounsbury & Beckman, 2015). Our study fits with the first group. The concept of organizational networks here may be understood as representations of the connections between organizations, as suggested in Ahuja, Soda and Zaheer (2012). Although we recognize that organizational units and individuals of informal networks may constitute different levels of analysis of networks, they are out of the scope of this study.

The benefits of networks, whether related to social benefits (Coleman, 1988) or private advantage (Burt, 1992) tend to depend on the network architecture and its evolution over time (Ahuja, Soda & Zaheer, 2012). As mentioned by Ahuja, Soda and Zaheer (2012, p. 435), "Understading how the architecture will evolve can help us predict and understand the changes in the distribution of benefits and constrains from the network. Thus, they help us understand the sustainability (or otherwise) of network-based advantages".

The network architecture comprises three primary elements: nodes (e.g., the number and identity), ties (e.g., its location, strength and content) and patterns or structures. The content – or the knowledge embedded in those network ties (Carnabuci & Operti, 2013) – is considered by scholars one of the most important characteristic of the network, since it is directly associated to innovative capabilities. However, in most cases, it is one of the biggest secrets saved by companies through confidentiality agreements. The patterns and structures of the networks are both related to characteristics or changings in the network itself, in the ties (or interconnections) among nodes and also in nodes. For example,

changings may occur as result of the addition or subtraction of nodes; from creation, dissolution or modification in terms of the strength or content of the ties (Ahuja, Soda & Zaheer, 2012); or from technological or negotial capabilities accumulation by the nodes. Examining the network dynamics may bring informations about the sources, types and/or implications of changes over time.

The characteristic of the PPP nodes brings many specificities to the relationships; for example (and perhaps the most important), the conflicts between economic and social interests. In this sense, examining how economic behaviour is embedded in a social context (Granovetter, 1985) acquires even greater relevance. As exalted in Lounsbury and Beckman (2015, p. 297), "Although it is widely accepted that embeddedness facilitates economic exchange (Uzzi, 1996, 1997), embeddedness may also result in biased decisions rather than better coordination that benefits both parties (Sorenson & Waguespack, 2006)". In other words, while some network theories advocated that networks facilitate coordination and cooperation (Granovetter, 1985), other studies about coordination across organizations (Schrank & Whitford, 2011) try to explain why networks fail (Lounsbury & Beckman, 2015). In this sense, the concept of governance here can be understood as an institutional arrangement (Coase, 1991) or the capacity of coordination and command of complex system (North, 1990). In other words, the "rules of the game in a society or, more formally, humanly devised constraints that shape human interaction", be it social, political or economic (North, 1990, p. 3).

The role of the institutions is crucial for the cooperation between firms and also for their outputs. If the institutions (in a global or national level) do not create incentives to cooperation or if incentives are inappropriate – inefficient by design or deliberately inefficient (Williamson, 1996) – the tendency is that the cooperations do not exist or that they do not last too much. Similarly, if the contractual design in the firm level is vulnerable or weak, one of the parties will be penalized probably, since there are opportunistic actions and contractual breaches. In consequence, the cooperations tend to finish also. The improvement of the governance requires the identification of institutional failures and organizational failures. They also require that the nature of the failures be understood and that actions be implemented in order to solve them. As mentioned by Zylbersztajn (2014), the role of the governance is almost indistinct from mechanisms for the generation of value and of control of value

capture by one party. This is a huge contribution for companies, sectors and countries that are interested in making longstanding partnerships.

For Greenwood et al. (2010), organizations face institutional complexity when they confront plural institutional logics, incompatible among them and refracted through field-level structures. The institutional complexity justifies the recent interest on institutional logics research by the scholars (Lounsbury & Beckman, 2015, p. 294). Due the "institutional complexity", the relevance to consider the influence of the institutional context inside organizations gained renewed strength more recently. The same is true when analyzing PPPs. When studying the agribusiness systems (SAGs), Zylbersztajn (2014) cited four dimensions that reveal the complexity of a system: internationalization; relationship with the society; diverse forms of regulation that the global SAGs are subject (at global, national and also firm level) and the use of finite resources. Two main potential institutional imperfections can occur: (i) the design of the institutions (that can be improper and generate disincentives for agents) and (ii) the failure to enforce the rules of the game (Zylbersztajn, 2014).

2.2 Agribusiness Systems (SAGs) and the Seeds Sector

Agriculture is the more dynamic engine of the economy in Brazil (Lopes, Sarti & Otero, 2014). The large productive chain of agribusiness – or agribusiness systems (SAGs) (Zylbersztajn, 2014) - represented 22% of the Brazilian GPD in 2014 (Barros, 2014). Since the value generated by the agriculture-based systems tend to be captured by the inputs sector and also by transformation, processing and distribution sectors (Zylbersztajn, 2014), it can be said that technological and organizational transformations in the Brazilian seeds sector are potentially relevant to economic and commercial conditions of the country.

Agricultural seeds are strategic inputs for agribusiness.The origin of the seed industry is characterized by the presence of specialized companies, limited to their home countries. However, this changed radically in the early 1980s when a wave of mergers and acquisitions among companies from different sectors - pharmaceutical, agrochemical and seeds sectors, especially - happened all over the world in

an intensive way. Growing demand allied with technological - the emergence of genetic engineering especially - and institutional factors - the evolution of the legal apparatus that ensured the appropriation of innovations - contributed to the interest of transnational companies.

Demand has long been recognized as a significant factor of influence upon innovation, especially in developing countries. Although the role of public demand for the development of the technology has been researched over a long period (Edquist & Hommen, 1999; Edquist et al., 2000), just more recently, significant efforts have been undertaken to unveil the specific role of demand on innovation (Malerba et al., 2007).

Concerning the technological factor, these large companies glimpsed two main opportunities. The first concerns the complementarities between the development of agrochemicals and the results of genetic improvement, that is, development of varieties adapted to chemical fertilizers and tolerance developed and marketed by chemical pesticides companies. The second is the potential expansion of economies of scope in the biotechnology research due to their multi-sectoral characteristics and due to the diversification of these companies towards the seeds industry (Carvalho & Pessanha, 2001).

Institutional factors also had a great influence in the dynamics of the sector. At the global level, the International Union for the Protection of New Varieties of Plants (UPOV) Conventions and the Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement had a crucial role pushing technological innovation. The UPOV Convention provided a sui generis form of intellectual property protection adapted for the process of plan breeding. The TRIPS agreement emphasized the protection and international trade. However, important problems of appropriation of innovative efforts remain due the two potential institutions imperfections mentioned by Zylbersztajn (2014) when faced with institutional complexity: both the design of the institutions and the failure to enforce them.

In the national context, the Biosecurity Act (1995), the Industrial Property Law (1996) and Plant Varieties Protection Act (1997) were probably the legal instruments that caused more effective impact in the industry more recently. However, it was the Plant Varieties Protection Act (PVPA) that is considered a “watershed” in Brazil, having stimulated private investment in the field of plant genetics

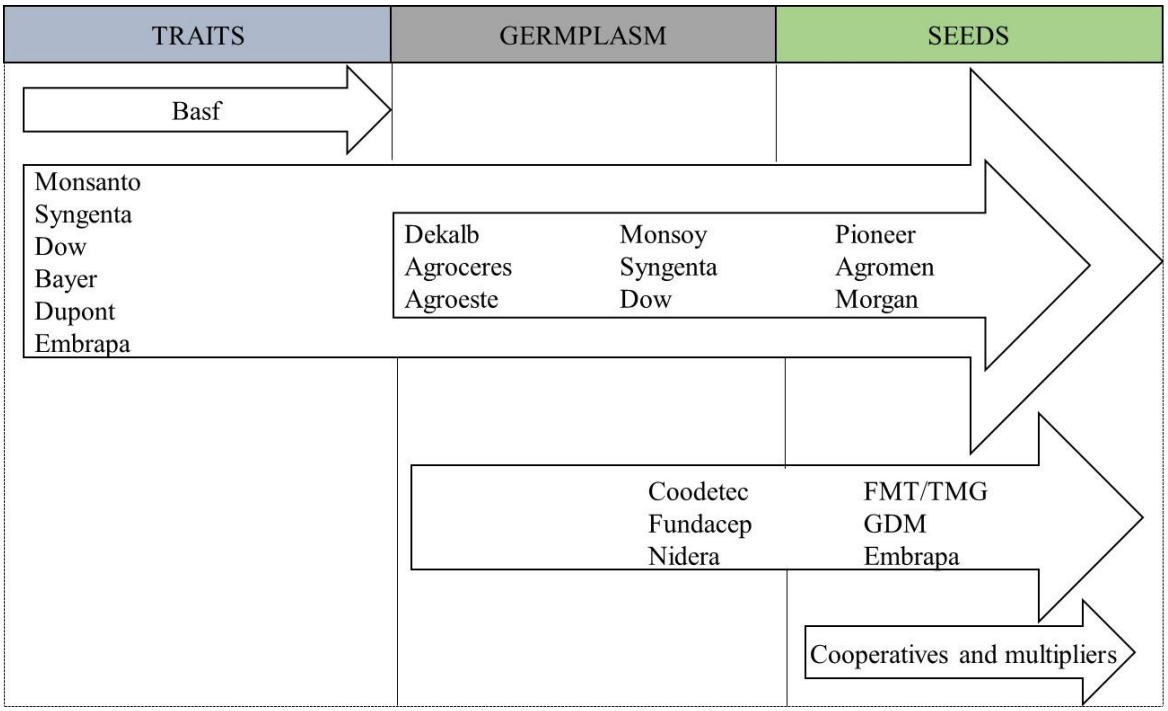
that produced immediate effect, as the acting of the private sector in the markets of varieties - before in the hands of public sector – and, according Zylbersztajn (2014), new kinds of contractual standards. These transnational companies made further heavy investment in biotechnology (transgeny).

In Brazil, there are two legal instruments dedicated to ensure protection of investments and innovations in the industry (property rights): (i) patents and (ii) the certificate of plant variety protection (sui generis mechanism). Although in other countries, as the USA, patents are used to protect transgenic cultivars, in Brazil since is prohibited the patenting of living organisms, the intellectual protection of transgenic organisms has been done through the Intellectual Property Law (IPL). Moreover, the protection made by patents is more effective and more lasting than the sui generis protection of cultivars made by sui generis mechanism (Yamamura, 2006). There are also problems related to the use of different legal instruments in different moments. For instance, a plant patented may be used to develop a new cultivar through conventional breeding (and vice versa) (Vieira & Buainain, 2004).

Nowadays, the seeds sector is global and also capital and knowledge-intensive. Companies of ‘traits’, germplasm and multipliers seeds interact among them (see Figure 1). Concerning the degree of industry concentration, the seed market can be characterized as an oligopoly (Moura & Martinelli, 2004; Bisang & Gutman, 2005; Varela & Bisang, 2006), where six companies, known as Gene Giants, control approximately 59.8% of the global market of commercial seeds and 76.1% of the agrochemical market. They are: Monsanto (USA), Syngenta (Switzerland), Dupont (USA), Bayer Crop Science (Germany), Dow (USA) and Basf Agroscience (Germany) (Thuswohl, 2013). The Gene Giants are also responsible for 76% of all private investment in the sector.

The Figure 1 shows the actors of the Brazilian seeds sector, which interact with each other.

Figure 1 - Relations in the Brazilian seed market



Source: Abrasem (2015)

Next, we describe the research method used to find out answers to our research question.

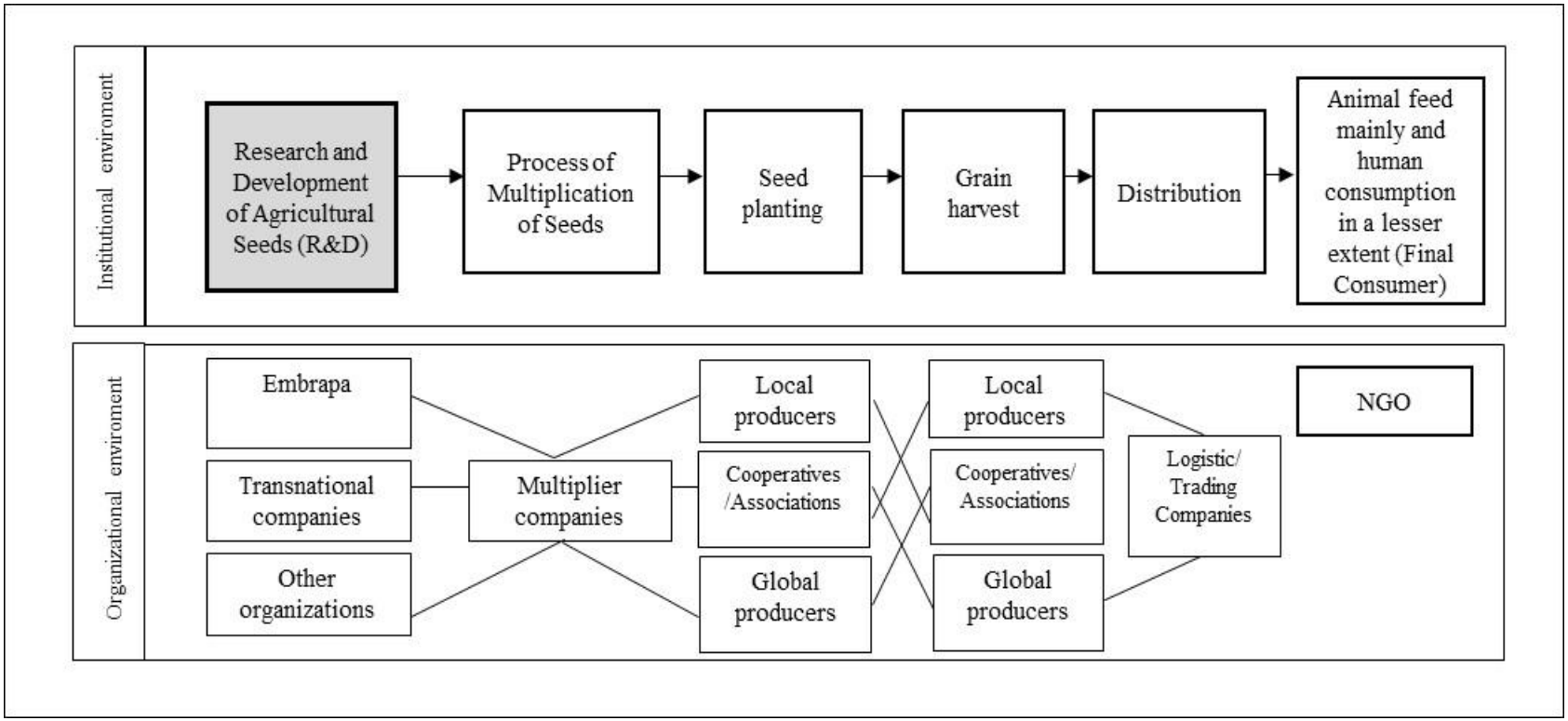
3 RESEARCH METHOD

This section presents the research setting, the research design and data collection and sources.

3.1 Research setting

The system of the seeds sector in Brazil comprises a great amount of actors: R&D organizations (agents of technological innovation), comercial organizations of seeds (agents of commercialization), multipliers of seeds (producers of seeds), agricultors and the final market (consumers). Figure 2 pictures this system in Brazil.

Figure 2. Systems of the seeds sector in Brazil



Source: Elaborated by the author. Adaptaded from Feltre (2004) and from Zylbersztajn (2014).

In our research we focus on the R&D process of seeds because it is the one that is most related with innovations outputs and also requires strong tecnological collaborations between different kinds of organizations, public and private ones. The R&D process of seeds requires especialized teams of researchers and is related to the creation of germoplasm banks and to activities of adaptability of these new varieties (cultivars[10]) to climate and land conditions. Since there are important differences in the process of R&D depending on the cultivar being developed, we focused on that one that has more relevance in economic terms to Brazil, the soybean. Thus, the study's scope is delimited to the soybean breeding programs of Embrapa

We choose the Brazilian Agricultural Research Corporation (Embrapa) to examine the evolution of its networks for many reasons. First, the mission of Embrapa is to enable research solutions, development and innovation for sustainable agriculture for the benefit of Brazilian society (Embrapa, 2016a). Thus, social values are the main important assets the company aims to generate. Second, since the creation of Embrapa in 1973 until now, the company has elaborated its business model in the form of networks. The company is responsible for coordinating the National Agricultural Research System (NARS), consisting of about approximately 122 organizations related to research in agricultural sciences, among federal public institutions, state universities, private companies and foundations. Third, Embrapa has the responsibility to transfer the technologies developed by it to the productive sector (Embrapa, 2016a). Finally, besides the numerous articles published about Embrapa, since 2001 the company has published its Social Balance. Therefore, there are sufficient data, which allow us to assess its innovative output and its contribution to the society.

3.2 Research design

The underlying logic of the research is the grounded-theory, which included inducting insights from both revision of the literature and fieldwork. Thus, our intention is not to prove a theory, but to present

10 “The cultivar is the result of improvement in a variety of plant that makes it different from the others in its color, size, disease resistance. The new feature must be the same in all plants of the same cultivar, maintained throughout the generations. Although the new cultivar be different from that which originated it, she can not be considered genetically modified, what occurs is a new combination of their own genetic material” (Brazil, 2016).

at the end our research propositions. Following directives from Davis and Eisenhardt (2011), Yin (1984) and Pettigrew (1990; 1997) mainly, we chose as research design a longitudinal single-case study. Conducting a longitudinal field research was necesssary in order to capture the dynamism of the networks of the company, its motivation and outcomes over time. We also made use of the network (Ahuja et al., 2012), both as a methodological tool and as a theoretical lens (Moliterno & Mahony, 2011). For this analysis, we use the R software version 3.2.1.

First, we looked for institutional and technological milestones (Pettigrew, 1997) after the creation of Embrapa in 1973. Since the arrival of the modern biotechnology is somewhat diffuse in terms of time, we decided to consider the Plant Variety Protection Act (enacted in 1997) as the main milestone to be considered in the analysis. This decision was validated during the interviews. Other milestone was the Biosafety Law, which entered in force in 2005. Thus, the first period of analysis was from 1973 to 1997, the second one from 1998 to 2005 and the third from 2006 to 2015.

Next, we initiated the systematic analysis of data. To identify the partners of Embrapa, we made use of the social network approach, based on the publications of Embrapa in collaboration with partners. Moreover, to examine the evolution (or changes) of the networks, we elaborated several relationship maps in chronological way, considering our milestones. We used the framework developed in Ahuja, Soda and Zaheer (2012)[11] to examine any model of network dynamics and that considered three dimensions: (1) the dimensions of network change, (2) the microfoundation of network change, and (3) the microdynamics of network change. Considering that our focus are on the ego-network level[12] (in our case, on the networks centered to the Embrapa), two dimensions of variance on tie patterns for the focal node are more relevant to be investigated – (1) its centrality[13] and (2) the presence or absence of structural holes[14], as suggested by the authors. Here, due the goals and nature of the thesis, we examined just the "centrality", leaving aside the "structural holes", since it would be necessary the

11 To a deep explanation of the framework and its concepts, see Ahuja, Soda and Zaheer (2012).
12 Ego networks is defined as the networks consisting of a single actor (ego) together with the actors they are connected to (alters) and all the links among those alters (Everett and Borgatti, 2005).
13 Degree of centrality: number of actors with whom Embrapa is directly related (Alejandro and Norman, 2005; UCINET, 2015) or number of direct links with other nodes (neighbors) (Vonortas (2013).
14 The degree of connectivity (or the lack of it) between a firm's partners (Burt, 1992) or the degree to which a firm's partners are linked to each other (Ahuja, 2000) or opportunities for bridging local clusters (Burt and Holmes, 1995).

development of mathematical modeling to measure them. The degree of centrality helped us to evince both the central role of Embrapa and other actors of the networks over time. Regarding the nodes, we considered in our analysis the number of nodes in the network, its identity, and the type of organization. As for the ties, we consider its location, strength and content, that is, what flows through them (Ahuja, Soda & Zaheer, 2012).

In order to find out the factors that made the organizations to invest in partnerships, or in other words, that explain changes in the networks, we made triangulation of data. They emerged, in addition to the information arising from the development of the networks, from data of the literature that were contrasted with qualitative data gathered in the interviews.

3.3 Data Collection and Sources

It is worth remembering that we examined knowledge networks developed by Embrapa in order to innovate in the R&D process of soybean seeds. Therefore, we seek to identify partners involved in this type of activity through innovation indicators. Although patents have been extensively used as a good indicator of innovation, the seed industry has some peculiarities, which limit its validity. For example, living organisms in Brazil, such as seeds, cannot be patented. Therefore, the patents have been used only as an instrument of appropriation of innovation efforts related to transgenic events (in the so-called 'traits' market), failing to consider innovation efforts in genetics market. It was for these reasons - and because of the difficult to get data in different way, such as partners of projects - that we decided to map the relationships of Embrapa based on publications written by the company and its partners, private or not.

The search for scientific articles was performed in two databases, Web of Science and SciELO Citation Index, both available via CAPES Portal.

The adopted search strategy was based on the combination of the company's name in the “organization” and keywords in the fields “title” and / or “summary” related to soy. We considered synonyms and relevant truncations. Initially, we made a search in SciELO, considering only synonyms

of soy and the name of the company. In this case, we recovered 576 publications, whose selection of relevant articles was made by reading the titles and/or summaries of them. From the analysis, we discarded subjects unrelated to the scope of the study.

In the next step, we analyzed 1,319 publications retrieved in Web of Science base. We excluded publications already recovered at the base of Scielo. After reading the titles and/or abstracts, we selected the relevant articles, which resulted in 299 articles that fit the focus of the study. Exclusively Embrapa, however, wrote some of them. As our focus is on partnerships, we disregarded them. Therefore, we found 224 collaboratively articles written over time, which constituted the sample publications and identified all the partner organizations of Embrapa through them. The partners of Embrapa was also classified in six groups: (1) universities and national research centers; (2) universities and international research centers; (3) international government institutions and agencies; (4) national government institutions and agencies (5) private national companies and (6) private international companies.

Data about publications of Embrapa (and its partners) were treated in Vantage Point®.

Beyond this data, in order to validate this data and achieve greater accuracy of results, we also used as secondary data industry and company reports, newspapers, data from web sites, materials provided by interviewees, among others.

The qualitative evidences, among others used to elucidate the reasons why the actors made partnerships, were collected predominantly in different areas of Embrapa and Embrapa Soybean through semi-structured interviews. In these companies, we interviewed professionals from multiple levels ranging from top management, to middle managers and to specialists (scientists, engineers, analysts, consultants, technical heads etc.). We also interviewed professionals from other organizations of the sector that somehow interact with the companies: Brazilian Association of Seeds and Seedlings (Abrasem), Agronomy Institute (IAC), Meriodional Foundation, Integrated Agroindustrial Cooperative, MT Foundation, Agribusiness Center at the Getulio Vargas Foundation, Center of Management and Strategic Studies (CGEE) and Kleffmann Group. We conducted 35 semi-structured

interviews over a year period with around 40 people. They lasted on average 60 minutes, but some of them took more than 3 hours. We generated over 488 transcribed single-pages of primary source material from these interviews.

To get a broader vision about the company and its strategies, we first visited Embrapa headquarters in Brasília. Next, we visited Embrapa Soybean in order to understand in detail the decisions and actions of the company. Then, to check the existence or not of other visions, we went to the other organizations. Finally, we came back to Embrapa and Embrapa Soybean to confirm our evidences and to solve some doubts.

We strategy of selection of the interviewees was based on the choice of specialists initially. We confronted the research goals and the functions exerted by the Embrapa professionals in areas previously selected. Both professionals from the directive board, managers from middle level and supervisors, analysts, engineers, assistants, technicians, experts and researchers made part of our sample. Next, we used the snowball strategy to select other professionals to be interviewed.

3.4 Procedures for the analysis of the empirical evidence

Based on Miles and Huberman (1994), we did the analysis of empirical evidence collected. Initially, we carried out the data cleaning activity. Then we performed the data reduction, ie selection, simplification, abstraction and transformation of the original data. Later, the data were organized in narrative texts, matrices, charts, etc. schemes to allow conclusions. Finally, we seek to identify patterns of answers, explanations and possible relations of cause and effect between the variables investigated (data interpretation).

4 THEORETICAL INSIGHTS AND RESEARCH PROPOSITIONS

In this section, we present our research findings. First, the evolution of the knowledge networks centered at Embrapa (ego-network), that is, how networks have evolved to take the forms they do. Next, we tried to explain the reasons for this evolution and to present the motivating factors that lead companies in the public and private sectors to enter into partnerships with each other.

4.1 Examining the Evolution of the Networks: structural analysis of the network and data triangulation

The six following maps show the evolution of networks centered at Embrapa over time – organizations (or partners of Embrapa) and types of organizations –, considering the three investigated periods: (i) before the PVPA (1973-1997) and after the PVPA, (ii) before the Biosafety Law (1998-2005) and (iii) after its enaction (2006-2015).

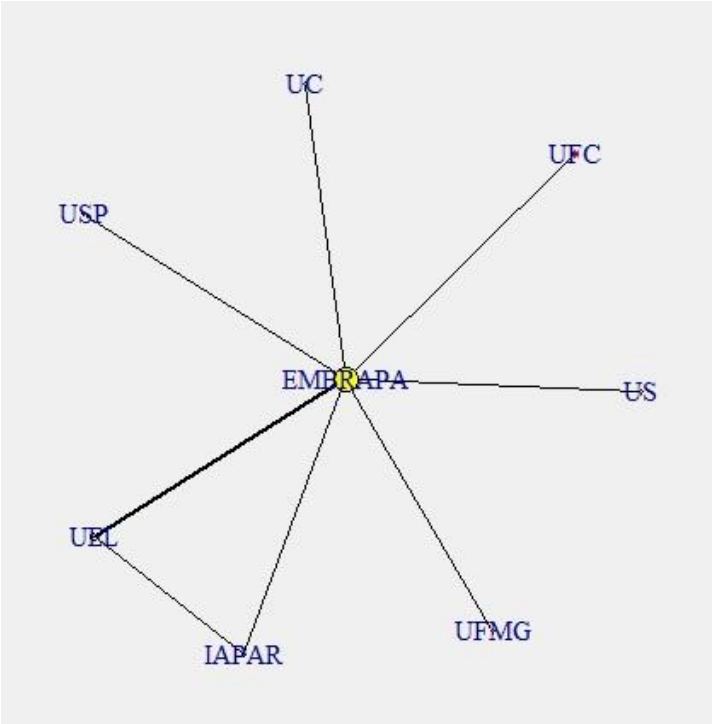
As mentioned before, we based on the framework developed in Ahuja et al. (2012) in order to conduct the structural analysis of the network. In our case, the circle represents the quantity of publication by an organization (some of them are too small and are not noticeable, although they exist). Thus, the larger the ball, the greater the amount of publication and vice versa. And the line thickness refers to the amount of relationships established between two players. The thicker the line means that there were more interactions.

Regarding the dimension of ties' 'centrality', it is important to highlight that since we are analyzing network centered at Embrapa and the company is responsible for coordinating the National System of Agricultural Research (SNPA its acronomy in Portuguese), it is natural that the sum of the interactions that Embrapa has with other actors be larger than the others. This will be true for all investigated periods.

The Figure 3 shows the partnerships of Embrapa for development of soy seeds from 1989[15] to 1997, so before the Plant Variety Protection Act.

[15] Since we found Embrapa's publications only from 1989 onwards, the structural analysis of the network of that period corresponds to 1989-1997. However, it was possible to find data of the period 1973-1989 based on secondary data and through interviews (see section.4.2.1.1).

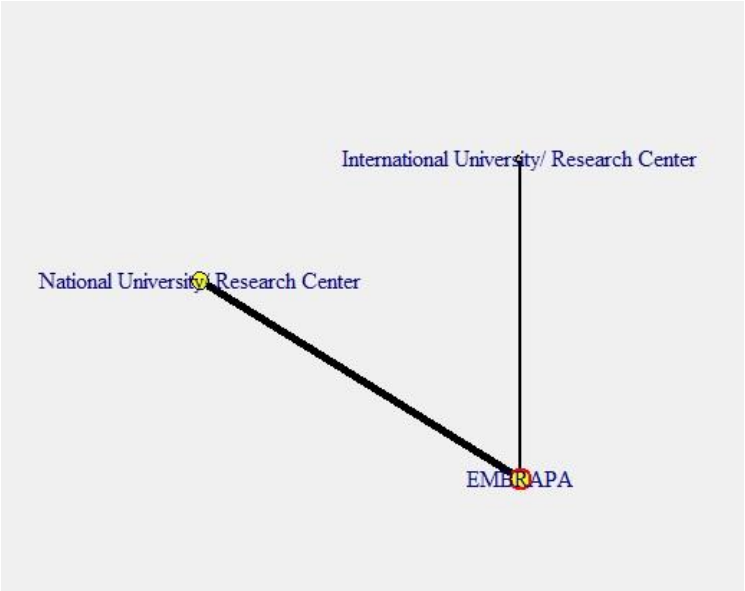
Figure 3 - Partnerships of Embrapa for development of soy seeds from 1989 to 1997 based on publications of Embrapa and its partners



Source: elaborated by the author

Next in Figure 4, we present the evolution of Embrapa's partnerships for development of soy seeds from 1989 to 2015 segmented by types of organizations.

Figure 4 - Partnerships of Embrapa for development of soy seeds from 1989 to 1997 segmented by types of organizations



Source: elaborated by the author

In this case, due the small amount of data, it seems to be more prudent to conclude that through this map it is possible to find out only a small part of the full picture. For example, based on the map, we observe that before the Plant Variety Protection Act (PVPA), the numbers of Embrapa's partners was not so big (mainly if compared with more recent periods) and that they were universities mostly (both national and international). The map also suggests an interaction among regional partners, which were close to Londrina, where Embrapa Soybean is located. These conclusions are consistent with the speech of the interviewees.

However, as highlighted by a respondent, the number of partnerships of Embrapa aimed to develop soybean cultivars was much bigger than the map suggests.

According a respondent from the Secretariat of Business of Embrapa, at the very beginning of Embrapa's life, the company made a strong partnership with international organizations, american universities and ARS/USDA mainly. Shortly thereafter, Embrapa invested on the National System of

Agricultural Research (NSAR). The R&D program of Embrapa Soybean happened almost exclusively through partnerships with public institutions, State Companies of Agricultural Research notably, as may be realized through the publication “Search results Embrapa Soybean 1997” (Embrapa Soybean, 1998).

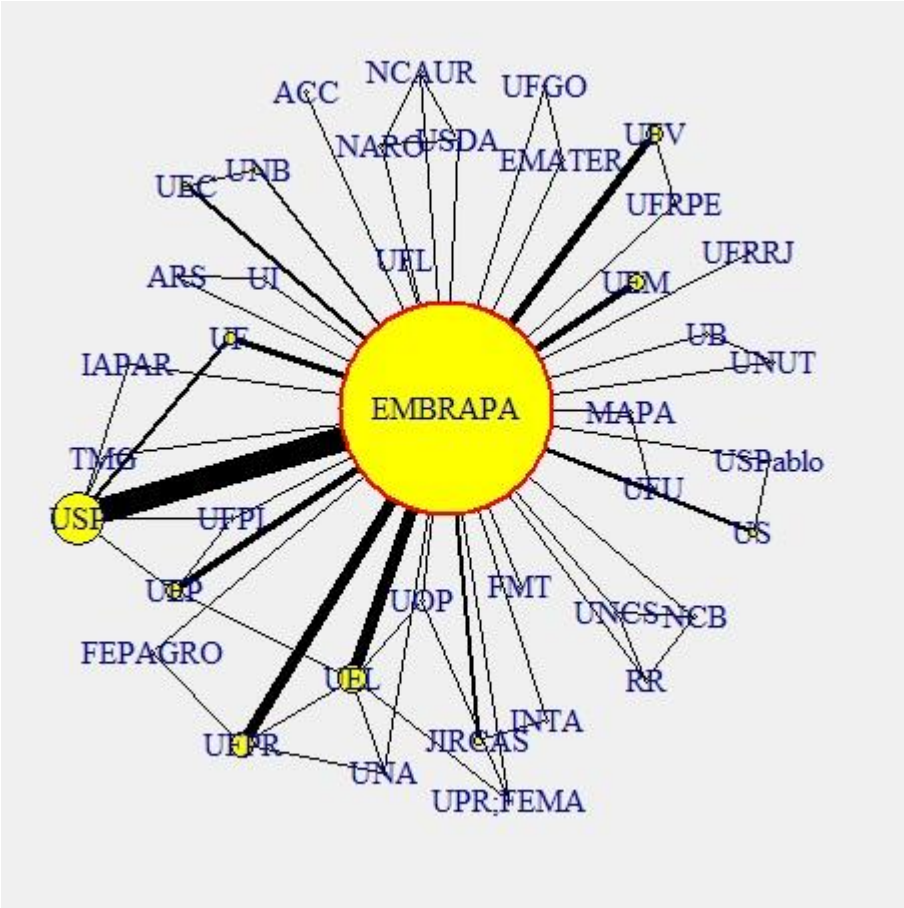
The report list the following Embrapa’s partner for soybean breeding program: State Agricultural Research Foundation (FEPAGRO), Company Agricultural Research Rural Extension of Santa Catarina (EPAGRI), Matogrossense Enterprise of Research, Assistance and Rural Extension (EMPAER), Bahiana Company of Agricultural Development (EBDA), Agronomic Institute of Pernambuco (IPA), Company Goiana Agricultural Research (EMGOPA) and also Foundation University of Tocantins (UNITINS) and Center for Nuclear Energy in Agriculture from São Paulo University (USP).

Thus, we conclude that, in fact, in the first period (1973-1997), the main partners of Embrapa aimed to the development of soybean cultivars were State Companies of Agricultural Research. Apart from these organizations that constituted the National System of Agricultural Research (NSAR), the other major partners of Embrapa were universities.

Since this map represents the network in the first examined period (1989-1997), we left out the dimension “network change”.

As suggested previously, the entry of the transnational companies in emerging economies, like Brazil, changed the balance of power among actors mightily. The Figure 5 shows the partnerships of Embrapa for development of soy seeds from 1998 to 2005, so between the enaction of the Plant Variety Protection Act and the Biosafety Law.

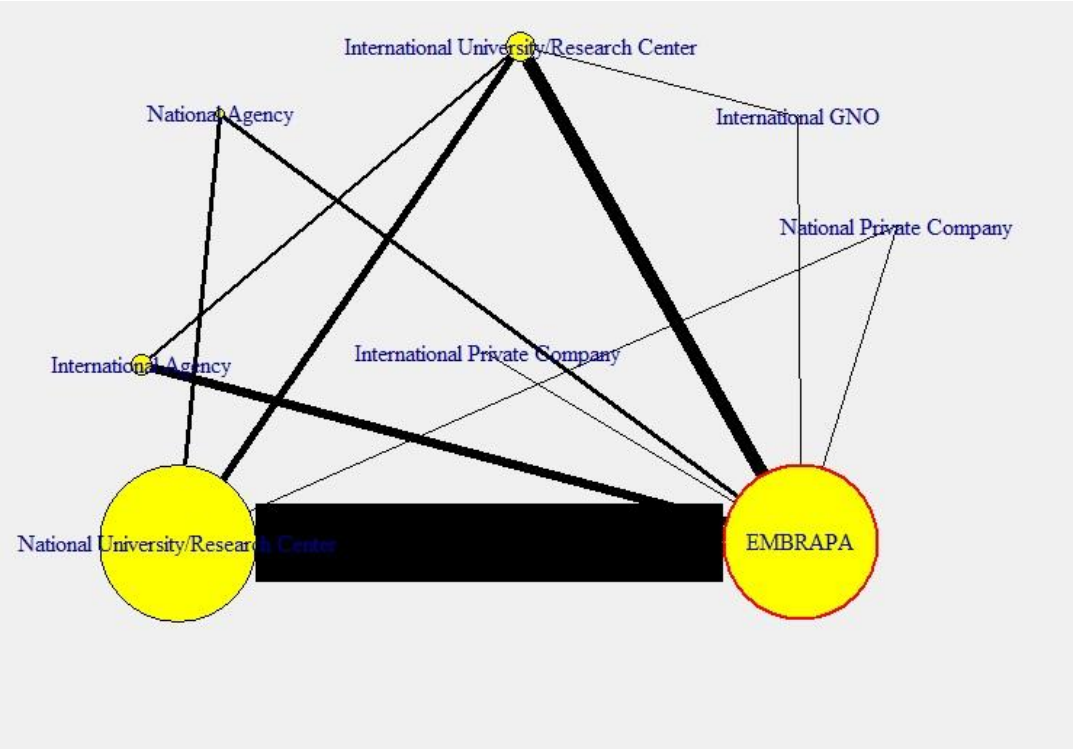
Figure 5 - Partnerships of Embrapa for development of soy seeds from 1998 to 2006 based on publications of Embrapa and its partners



Source: elaborated by the author

The Figure 6 shows the partnerships of Embrapa for development of soy seeds from 1998 to 2005 segmented by the types of organizations.

Figure 6 - Partnerships of Embrapa for development of soy seeds from 1998 to 2006 segmented by types of organizations



Source: elaborated by the author

Here, we have noted a very different picture. Different from the previous period, in adittion to universities and Agricultural Research State Foundations and Technical Assistance/Rural Extension Companies - which comprise the NSAR -, we can easily observe the presence of other actors: private Foundations, such as MT Foundation (FMT), and international agencies, such as *Instituto Nacional de Tecnología Agropecuaria* (INTA), United States Department of Agriculture (USDA), Japan International Research Center for Agricultural Sciences (JIRCAS) and National Agricultural Research Organisation (NARO). This latter group represents the Network of International Embrapa Cooperation, which includes both scientific cooperation[16] and technique cooperation[17]. Based on

[16] Exchanges of knowledge and advances in scientific and technological research with various institutions in the world, for the benefit of the Brazilian agriculture (Embrapa, 2016b).

[17] Promotion of multilateral and bilateral cooperation, helping to reduce poverty and hunger in countries in Africa, Latin America and the Caribbean (Embrapa, 2016b).

interviewees, other examples of private Foundations, which made partnerships with Embrapa at that moment in order to develop cultivars, were Triangulo Foundation, Midwest Foundation, Foundation of Support to Corridor of Northern Export (FAPCEN), and Technological Center for Agricultural Research (CTPA). In addition to these groups of actors, at that time Embrapa started partnering with big private companies, Monsanto and Basf mainly.

With respect to the dimension of the network – network change – through the relationship map we observe that after the PVPA, the number of Embrapa partnerships increased significantly. We observe the same trend of the largest number of partnerships with universities/research institutions, both international and national, but the latter mainly.

Through data of 'strenght' obtained in R software, it is possible to observe that State University of Londrina (UEL) played a crucial role, as well as São Paulo University (USP) and other universities located in Paraná and São Paulo. Based on the maps, other examples we may mention are Federal University of Parana (UFPR), Federal University of Viçosa (UFV) and State University Maringa. Interviewees also mentioned Paranaense University (UNIPAR), West Paraná University (Unioeste), Paulista State University (UNESP), Assis City Educational Foundation (FEMA). Thus, attuned to our respondents, we can say that, at least in the case of innovation efforts in the agricultural seed sector in Brazil, the regional proximity exerted influence on the choice of partners and on the number of interacions with them (see "Location" in Table 1). Moreover, it seems that Embrapa still considered the partnership with university the main option to realize work together.

"Betweenness" tell us about the importance of an actor in the network, since it expresses the "communication control" and represents, therefore, the possibility that a node has to mediate communications between pairs of nodes (Alejandro and Norman, 2005; Ucinet, 2015). Based on the map (Figure 5), apart from Embrapa, other organizations that appeared to play important role as mediator were Federal University of Piaui (UFPI), Rural University of Pernambuco (UFRPE), *Universidad Nacional de Asunción* (UNA), State Agricultural Research Foundation (FEPAGRO), *Instituto Nacional de Tecnología Agropecuaria* (INTA), Chiba University, State University of Londrina (UELA) and Agronomic Institute of Parana (IAPAR). Thus, we can come to two important

conclusions. The first is that, besides traditional partners from the South and Southeast, other partners from northeastern states passed to exert proemince role in the network. Similarly to the first, the second is that besides traditional partners from developing countries, other partners from developing countries such as the National University of Asuncion, from Lima, began to have greater relevance.

The Figure 7 shows the partnerships of Embrapa for development of soy seeds from 2007 to 2015, so after the Biosafety Law.

Figure 7 - Partnerships of Embrapa for development of soy seeds from 2007 to 2015 based on publications of Embrapa and its partners

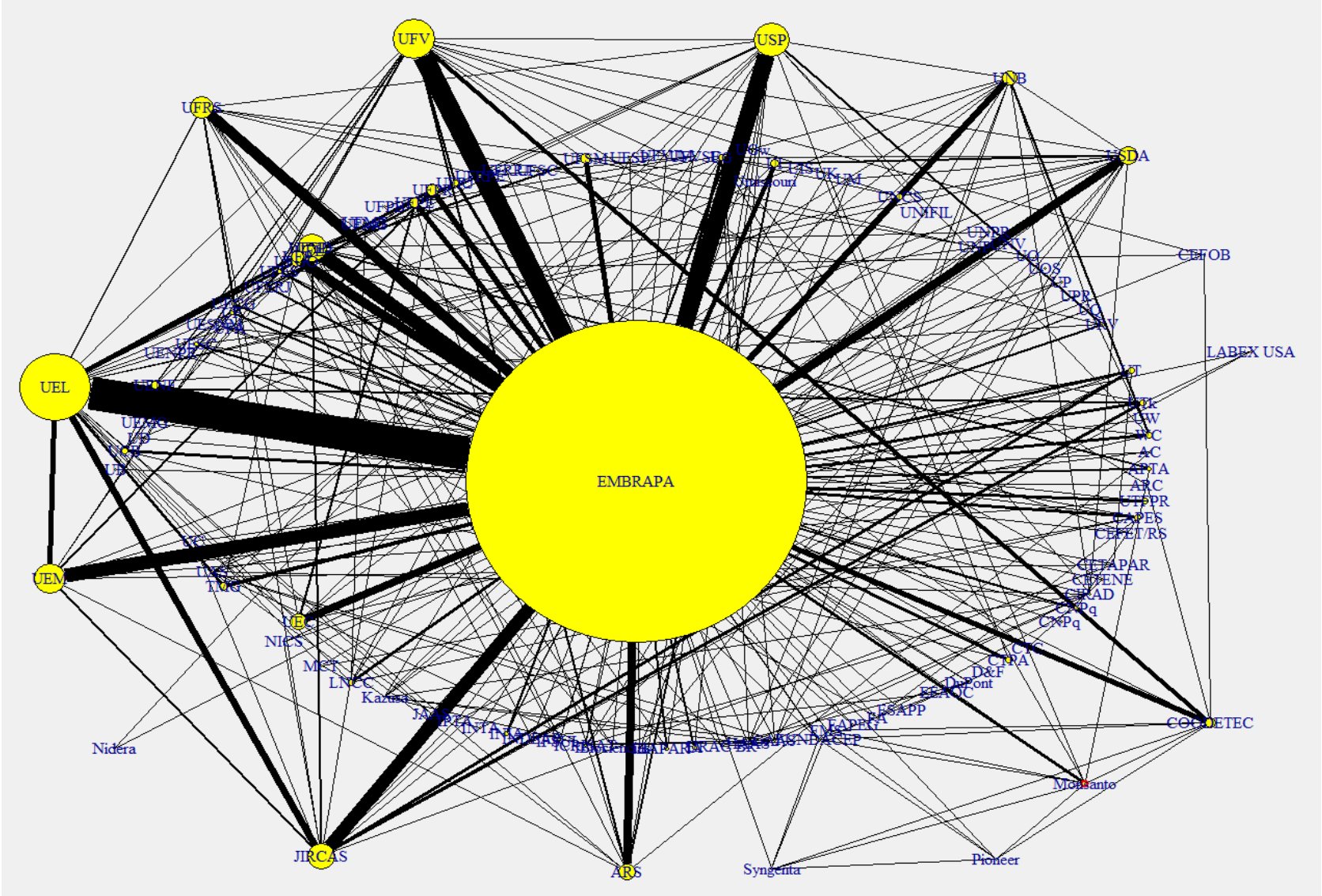
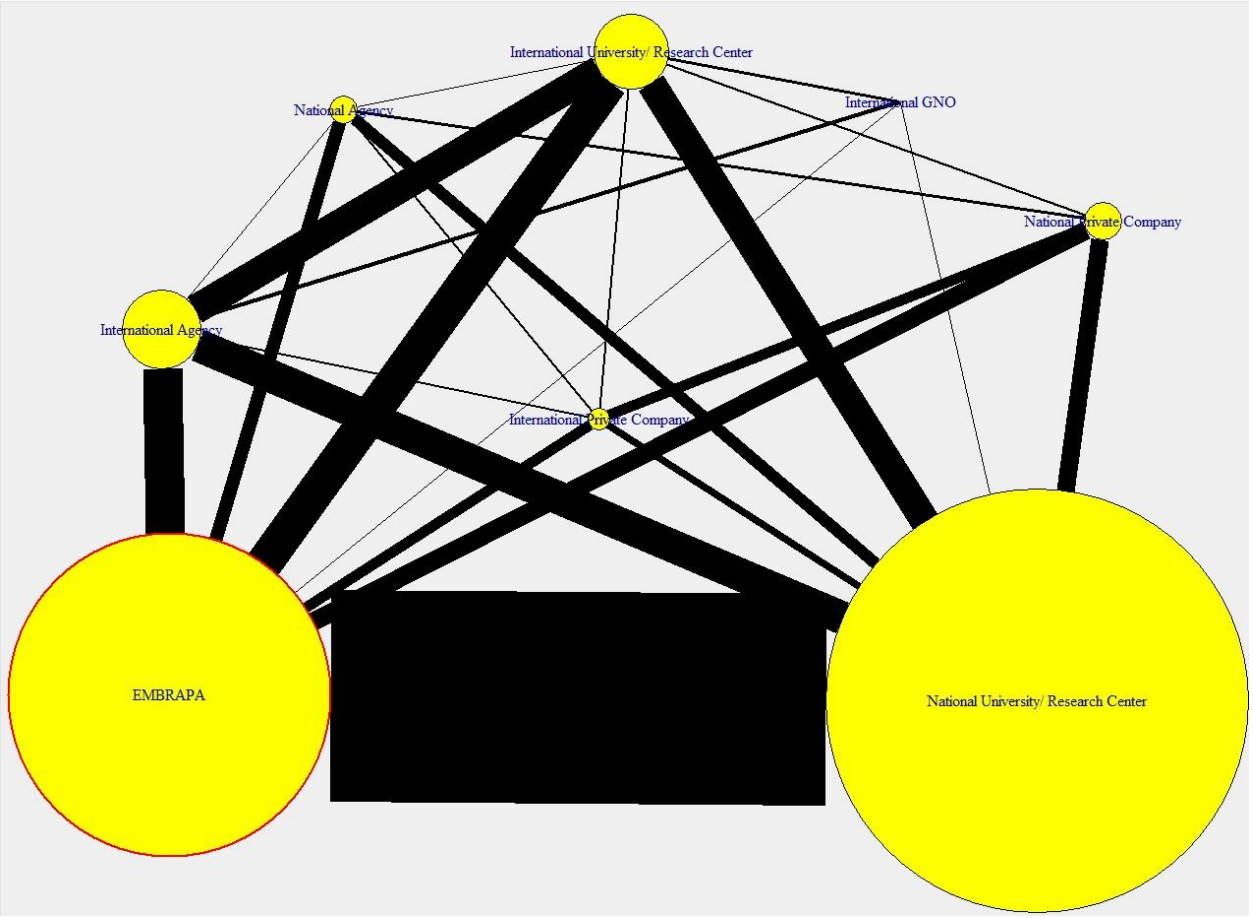

UFV
USP
UNB
UFRGS
USDA
UEL
EMBRAPA
UEM
LABEX USA
CEFOB
COOPETEC
Monsanto
Pioneer
Syngenta
ARS
JIRCAS
Nidera
NICS
MCT
LNCC
Kazan
CIRAD
CNPq
CIRAD
D&F
DuPont
ESAPP
UNIFIL
UNOS
UNIV
UNPR
UNIVASF
UNIVASF
UNIVASF

Figure 8 - Partnerships of Embrapa for development of soy seeds from 2007 to 2015 segmented by types of organizations



Source: elaborated by the author

First, with respect to the dimension of the network – network change – through the relationship map we observe that the number of partnerships is much bigger yet. In fact, what we see nowadays is a complex network, fully interconnected, that reflects the myriad of organizations with whom Embrapa has interacted.

Although the greatest amount of Embrapa's partnerships is also with universities/research centers, especially national ones, we observe an important difference between this map (2007-2015) and that

one that register the relationships in the period 1998-2006. Beyond the partnerhips with the same groups of actors, we now see more clearly the presence of some of the Big Six or Gene Giants, which are Monsanto, Syngenta, Nidera and Pioneer. In fact, through map (Figure 8) and data from software R (Table 1), we observe that Embrapa increased significantly its relationships with international partners in this period. Moreover, the numbers of interactions with Monsanto, for example, were only below of partnerships with very traditional partners, such as UELA, USP, JIRCAS, USDA, ARS, UFV, UnB, UEM, UNESP and COODTEC.

In line with data from the map, a respondent of the Secretariat of Business mentioned that the NSAR nowadays is constituted by "Embrapa, the State Organizations for Agricultural Research (Oepas), universities and the federal or state level research institutes, and other public and private organizations directly or indirectly linked to agricultural research activity". Similarly, Contini and Andrade (2013) mentioned that an important form of Embrapa's action nowadays is through the structuration and formation of networks, partnerships and arrangements with both private and public sector that generate technologies for the country.

It is important to be emphasized the proeminent role of international organizations, such as USDA/ARS, JIRCAS and other biotech organizations, such as Ctr Estudios Fotosintet & Bioquim (CEFOB), LABEX USA Plant Biotechnol and COODETEC in the networks.

All of them presented high level of "Betweenness"; in other words, high level of possibility to mediate communications between pairs of nodes. In addition to them, other international organizations that stood out were Monsanto, Pioneer and Syngenta. Considering national organizations, universities from Paraná and São Paulo – USP, UELA, UFV, UFRGS, Unicamp – were some that obtained higher degrees of "Betweenness". Aside FM Foundation, none national company appeared as having strong potential for connectivity.

Then we present in Table 1 data about nodes, ties and variance on tie patterns of the Embrapa's networks (ego-network).

Table 1 – Data about nodes, ties and variance on tie patterns of the Embrapa's networks (ego-network)

	Nodes									Ties		Variance on tie patterns
	Number	Type of Organization								Location	Strenght*	Centrality**
		NPC	IPC	NU	IU	NA	IA	NNGO	INGO			
89-97	7	0	0	5	2	0	0	0	0	Paraná - Paraná	2 (EMBRAPA - UEL)	IAPAR e UEL (2)
98-06	41	1	1	20	9	3	6	0	1	Paraná - São Paulo	13 (EMBRAPA - USP)	UEL (7)
07-15	112	9	6	46	27	9	14	0	1	Paraná - Paraná	34 (EMBRAPA - UEL)	UEL (25)
		10	**7**	**71**	**38**	**12**	**20**	**0**	**2**			

Legend:
NPC: National Private Company
IPC: International Private Company
NU: National University/Research Center
IU: International University/Research Center
NA: National Agency
IA: International Agency
NNGO: National NGO
INGO: International NGO

*Which pairs has the strongest tie, that is, which ones have made more interactions

**Organizations that, after Embrapa, have the largest numbers of direct links with other actors (does not take into account the weight of the interactions, but only the amount)

Source: elaborated by the author

As can be seen throught Table 1, the number of Embrapa's partners increased significantly between 1989 and 2015. This trend happened with almost all types of Embrapa's partners. However, universities (national mainly, but also international ones) were always the major partners of Embrapa. Embrapa-UEL and Embrapa-USP were examples of pairs of organizations that had bigger numbers of interactions. International agencies were also other type of partners that exerted proeminent role, even more than national agencies. In less proportion (but no less important), national and international private companies were also important partners.

4.2 Understanding the Reasons for Changes in the Networks and in Designs of PPP

Based on secondary data and interviewees, we tried to reveal the reasons why different actors – public and private ones - seek to form partnerships.

4.2.1 From Embrapa perspective

As public company, it is expected that Embrapa had always been oriented to improve social benefits.

4.2.1.1 From 1973 to 1997: soybean market demand and need to accumulate technological capabilities in genetics

In the very beginning phase of Embrapa Soybean's life, the main focus of the company was to introduce in Brazil the soybean crop in the most economical way, and acquire existing knowledge in developed countries. Thus, the company made a strong partnership with American institutions - mainly universities and the Agricultural Research Service (ARS) of U.S. Department of Agriculture (USDA), as well as sent its professionals to capacitation abroad.

Almost simultaneously, Embrapa invested on the National System of Agricultural Research (NSAR), in which State Companies of Agricultural Research played a crucial role. Through interviews, it was possible to get the reasons of the prevalence of Embrapa's partnerships with these companies at that time. In the words of a respondent:

> These partnerships were of technical nature mostly and they involved the free movement of plant material between the organizations and conducting evaluation tests cultivars in nationwide. These organizations constituted the NSAR. Then, as there was not much concern for the protection of plant varieties in Brazil and also due to lack of regulatory framework for this, the partnerships took place in a cooperative manner in which the members of the network developed R&D and testing of Embrapa's soy materials and of other components of the network.

Thus, we may affirm that the beginning of Embrapa Soybean's life and its effort for innovation was "demand-driven", which propelled the company to accumulate technological knowledge in genetics. To achieve its goal, the company tried to increase as much as possible the capillarity of its networks in order that other companies help it with R&D and testing activities, in addition to technology transfer activities to producers. So, we advocate that at that time, the higher the demand of soybean, the greater the Embrapa Soybean´s interest in making partnerships with leading organizations of developed countries in order to catch-up in Genetics. However, since at that time the private sector did not make part of the industry in a systematic way, this proposition will not make part of our framework.

4.2.1.2 From 1998 to 2005: new regulatory framework and new inter-institutional arrangements with participation of the private sector and financial cooperation agreements

In the next phase of Embrapa's life, according an interviewee of the Secretariat of Business of Embrapa, "faced with the changes due to the implementation in 1997 of the PVPA, Embrapa sought the development of new inter-institutional arrangements to continue providing the result of its plant breeding programs within the new regulatory framework". These arrangements resulted in 21 technical and/or financial cooperation agreements with state research organizations, with foundations that support research, consortium of companies and seed producers associations of Brazil (Embrapa, 2016). Based on our fieldwork, we found out that these arrangements and partnerships were developed mainly in order to expand the breeding capacity, testing and multiplying of new cultivars. These arrangements should also help Embrapa to maintain its capillarity, since the public agencies such as the State Institutes for Rural Extension (Ematers), in some states of Brazil, left agribusiness and began to devote themselves only to family farming.

Therefore, the private sector began to participate more actively of the activities of the seeds industry. However, at the wider process of establishing of partnerships between Embrapa and the private sector, as representatives of the latter group, were foundations and associations of small and medium-sized private seed companies. These companies, in general, are not R&D seeds companies, although directly linked with them. As mentioned by an interviewee, these enterprises had no capacity or scale to develop research programs to generate new cultivars, depending on the public programs of plant breeding for staying in the market.

Thus, despite the large number of partnerships of Embrapa with national private companies, regarding the R&D function in genetics - R notably -, apart from few companies, such as Meridional Foundation, we may say that Embrapa was (and still is) virtually alone. Partnership between Embrapa and Meridional Foundation[18] is a good example of PPP that worked well (and still works). In sum, although in this phase the private sector began to play greater role, most private partners of Embrapa were national private companies that had important financial, technical and management limitations. Even so, these partnerships bring important benefits to the company. Thus, we came to our first proposition, which refers to the first period of Embrapa Soybean's life after the PVPA.

Proposition 1: the higher the market competition, the higher Embrapa's interest in making partnerships with private companies in order to get capillarity and expand the breeding capacity, testing and multiplying of new cultivars

4.2.1.3 From 2006 to 2015: market demand for genetically modified seeds (transgenic events)

After the Biosafety Law, in the setting of Brazilian seeds sector, the demand for seeds, in qualitative terms, changed sharply, having the producers given preference to genetically modified seeds. In fact, the demand for transgenic seeds began since the entry of smuggled seeds from Argentina, around 2001. At that time, although prohibited in Brazil, all of them were transgenic seeds. Despite

[18] The Meridional Foundation is composed by 61 seed producers from Santa Catarina, Paraná, São Paulo and Mato Grosso do Sul, associated with their respective state associations, which account for 95% of soybeans produced in its region. Headquartered in Londrina - PR, the organization enables technical and financial cooperation with research programs of national public institutions. Furthermore, the foundation develops works related to transfer of technology to farmers by carrying technologies showcases, field days, lectures, demonstration units, among other methodologies of disclosure (Meridional Foundation, 2015).

the fact that productivity of transgenic cultivars does not seem to be bigger than conventional cultivars, as mentioned by many respondents, more than 90% of the total of cultivated area of soybean in Brazil uses transgenic seeds (Kleffmann Group, 2015).

As a result, Embrapa intensified its partnerships with transnational corporations, aside from foundations and associations of national small and medium-sized private seed companies. In fact, more recently, Embrapa signed contracts with the private transnational companies Monsanto (2000 and 2008), BASF (2007) and also with the Japan International Research Center for Agricultural Sciences (JIRCAS) (2004) – a national institute of Japan - for transgenic soybean development. The partnerships with transnational companies involve confidentiality agreements in their majority. Thus, it is not easy to identify precisely their goals. Nevertheless, some characteristics of the partnerships are made explicit in Contini and Andrade (2013, p. 582-584), as may be seen in Table 2.

Table 2 - Examples of characteristics of PPP of Embrapa and transnational companies

Transnational Company	Characteristics of the PPP
Monsanto of Brazil	Cooperation Agreement for the genetic development and research for the development and testing of new soybean varieties INTACTA RR2 PRO with glyphosate tolerance and insect resistance.
Basf S.A.	Technical cooperation in agricultural research to define, plan, coordinate and implement studies, surveys, researches, plans and programs aimed to deep the technical-scientific knowledge and the generation of technologies; validation and development of technologies (products and processes) of common interest; transfer activities technologies and sustainable social development actions.
ABRASEM, BASF	Externalize the purpose of joint efforts for the strengthening of the production chain of seeds.
Basf S.A and Tropical Improvement in Genetics Ltda.	Copyright contract/licensing, establishing license of rights of intellectual propredade for the tecnology CULTIVANCE® to the TMG, to continue the work of developing CULTIVANCE soybean cultivars, sale or distribution of breeder seeds of the obtentor under the trademarks CULTIVANCE.
Syngenta Seeds Ltda.	Sending of samples of genetic heritage components for scientific research purposes without economic potential to Embrapa, to be used in the project named “studies of resistance of cultivars to pathogens and laboratory experiments”.

Source: Based on Contini and Andrade (2013).

As may be inferred, the private sector went on to participate in the sector differently, when compared to the previous phase. Transnational companies were in charge and the emphasis was on providing seeds with transgenic events.

Differently from transnational companies, Embrapa considers the investiment in conventional route – in contradistinction to transgeny - priority. The company justifies its positioning due the necessity to think about the Brazilian seeds sector in long terms, taking into account prevention against risks of diseases and care for the environment mainly. Moreover, Embrapa fulfills its market regulatory role, offering alternatives for the market and being always ready to quickly supply and meet demand of the Brazilian producer if necessary. Nevertheless, Embrapa is aware that she must answer local demand. Thus, the company invests on partnerships with transnational companies – Monsanto, Syngenta, Bayer, Dow – mostly to have acces to some transgenic events. As we saw, with Basf, Embrapa developed and launched together the "Cultivance", its first transgenic cultivar.

Almost all respondents considered that the partnerships with private companies are indispensable and increasiling important, remarkably due to inflow of knowledge. However, we found out that, when choosing its partners, Embrapa and other companies try to identify in the other a set of skills that they do not intend to invest on. In the words of a respondent: "We have a clear perception that companies (national and transnational) do not have interest in having all these capabilities. We have corporate partnerships with 102 companies and, consistently, companies arrive here wanting to make partnerships with Embrapa...because they identify a set of national skills which they do not intend to invest on, as well as Embrapa".

Thus, since Embrapa does not have interest in investing on all technological capabilities with the same intensity in order to develop technologies, we advocate that nowadays:

Proposition 2: the higher the demand of transgenic seeds, the higher the Embrapa's interest in making partnerships with private companies, especially transnational ones in order to have access or to develop new traits, being closer to the local market

It is widely acknowledged by scholars the limitations of public companies, especially the scarcity of financial resources, which is stronger yet in developing countries.

The complexity of technologies related to transgeny, such as genetic engineering, allied with the speed of their evolution, requires high level of financial investiments. In addition to the high prices of patenting that practically prevents small and medium-size companies from developing country participating in the so-called 'traits' market withouth partnerships with big companies, transnational companies mainly. In fact, the costs of complying with regulatory biosafety requirements and the costs of patenting can reach levels up to 10 times higher than those connected with developing the new transgenic event (Andersen et al., 2015). Thus, companies from developing countries do not have conditions to bear the expenses of patenting.

Embrapa has tried to minimize financial problems through partnerships. As explained by a respondent, Embrapa currently has two main forms of (regimented) partnerships – "technical partnerships" and "technical and financial partnerships". In the first one, there is no transfer of financial resources, but a counterpart both to Embrapa and its partner, since there are common goals. The latter is a form of cooperation that is both technical and financial, in which the private company puts financial resources for the operation of the object of the contract. An interviewee of R&D Direction mentioned about the way Embrapa looks for funds, somehow confirmed by a respondent of the Department of Products and Market. "...Or you look for a ready technology (e.g., transgenic events) and try to add it into our technology (cultivars) so that we can get closer to the market or often we seek funds with these companies because they are interested in investing in certain products to be developed together". So we come to our third proposition:

Proposition 3: the higher the necessity of financial resources, the higher the interest of Embrapa in making partnerships with private companies

From the perspective of the private companies, the interests in making partnerhips with Embrapa are determinated by very different reasons, which have changed over time.

4.2.2 From private companies' perspective

In opposite side of Embrapa, it is expected that private companies must always invest focused on expanding their profits.

4.2.2.1 From 1998 to 2005: new regulatory framework and entry of transnational companies in the local market with help of Embrapa

When transnational companies arrived in Brazil, they were faced with the presence of Embrapa, a public research company with great market share of soy seeds, very high positive image in the industry and society and technological capacity in Genetics similar to other world leaders, which included benefits from its germplasm banks.

As highlighted by an interviewee of the R&D Direction, transnational companies at the first moment aimed to join with Embrapa to facilitate their entry into the local market.

> The objectives of the multinational companies have changed over time. At the beginning, since Embrapa was a company that had credibility in the country, a partnership with us would put them well ... They came here and said: could you test it for me? We did a partnership to test it, the result was good; then, they opened the market ... Over time, they found out: Embrapa has knowledge that we can use to develop products together ... Today we have made partnerships to develop products jointly. I have this knowledge, you have that knowledge; we will work together to develop together ... to develop products jointly. We did some partnerships in this way; we are growing.

In plant breeding programs, a very important knowledge base is Genetics. As mentioned by a respondent of the Secretary of Business, "... The important is not the cultivar, the important is the genetics, that plant's ability to resist a disease, that plant's capacity to produce more, that plant's capacity to adapt to a specific condition". Since its creation, Embrapa has accumulated experience and knowledge in Genetics and technologies related to plant breeding programs, such as crop rotation and livestock, farming and forests integration. In fact, Embrapa was able to catching-up in a very short period of time and to become a global leader. Embrapa, for example, developed its own cultivars to different regions of Brazil with very different and more problematic edaphoclimatic conditions, such as the 'cerrado'. This achievement opened a promising avenue not only for Brazil but to rest of world.

In addition to Genetics, other advantage of Embrapa is its germplasm banks. Germplasm "is the element of genetic resources that handles the genetic variability between and within species, in order to make researches with purposes in general, especially for genetic breeding, including

biotechnology" (Goedert, 2002). The germplasm contains genetic information of plants. Its conservation, therefore, acts as an insurance against the extinction of the species in their natural habitat due climate changes, in the landscape and also the lack of conservation measures. The role of the environment - land, climate, weather conditions and other national specificities – requires that seeds developed to other context be adapted and tested on the campus in order to guarantee its quality, which seem to reinforce the interest of transnational companies in joining with Embrapa. This issues were comented by an interviewee of the Department of Products and Market when talking about the reasons why transnational companies make partnerships with Embrapa: "... if they get a cultivar there in the USA and bring it to Brazil... the process of adaptation, of selection is gigantic, the probability of success is often very small…"

In the case of soybean, even though it is originally from China[19], Embrapa has increasingly invested on its germplasm banks, which includes wild species and therefore increase its chances of success. The breeding researchs have in the germplasm banks their main source of raw material. Today the company has the largest seed bank in Brazil and Latin America and one of the largest worldwide, with more than 120,000 samples of about 600 species (Embrapa Soybean, 2016a). Around 35,000 of these samples are for soybeans only.

Based on our interviewees, after transnational companies became consolidated at the local market, their interests changed; the same happened with the scope of the partnerships between them and Embrapa. As mentioned before, while at the beginning the transnational companies were interest on just testing its cultivars, latter they demonstrated interested in developing products and technologies jointly. Nowadays Embrapa has partnerships with almost all of the companies that compose the small group of powerful transnational companies that dominates the sector.

Thus, we advocate that during their entry phase in the local market:

19 "Soy is a plant originally from China, regions located between parallels 35° and 45°N" (Embrapa, 1985) and considered a short-day plant (long nights); thus, much of the world area planted with this crop is located at latitudes greater than 30 degrees, where prevail temperate conditions" (Almeida et al., 1999).

Proposition 4: The higher the demand for soybean, the higher the interest of transnational companies in entering in the Brazilian seeds market and making partnerships with Embrapa in order to exchange knowledge in Genetics and breeding activities mainly

4.2.2.2 From 2006 to 2015: market demand for genetically modified seeds (transgenic events) and non-genetically modified seeds

In 2015, around 90% of the planted area with soybean in Brazil used transgenic seeds. However, it is important to be highlighted that any plant breeding process, whether through genetic engineering route (transgenic route) or conventional route, require knowledge in Genetics. In fact, there are not transgenic seeds that do not stemmed from conventional seeds (seeds without 'traits'). These 'traits' (or events) are inserted into the germplasm. Thus, even considering that transnational companies are mostly driven to develop transgenic seeds, they have much interest in making partnership with Embrapa in order to exchange knowledge not only in Genetics, but in other knowledge areas related to breeding activities.

Thus, we advocate that:

Proposition 5: the higher the demand for soybean, the higher the interest of private companies in developing transgenic seeds and making partnerships with Embrapa in order to exchange knowledge in Genetics and other knowledge bases related to breeding activities mainly

On the other hand, although the high percentage of areas cultivated with transgenic soybeans in Brazil, some consumers requires non-genetically modified seeds. While the transnational companies (the Gene Giants) are driven to develop transgenic seeds, some national private companies are focusing on market demand for non-genetically modified seeds mainly. As mentioned by a respondent of the Secretary of Business, "... there is some niche markets that still want conventional seeds" and that Embrapa should attend.

A good example of PPP, whose focus is on the market of not genetically modified soybean cultivars, has been the partnership between Embrapa and various actors of the productive chain of

soybean in Brazil directed to the “Free Soybean Program”. These actors act in different areas, such as generation of news varieties of soybean, development of production systems, commercialization, processing, industrialization and export (Organic Planet, 2016).

Under coordination of Embrapa and the Association of Producers of Soybean and Corn of Mato Grosso State (Aprosoja-MT) (Embrapa Soybean, 2016b), the program has as primary aim the increasing of the supply of conventional soybeans and its access to producers, guaranteeing freedom of choice to farmers interested in answering the demand of consumer markets that prefer conventional soybeans (Organic Planet, 2016). In addition to the traders’ interests which had (and already have) market for conventional soybeans in Europe and Asia, the program was created to meet a need of the state’s producers of Mato Grosso and their associations. The Brazilian Association of Producers of Not Genetically Modified Grains (Abrange) was a key partner of the program while it existed, assisting in the dissemination of Embrapa's conventional cultivars and of other companies. The program is sponsored by Caramuru, Aprosmat, New Frontier Seeds, Green Gold Seeds, Coati Seeds and Celi Seeds. Other companies that participate of the program are: Bag of Seeds and Agribusiness (BS&A), Agricultural Development Cooperative (Coodeagri), Cerrado Foundation and Triângulo Foundation (Embrapa Soybean, 2016b).

As a result of these arguments, we argue that:

Proposition 6: the higher the demand for non-GM seeds, the higher the interest of traders and producers (and its associations) in making partnerships with Embrapa in order to exchange knowledge in Genetics and breeding activities mainly

4.2.2.3 Social benefits and private advantage

The public nature of Embrapa contrasts with the nature of its private partners. The challenge is to develop partnerships able to create value and private capture, while safeguarding the public interest.

Regarding the plant breeding process, the main goal is the improvement of the quality of the seeds driven primarily to the increase of productivity. However, the mission of Embrapa is “to enable research solutions, development and innovation for sustainable agriculture for the benefit of the

Brazilian society" (Embrapa, 2016). Thus, the company, beyond investing in genetics in order to improve productivity, is keen to use a long-term view in their breeding processes, which includes care for the preservation of the environment and major diseases. A good example is the preventive breeding, that is, the developing of plant varieties with genetic resistance to high risk quarantine pest for agricultural activity (Embrapa, 2016).

The benefits that resulted from improvements of Embrapa's plant breeding programs is not only restricted to Brazil. As highlighted to an interviewee of the Secretary of Business mentioned "…with the problems on funds to research in Australia, for example, Brazil is practically the only global research company with strong breeding program in species of tropical zone; then the demand upon the Embrapa cultivars is very large because there is no alternative, especially for Africa".

From the side of private companies, even considering their interests in profits, the companies have much to offer both to public companies and to society. In the setting of the seeds industry, for example, transnational companies helped a lot to the advances of the modern biotechnology, which in turn reduced substantially the entire time of the breeding process.

Perhaps difficults in making partnerships with each other happen from both public and private sides, but due the more restrictive condition of the public companies, it seems that they have do deal with issues that, although urgent, involves more complexity nowadays. As an example, an interviewee of the R&D Direction questioned: "how far can a public company do a partnership with the private sector without this being a delivery of public goods? As can we, for example, study biodiversity of tropical plants, whether for cosmetic, whether for pharmacy, since the private companies will not have very much interest to do this? In some cases they have, in others not". The respondent mentioned that, in order to get more flexibility, Embrapa has tried to increasingly work with the design (concept) of open innovation. However, he made a point of some difficults to solve them: "... this is not so simple to a company that worked for a long time in one form of innovation, too over a closed circle, where partners came early (at the beginning of the project) and came together with us ... now we have a little difficulty in negotiating these IP issues, different times within the project ... we're working on it, we are learning ...".

In order to reduce some of its limitations, Embrapa has invested on (internal and external) institutional flexibilization trying to get more resources and improve its partnerships, especially with transnational companies. According the respondent of the Secretary of Intelligence and Macrostrategy, there are some proposals being analysed by the Congress nowadays. One of them is the EmbrapaTec, a private arm of Embrapa similar to the National Research Institute of France (INRA) in France. Beyond the attempts of changes in its legal constitution, Embrapa is also trying to make more flexible its internal rules. In fact, the company is reviewing all internal regulations with regard to cooperation and partnerships.

The fact is that, leaving aside the differences between Embrapa and transnational companies – their interests and technological capabilities mainly - one seems to have much to offer to the other. Our fieldwork indicated also evident mutual interests between Embrapa and private companies in making partnerships in order to get benefits. Notwithstanding, it is also plain that the relationships between Embrapa and some private companies, as the transnational ones mainly, are much unbalanced and that require strong governance mechanisms in order to make them fair and favorable for the society in long terms. In fact, we strongly confirmed the statement of Zylbersztajn (2014, p. 270), “consider the need for a specialized structure to coordinate economic relations of production implies assume that the price system is not able to fulfill that purpose alone”. As is known, this necessity becomes stronger when we are facing complex institutional setting, as we can infer about the seeds sector due the its characteristics - global nature of the industry, intersectoral interactions, great amount of actors with different levels of power, different technological capabilities among the actors, conflits between global and national legislations and much more. All these characteristics, at once converge to reinforce the necessity of partnerships between actors (public and private organizations, global and local ones) add many difficults to the relationships among them.

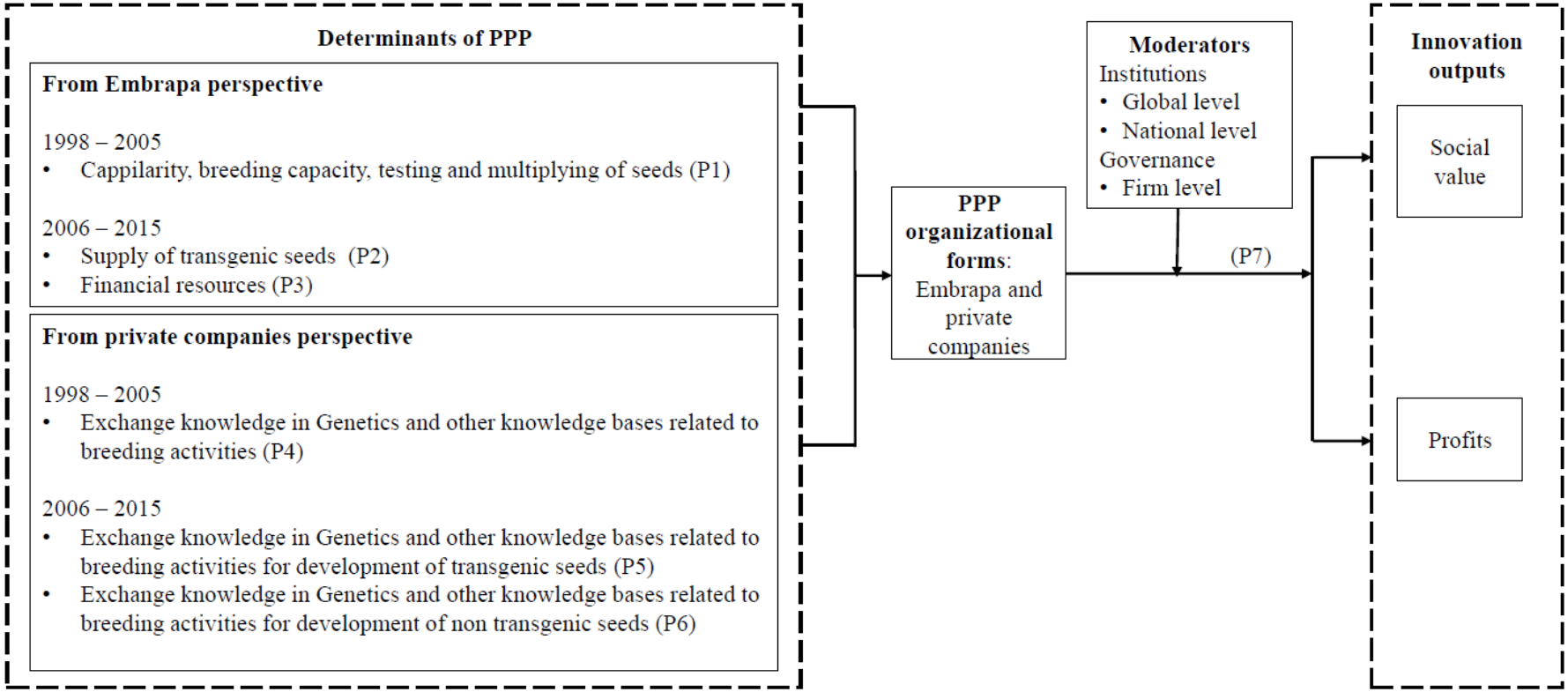
So, since Embrapa (a public company) and private companies (both national and transnational ones) have much to contribute to the development of the sector and to the welfare of the society, it is of paramount importance to find out which are the determinants that make one look for making partnerships with the other.

Thus, if the benefits of PPP will tend more (or less) to social benefits or private advantage will depend on the network architecture and in which way it will evolve over time. However, they suffer influence of the institutions in global and national levels; not less important are the effects of the governance of the firms. Therefore, we advocate that:

Proposition 7: the benefits of PPP may occur in form of social benefits or private advantage, being moderated by institutions in global and national levels and also by governance mechanisms in firm level.

The Figure 9 shows the proposed theoretical framework.

Figure 9 - Proposed Theoretical Framework



Source: elaborated by the author

5 DISCUSSION AND IMPLICATIONS

As results findings, besides the confirmation of the pertinence of the framework developed in Ahuja, Soda and Zaheer (2012), we presented the determinants of a network evolution centered at Embrapa (ego-network level) aimed at developing soy seeds and their evolution over time. Moreover, we developed a theoretical framework to explain the dynamics of PPP in the setting of Brazilian seeds sector and with the same goal. It was possible to understand why the knowledge networks and PPP developed in the way they did and also to be aware about the main concerns related to the future of the seeds sector, particularly of soy.

The ego-networks of Embrapa (including PPP) have evolved as seeds sector changed. We found out that Embrapa focused mainly on the characteristics of the nodes they link to, to form or dissolve ties mainly and less on the network structure and patterns of ties. More recently, the company began to intensify the revision of its partnerships strategy with private companies and invest more heavily on examining the patterns of ties, particularly with the transnational companies. In other words, although Embrapa consider the risks of a high verticalization, it seems that the changes of the Embrapa networks have been more nodal-change driven and less ego-structural change driven until now.

The high degree of centrality of Embrapa in the networks may be observed through the number of partners of Embrapa ("Number" minus 1 in Table 1). Through of analysis of the evolution of the examined periods, we observe that Embrapa increased a lot the number of partners over time. Moreover, in all periods, we may observe that the diameters of circumferences of Embrapa are much higher than its partners, which reflect the bigger quantity of publication of Embrapa. These phenomena seem to be natural, since we are examining a network centered at Embrapa (ego-network level). However, it is important to find out whether other companies also have a special influence in the network. The high degree of centrality of Embrapa in the networks happened during its entire life, both before and after the Plant Variety Act. Although the greatest amount of Embrapa's partnerships was with universities/research centers, especially national ones, the same pattern happened with the private companies. Therefore, it is expected that the company has had "a wide variety of potential benefits, such as access to diverse information or higher status or prestige" (Ahuja, Soda & Zaheer, 2012, p. 436). We confirmed this expectation, but some caveats must be

mentioned. In fact, Embrapa has high status and prestige among all kind of partners (types of organizations), institutes and agencies of national governments, institutions and agencies of international governments, universities and national research centers, universities and international research centers, national companies and also international companies. The company also has a strong identity, a recognized high level of technological capabilities and important results in its curriculum. However, perhaps even not all these positive characteristics of Embrapa were enough to make difference in the balance of power. The transnational companies do dominate the sector.

We confirmed through the field research the existence of the four primary microfoundations (or basic factors) supposed to drive the formation, persistence, dissolution, and content of ties in the network: agency, opportunity, inertia and random/exogenous (see Ahuja, Soda and Zaheer, 2012).

Concerning the agency, as expected, it can be said that Embrapa is extremely motivated to shape relations in order to create beneficial links or to shape networks in an advantageous social structure that favor it. Since the beginning of Embrapa's life, the company has invested on partnerships highly. At first, although international partnerships existed, like in Labex, the emphasis was on its national partners, especially state organizations of agricultural research (public companies). After the Plant Variety Act, the number of Embrapa partnerships increased significantly. Both universities and private companies compose the partnerships of Embrapa. With regard to the PPP, we observed links mostly with national companies and less with transnational ones. However, we have to consider that partnerships with transnational corporations are more recent. Moreover, there are just few transnational companies that participats of the sector. Thus, considering the two paths of network-changing behavior at the ego-network level, presented by Ahuja, Soda and Zaheer (2012) - the nodal change and the ego-structural change -, we argue that the agency behaviors and actions of Embrapa to accomplish its goals is more compatible to the former. We did not find evidences that Embrapa is trying to modify its ego's structural dependency on the other nodes in the network.

However, the company is on the process of learning how to "devise unique responses to improve their own situations in the network" (Ahuja, Soda & Zaheer, 2012, p. 438). We argue that the company will have to learn yet how to reap benefits from its advantages, such as its image, its technological capabilities, and also some natural protections. For example, the nature of the sector that requires adaptability of the seeds to environmental conditions, as well as of the natural

advantages of the country - its extensive arable land area, the (relative) plenty of water and climate conditions. No less important are the company's assets, such as its rich germplasm bank that need to be negotiated intelligently, that is, in a way that ensure the company's access to the most advanced technological and knowledge resources. Moreover, the focus of the negotiation must be on the long term in order to ensure sustainable economic returns. In other words, the company must invest heavily on governance innovations, and this was exactly what we observed that Embrapa is trying to do.

Concerning the argument that agency may both provide motivation to brokerage (more-open structures, more heterogeneous set of alters) and, in the contrary, closure (house new ties in the relational context of existing ties) (Ahuja, Soda & Zaheer, 2012), we argue that Embrapa acts in the direction of brokerage mainly.

The microfoundation “opportunity” became quite evident at the time of the advent of the modern biotechnology. At that time, private companies glimpsed important complementarities between agrochemicals and genetics area and potential economies of scope in the biotechnology research. Therefore, the networking behaviors were driven by convenience (Ahuja, Soda & Zaheer, 2012). We also observed clearly the possibilities of complementary between Embrapa and transnational companies in the seeds sector. We also found evidences of the “proximity”, especially in the ties of Embrapa and national companies since they have the same goals most of times. Thus, it can be said that the microdynamics by which the networks of Embrapa change involves both similarity between the ego and alter (homophily) and the possibility of complementarity (heterophily).

With regard to inertia, pressures for persistence and changes come from diverse sources. For example, sometimes there are political influences that greatly affect the company positioning in terms of technology, that is, which technological routes the company must invest on and which ones will not be privileged. Political interferences had already influenced Embrapa not to invest on modern biotechnology in the past. Decisions about the positioning of Embrapa by the board of the company and also ideological issues from the legislators have contributed to Embrapa investment on genetics predominantly. But if political, strategic and ideological constraints have pushed Embrapa in the direction of the genetics, the local market demand is pushing Embrapa in the direction of the modern biotechnology (or transgenic events). The transnational companies offer

cultivars with transgenic events in very advantageous commercial conditions to the local producers. This mainly enabled that companies first entered into the local market and next, expanded their market share.

The changes in the architecture of the network examined through the evolution of the graphs, although including other actors, such as universities and institutions and agencies of government, helped us to predict and understand the changes in the distribution of benefits and constrains among the public and private sectors. As a result, they also tell us about the sustainability of the partnerships between Embrapa and private companies. To get robustness to our findings, we also used information from the fieldwork and secondary data.

The determinants of the rise of novel organizational forms between public and private companies changed over time. From the side of Embrapa, with few exceptions, at first, most of the partnerships established by Embrapa with private companies were aimed at, beyond getting cappilarity, also testing new cultivars in different environments, multiplicating seeds and transfer technology. At that time, partnerships were carried out with national private companies mainly. In a second moment, the interest in getting close to the market, which asked for transgtenic seeds, were ones of the main drivers that pushes Embrapa to making partnerships with transnational companies. Thus, it was important to Embrapa to have access to different technologies and diversify its technological capabilities. Beyond this, we made clear the search of Embrapa towards of getting financial resources. From the side of transational companies, we identified diverse drivers that changed over time. At the begining of the partnerships with Embrapa, the companies looked for being together with a company whose image was strong. In this way, it was easier to enter into the local market. Then it emerged the interest in developing products in partnership with Embrapa, since the company had got confidence and proved to be competent for this. This included the assets of Embrapa, such as its technological capabilities in Genetics and notably its rich bank of germplasm. National private companies seems to be the more interested in the Genetic of Embrapa in order to answer the demand for non-genetically modified seeds, a niche market not filled by the transnational companies. Thus, we developed to our propositions 1-6.

Regarding the role of the institutions, what we observed is that institutions in different levels have caused a very large effect on the sector in a general way and on partnerships between public and

private companies in a particular one. As we could observe, the institutional context in which Embrapa is involved is of such complexity, setting up what Greenwood et al. (2010) named "institutional complexity". Among the diverse characteristics of the sector, it can be highlighted its global nature, a great amount of actors with different levels of power, different technological capabilities and commercial conditions among the actors and conflits between global and national legislations.

In fact, Embrapa faces both global and national institutional constraints. A very important one that somehow result from an international agreement is the low effectiveness of the *sui generis* mechanism (the certificate of plant variety protection), especially if compared with patents. At the national level, both laws specific to the sector and other national laws constrain Embrapa.

Beyond laws specifics to the sector, Embrapa, as a public company, faces important institutional constraints. One of them is the 8.666 Law, which makes the partnerships between Embrapa and private companies an arduous work. For example, it is not possible for the company to choose its partners freely, without facing a long process of public bidding. The revenues of Embrapa cannot be reinvest on R&D activities since they go to to Federal Government first. Another difficult of Embrapa is related to cultural characteristics of the country, perhaps due the Government protectionist feature and due the economic and institutional instability. The fact is that national private companies are not interested in investing on R&D usually, as we see in other countries as the USA. Embrapa is trying to influence the legislators in order to make changes in its legal constitution. For example, suggesting to the Congress the creation of a private arm of Embrapa, the EmbrapaTec. Beyond this, there are also other proposals there. Recently we observed important advances in national laws, particularly in the Biodiversity Law, which counted to the help of Embrapa. At the firm level, Embrapa has made a huge effort to enhance flexibility of its internal rules and to improve its mechanism of governance.

Exogenous effects are the last primary microfoundation, which contributed to changes of the ego-networks. In the case of the seeds sector, some example of these effects are the increase of world population and the problem of food security, the increasingly close relation between agriculture and clean energy production, the sustainability of production, concerns about climate change and global governance, among others. These exogenous effects highlight that serious issues of our society are

involved with the sector and so, that the economic profit cannot be the primary interest of the sector.

An important advance to this research would be the examination of the seeds sector in the whole-network level. In sum, we confirmed Burt's idea that different (kinds of) networks structures and positions imply different effects, in form of advantages or constrains (Burt, 1992). However, to find out the content in the ties, that is, exactly what is being delivery by/for whom seems to be one of the most important questions. In fact, it seems to be one of the biggest secrets to be discovered, that is, it is like "a secret guarded with seven keys". Although it is early to say which impacts will occur in the Brazilian seeds sector due the partnerships between Embrapa and private companies, we advocate that "governance" is the keyword for the public company. As well as in the agricultural sector (Zylbersztajn, 2014), it is up to the Brazilian seed sector to expand its technological capabilities (especially in modern biotechnology route), but mainly their managerial competence to establish vertical and horizontal relationships (read up governance).

Concerning to cooperation mechanisms of PPP, special care should be taken by Embrapa with institutional arrangements (or contractual structures) with R&D private companies oriented to develop agricultural seeds, especially with the control of important nodes of networks that results on appropriation of knowledge and of value. Perhaps the main challenge of Embrapa would be how to succeed in partnerships that are fair, fruitful for both parties and ergo sustainable in long terms. In other words, how to answer the local (and global) demand without handing over its assets and do not having as counterpart another relevant asset in exchange which permit (or help) it to be competitive in long terms.

It is unarguable that there are many potential benefits in partnerships between Embrapa and national/transnational companies. But it seems also true that transnational companies have some competitive advantages that make this kind of partnerships potentially unbalanced. Due to its competitive advantages owed to its sizeable financial resources, these companies had already virtuallly dominated the local market of basic seeds. More recently, we have witnessed the production of grains in Brazil, soybean for example, be exchanged by technological packages, such as seeds and fertilizers. In other words, these companies are increasingly obtaining benefits from both R&D of agricultural seeds and production and export of grains.

One could say that the aim here would be protect the local market simply. We are aware that in today's economic environment, novel, innovative forms of collaboration between public and private organizational actors take an increasingly prominent place. However, what we argue is that it is necessary to create conditions in a way that important interests of mundial society be attended, which may be obtained by the preservation of germplasms, the protection of the plants against diseases, the increase or productivity and much more. We are talking about a sector that is inextricably linked to agriculture and therefore is involved with concerns about the increase of world population, food security, clean energy production, sustainability of production, climate change etc.

We advocate here that there are some global institutions that seem to deserve a more deep analysis. There are also some national institutions whose merits also require a more profound investigation. It is also important that the natural resources of Brazil be valued fairly, since Brazil is a country that concentrates a great amount of advantages related to enviromental conditions, such as its continental dimensions, its extensive amount of arable land, and its rich biodiversity. As stated Zylbersztajn (2014, p. 270), "consider the need for a specialized structure to coordinate economic relations of production implies assume that the price system is not able to fulfill that purpose alone". For all this, we suggest our seventh proposition, and wish that institutions in all levels work better than they have done until now.

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ARTICLE 3: TECHNOLOGICAL TRAJECTORY OF EMBRAPA AND THE CONQUEST OF CERRADO

ABSTRACT

Despite the existence of numerous studies devoted to investigate the technological trajectory of the firms, little attention has been given to some characteristics of this trajectory. As examples, we may mention the time that firms take to catching-up and the influence of factors such as knowledge networks and learning mechnisms in the technological capability of the firms. Actually, the relation network-capability is considered by some authors one of the most important interactions, which has been neglected. This paper aims to minimize these gaps. Specifically we examined the technological trajectory of the most important Brazilian firm of the seeds sector agrícolas – Embrapa –, including the time to caching-up and the relation knowledge networks-technological capabilities. In the process of examining the technological trajectory of Embrapa, we examined how Embrapa conquest the Cerrado and measure some important outputs of technological innovations – production and export. Through a longitudinal single-case study, we concluded that Embrapa, adopted different trajectories over time. Initially the company adopted the "path-following" trajectory, then the "path-skipping" trajectory and later the "path-creating" trajectory. Embrapa also changed their partners over time (or their roles were adapted to conditions of the time). With the help of partners, Embrapa was able to reach quickly the level of world leadership. Moreover, production and export indicators proved to be relevant indicators to measure results of innovation efforts.

Keywords: Technological trajectory. Catching-up. Knowledge networks. Seeds sector. Brazil.

RESUMO

Apesar da existência de inúmeros estudos dedicados a investigar a trajetória tecnológica das empresas, pouca atenção tem sido dada a algumas características dessa trajetória. Como exemplo, podem ser citados o tempo que as empresas levam para avançar tecnologicamente e a influência de fatores, tais como as redes de conhecimento e mecanismos de aprendizagem na capacidade tecnológica das firmas. Na verdade, a relação redes-capacidades é considerada por muitos autores uma das mais importantes interações, que tem sido negligenciada. Esse artigo busca minimizar esses "gaps" na literatura. Especificamente, nós examinamos a trajetória tecnológica da principal empresa brasileira do setor de sementes agrícolas – Embrapa – incluindo o tempo para avançar tecnologicamente e a relação redes de conhecimento-capacidades tecnológicas. No processo de examinar a trajetória tecnológica da Embrapa, nós examinamos como a Embrapa conquistou o Cerrado e mensuramos alguns importantes resultados de inovações tecnológicas – produção e exportação. Por meio de um estudo de caso longitudinal, nós concluímos que a Embrapa adotou diferentes trajetórias ao longo do tempo. Inicialmente a empresa adotou a trajetória "path-following", em seguida a trajetória "path-skipping" e, posteriormente, a trajetória "path-creating". A Embrapa também mudou seus parceiros ao longo do tempo (ou eles tiveram seus papeis adaptados às condições da época). Com a ajuda de parceiros, a Embrapa foi capaz de rapidamente alcançar o nível de liderança mundial. Ademais, indicadores de produção e exportação provaram ser relevantes para mensurar resultados de esforços de inovação.

Palavras-chave: Trajetória tecnológica. Catching-up. Redes de conhecimento. Setor de Sementes. Brasil.

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INTRODUCTION

This paper aims at examining some characteristics of technological trajectory at firm level in a developing country, influential factors for accumulation of capabilities and some results of innovation efforts. Specifically, we examined the time to catching-up, the knowledge networks centered at firm and learning mechanisms, and the relation between knowledge networks and technological capabilities, to which we gave special attention. In the process of examining the technological capability building of Embrapa, we examined the path followed to the conquest of the Cerrado. Despite this achievement has occurred many years ago, its results last until today. We used data of production and exports to measured results of innovation efforts.

The motivation of the research resulted from the gaps in the literature about the trajectories of innovative technological accumulation in emerging economies. In spite of many advances related to the description of trajectories of technological capabilities accumulation, we may observe important limitations. For example, researches with this focus have been particularly weak in dealing with explanations related to the characteristics of trajectories in accumulation of technological capabilities, such as time to catching-up and the influence of knowledge networks centered at firm. Actually, many authors, including Dantas and Bell (2011), advocate that networks-capabilities is one of the most important interaction. Unfortunally, no or little attention has been given to it.

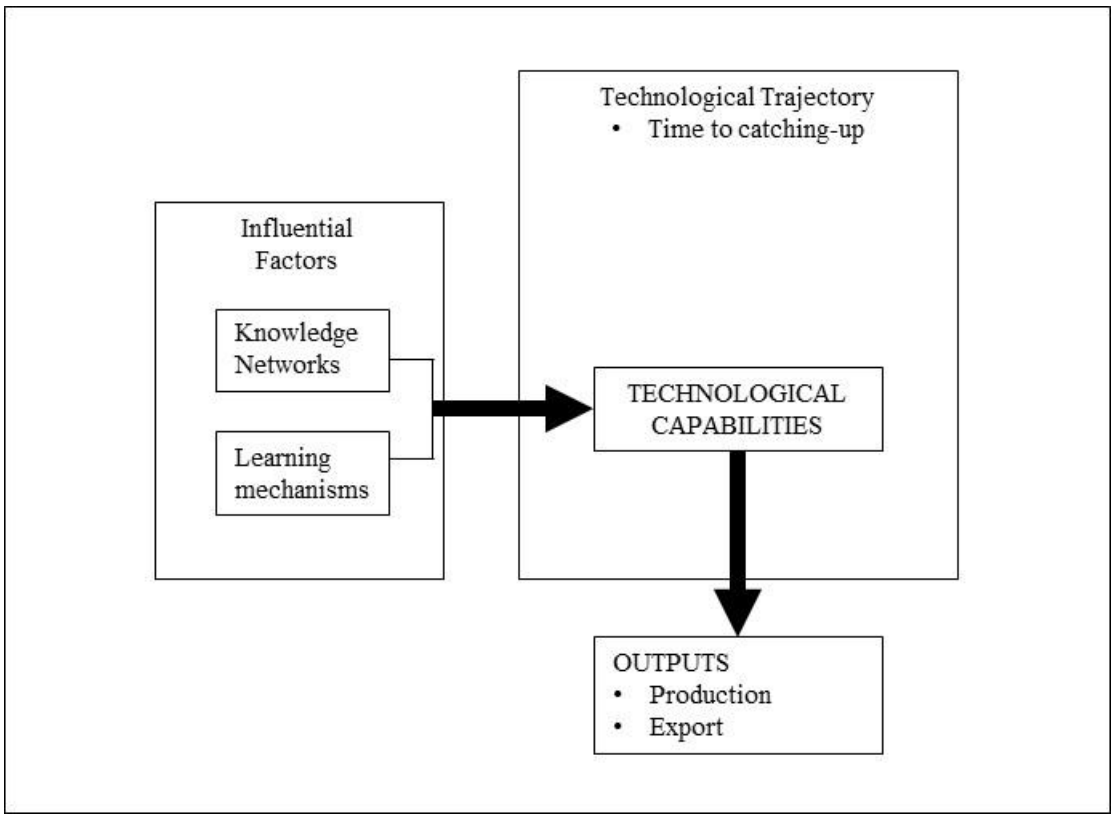
Regarding the theoretical basis, the study is based on precepts of the evolutionary theory and on literature of technological innovation that steams from it. As a method of research, we conducted a single case study with an inductive approach based on empirical evidence gathered through extensive fieldwork.

We chose the Brazilian seeds industry as the empirical setting to be investigated due to its great economic relevance and strategic importance not only for the Latin America and Brazil, but for the world. The choice of the company - Brazilian Agricultural Research Corporation (Embrapa) - was due its leading role concerning the organization of the sector, both as a public research institution and the ultimate provider of seeds in the supply to the domestic market. The scope of the study is the technological function ‘conventional plant breeding process’, since it refers to research and development and therefore is directly involved with innovative activities. Considering that the

processes of development of seeds are very different depending on the crop, we chose the soybean to be examined due its economic importance for the country. We were particularly interested in the conquest of the Cerrado - a previously barren land - and in its implications to outcomes of the Brazilian agriculture of soybean.

Figure 1 shows the framework of the article.

Figure 1 - Framework of the article



Source: elaborated by the author

As article contribution, it is expected that: (i) evidence based on intra-firm and intra-industry perspectives may expand the knowledge about the characteristics of the technological trajectory in developing countries and (ii) be generated important inputs that may contribute to the improvement of public policies and business strategies in the agricultural seed sector.

2. LITERATURE REVIEW

2.1 Evolutionary theory

Modern economic analysis drives the theory of the dynamics of the market economy evolving towards an evolutionary orientation (Nelson and Winter, 2002). Evolutionary theory, therefore, is opposed to orthodox models in which agents, perfect information and total and unlimited rationality and static equilibrium are theorized (Nelson and Winter, 1982).

In recent years, a branch of evolutionary economics has explored the historical development of industries, especially noting the co-evolution of technology and industry structure and the existence of life cycles in the industry.

As stated by Dosi (1982), the selection of new technologies is achieved through a complex interaction between fundamental economic factors, along with powerful institutional factors. Therefore, technological trajectory should be perceived as the direction of advancement within a technological paradigm, whose progress depends on economic and technological trade-offs. To the extent that it advances to later stages in the industry's history, the technological variety and of design tends to decrease, since emerges a natural selection process that tends to define a dominant design. Self-strengthening mechanisms create path dependence and prevent return to the previous branch points (Nelson and Winter, 2002). Thus, new technological paradigms will emerge only as a result of the relationship between scientific advances, economic, institutional variables and also unresolved difficulties in establishing previous technological paths (Dosi, 1982).

The evolutionary thought, however, also applies to the analysis of the dynamics of economic change at the organizational level, particularly in settings where the innovative performance plays a crucial role in the competitive struggle. In theory and evolutionary models, firms are modeled as having certain capacities, internal decision rules and limits to adaptation in changing environments, responding to changes in demand, supply and technology conditions (Nelson and Winter, 1982; 2002).

In the evolutionary view, if on the one hand the competence of firms is magnified because of learned skills and routines, which were improved through practice, on the other it must be evaluated

in contrast to the standards involved historically, since they change, requiring new skills. It is in this sense that the role of learning both for individuals and for organizations should be perceived. In the short term, learning guided by clear feedback can be remarkably powerful, even to face complex challenges. Nevertheless, it does not allow sophisticated forecasts or decisions logically structured, and improvisation of new patterns of action. Thus, the evolutionary answer to the puzzle of competence focuses on the role of learning and practice, considering the degree of correspondence between the current challenges and the previous contexts in which tasks are created or developed (Nelson and Winter, 2002).

2.2 Catching Up, Technological Frontier and Technological Capability

The intent to advance technologically is intrinsic to the latecomers[20]. In this sense, firms from developing countries tries to reduce the technological gap and so, catch-up. Thus, following the precepts of Bell and Pavitt (1993; 1995), catching up should be understood as the gaps reduction process relating to technological capabilities, taking as reference the technological capabilities of companies that are in the international technological frontier. Technological frontier is defined as the highest level reached in a technological route with respect to the relevant economic and technological dimensions (Dosi, 1982).

There are several approaches in the literature to understand the process of accumulation of technological capabilities at firm level, including those presented in Dahlman, Ross-Larsen and Westphal (1987), Lall (1987, 1992), Bell and Pavitt (1995), Dutrénit (2000), Marcelle (2004 and 2005). The concept of the technological capability to be adopted here is based on several conceptual contributions, especially on the ideas of Bell and Pavitt (1993, 1995) that define it as the organization's resources to generate and manage technological changes, including skills, knowledge and experience, institutional structures and connections networks. This concept of capacity has premised on the idea that innovation is a process that has as quality inherent in gradation or *continuum* of activities that advance towards increasing degrees of sophistication and difficulty. Therefore, the technological capability can be constituted since the ability to perform simple activities of acquisition, use and operation of existing technologies until to the ability to undertake

[20] The concept of latecomers to be adopted in this study is based on the ideas of Hobday (1995) – who first introduced the term -, Mathews and Cho (1999) and Mathews (2002).

complex activities related to new technologies. By accumulating capability, the latecomer firms narrow the technological gap with the developed countries.

The literature also points to existing tenuous border between two types of technological capacity, the production capability and the innovative capability (Kim, 1997; Dutrènit, 2000). Since we examined a process that involves R&D activities only, we just considered the innovative capability.

3. RESEARCH BACKGROUND AND RESEARCH QUESTIONS

We chose the conventional plant-breeding program as technological function to be examined since it involves some of the activities that most contribute to the increase of yields of seeds, including the adaptation of seeds to different edafoclimatics conditions, as happened in the case of the Cerrado.

Due the complexity of the activities involved in plant breeding programs – in this case, conventional plant breeding programs –, we decided to first explain the goals of each phase of the programs and detail the activities involved on them in order to enable a better understanding of the technological trajectory of the company. In addition, this will made possible to observe in which phases there are more potentialities to promote innovations.

3.1 Plant Breeding Programs through Conventional Breeding Route

Plant breeding programs are developed with the main goal of improving the quality of the seeds driven to high productivity. However, issues related to social and environmental sustainability, beyond health safety are becoming increasingly relevant.

Quite widely, we can consider the existence of three main phases in a plant-breeding program: pre-breeding, breeding and post-breeding. The two first are aimed to the development of new cultivars, being the border that distings one from the other very tenuous and diffuse in real life[21]. The pre-breeding includes activities related to germplasm banks. The post-breeding phase refers to

[21] In fact, since breeding is a cycle process, in which the better materials enter again in another cycle of breeding, Embrapa Soybean uses the term “recurrent selection” to refer to the pre-breeding phase.

marketing and communication activities. In this study, the pre-breeding and breeding processes are dealt, getting beyond the scope of this study the post-breeding process.

3.1.1 Pre-breeding Phase

In the pre-breeding phase of the genetic industry, technological innovation is oriented toward the improvement of genetic variability. It is a phase to broaden perspectives and look for materials that can meet the features of interest previously defined. This feature has moved over time. For example, important changes concerning to plant architecture happened in both types of growth - that moved mainly from determined habit to indeterminate habit - and in the medium cycle - that is dwindling (early cycle). The improvement of genetic variability is also obtained through the greater divergence among the parentals. Thus, the quality of vegetal genetic resources and the bank of germplasm matters. Generally, countries with high plant biodiversity, like Brazil, have advantages in this regard. In the case of soybean, even though it is originally from China[22], Embrapa has increasingly invested on its germplasm banks, which includes wild species and therefore increase its chances of success. This means that companies from different countries will try to exchange access[23] among them.

Thus, prebreeding refers to all activities designed to identify desirable features and/or genes from unadapted (exotic or semi-exotic) materials, including those that, although adapted have been subjected to any kind of selection for improvement" (Nass & Paterniani, 2000, p. 582). The pre-breeding programs acts as a link between the vegetal genetic resources and the breeding process (Nass, 2011) and involve the following activities: (a) determination of the comprehensiveness area; (b) determination of the features of interest and (c) selection and choice of parental.

[22] "Soy is a plant originally from China, regions located between parallels 35° and 45°N" (Embrapa, 1984) and considered a short-day plant (long nights); thus, much of the world area planted with this crop is located at latitudes greater than 30 degrees, where prevail temperate conditions" (Almeida et al., 1999).

[23] It is a widely used term by conservationists. It is employed to denote all sample germplasm representing the variation of a population or an individual clonally propagated (Vilela-Morales et al., 1997).

a. Determination of the comprehensiveness area

The breeding programs must be developed for specific regions, since edaphoclimatic conditions influence the performance of cultivars. Thus, it is important to characterize the coverage area of the ongoing breeding program, that is, the environments where you want to cultivate the varieties to be developed. The criteria for characterization of the areas vary by culture. However, such a characterization "should allow the grouping of the environments and the consequent rationalization of the number of sites to evaluate the germplasm without losing the representativeness of the target macro environment" (Pípolo et al., 2007, p. 1).

b. Determination of the characteristics of interest

In this phase, the main question that is placed is "what kind of features are we looking for"? That is, besides the productivity potential and the production stability, it must be considered the main desired characteristics, such as: (i) plant architecture: type of growth (determined, semi-determinate and indeterminate), lodging resistance, average plant height; (ii) the medium cycle (level of precocity); (iii) average teor of protein; (iv) average teor of oil. Besides this, it must be considered planting dates, sanity of cultivars (fungi, bacteria, viruses and nematodes, caterpillars and bugs weed (ervas daninhas)) and seeding conditions (including the edaphoclimatic adaptation regions), among others. It is also important to consider the market requirements. For example, a major concern of today has been the protein teor, which has fallen in recent years.

3.1.2 Breeding Phase

While in the pre-breeding stage, researchers are aimed to broaden perspectives, seeking even to explore unknown materials, in the breeding phase, they shift to the opposite direction, that is, it is time to narrow the scope (see section 3.1.2). In this phase, technological innovation is oriented toward of pursuing the development of technologies that enhance productivity, while taking into account the preservation of the environment and the sector's sustainability. This includes the development of cultivars that if not solve at least minimize problems related to biotic and abiotic factors. For this, it is necessary to select and choose the parental and identify and selected superior genotypes and lines that have the desired agronomic characteristics, always in interaction with the environment. In order to evaluate the lineages, it is necessary to carry out tests in the field.

The plant breeding is a continuous process of development of new cultivars, aimed to the solution of real and potential limitations of the cultivars front of biotic and abiotic factors that interfere in soybean production (Almeida et al., 1999). The authors explain the challenges of productivity in this way:

> The expression of productivity is function of the genetic and environmental components and the interaction between them. Because of environmental variation and interaction that the cultivars present in the various environments, productivity is a quantitative character that normally has low heritability. This complicates the selection and evaluation of the productive potential of the genotypes. As a result, it is necessary to perform an extensive evaluation (testing conducted in multiple locations and years) to identify superior genotypes in yield and yield stability in certain range of environments which representing the limiting effects of climate, soil, pests and diseases.

The genetic breeding of soy involves different phases: (a) Developing of population; (b) Process of selection and (c) Evaluation of lineages (Almeida and Kiihl, 1998). However, first we need to select and choose the parental.

Selection and choice of parental

The importance of choice and selection of parentals is the possibility of increasing the variability required to meet program objectives. In addition to high productivity and production stability - major goals of any breeding program -, it should be considered the features of interest to be recombined in new cultivar. Therefore, the choice of parentals involved in hybridization depends on the objectives set in the breeding program. In other words, all the features of interest must necessarily exist in parentals (Pípolo et al., 2007). As exemplified by the authors, parentals with inappropriate cycle to the interest of the new cultivate will likely produce new populations with similar cycles and therefore the possibilities of selection of cultivars with the desired cycle become reduced. The sources of variability, however, are different, and may arise from own commercial cultivars, from lineages and plant populations of breeding programs, introductions of plants of the germplasm banks and also as a result of the biotechnology amenities, of any organism live. Theoretically, the greater the divergence among the parentals, the greater the variance between populations produced and, consequently, the greater the gain from selection. In an attempt to

measure the genetic divergence between parentals, different methods have been used (Pípolo et al., 2007).

a. Developing of "segregating populations"

Once chosen the parentals, the segregating populations are developed through artificial hybridizations (Almeida et al., 1999). First, the F1 generation of cultivation are performed, from where emerge the segregating populations. From the F1 generation, the populations go to the field in order to go through the process of advances of generations of the "segregating populations". "For soy, this process begins in the F2 generation and goes, at most, until the F6 generation" (Pípolo et al., 2007, p. 4).

b. Process of selection

According Almeida et al. (1999, p. 137) and in line with our research findings, "a cultivar must be uniform for the different features of interest, such as cycle, carry plant, flower color and pubescence, among other features of easy viewing". Hereupon, since the lineage needs to be uniform genetically for these features, "they need to be homozygous for the genes responsible for these qualitative characters". That it is why a phase of advances of generations is required, that is, "to achieve a high level of homozygosity in the populations, allowing the selection of plant that produce uniform lineages". From populations at more advanced generations, plants are selected for the establishment of progeny testing and selection of lineages having desirable agronomic characteristics (Almeida et al., 1999).

c. Evaluation of lineages (phases of tests of progenies)

In this phase, we evaluate both productivity and production stability in a large number of lineages. Since we are interested in selecting superior genotypes, it is "required to employ the evaluation trials, repeated in several environments (local and year) in order to identify the interaction of the genotype with the environment and its possible adaptation as a function of productivity and stability" (Almeida et al., 1999, p. 137).

Thus, we proceed with the trials, both preliminary and final ones. The soybean lineages assessment process generally include two stages. The first one is called Preliminary Evaluation in which the lines are evaluated in a small number of environments (Pípolo et al., 2007).

Preliminary trials

The next step is to proceed to the development of the cultivar to the market. The cultivar is more proper to a market niche or it fit better as a commodity? Thus, we advance with the preliminary tests.

The preliminar tests can last two or three years. The process is divided in tests of 1st, 2nd and 3rd years, in a consecutive way. At the end, we wish that we have obtained selected lineages to the field with high yields and resistance to the main diseases. In order to optimize the process, "the lineages with low yields may be discarded at the end of each year of trial". With the same goal, "the resistance tests to the major diseases can be made from the early stages, leading to the later stages only the resistant lines. Genetic resistance to some diseases is necessary. "Therefore, it is interesting to submit the lines for evaluation for these diseases during the first preliminary assessments and/or second year, reducing the number of lines that will occupy space in the following experiments, since they will be discarted if they are susceptible (Pípolo et al., 2007, p. 6).

We consider these phases as the "D" (Development) of the R&D process. Most of time, they are developed in partnership among Embrapa and different partners.

Final trials (VCU)

The process of plant breeding is finished with the second performance evaluation stage, called the Final Evaluation (ensaios). The final tests aim to identify the value of cultivation and use (VCU), that is, the goal is to test the stability related to productivity mainly in different years. The VCU is required in order to get the product registered (and protected) at MAPA and thus be able to be commercialized in the market. It is performed during two years or more in a large number of locations; thus, it is realized the VCU tests of the 1st and 2nd year. Since the development of the cultivars is driven to the market, in this phase the goal is to show to the producers the performance of the seeds. We use small demonstration plots (for exhibition). There are farmers looking at,

measuring, discussing and making comments. Embrapa begin to depend to the partners, specially the seeds producers, private companies mostly.

In sum, we may say that many factors contribute to the quality of seeds and increase of productivity. Technological innovations may happen both in pre-breeding phase and in breeding phase. For instance, when determining the characteristics of interest (pre-breeding phase), a correct choice may please the producers and become a competitive diferential. Concerning the breeding phase, beyond the interest in improving quality and productivity of cultivars (as through the selection and choice of good parentals), it is also possible to develop technological innovation in order to reduce the time to get the cultivars ready, for instance through the process of selection and evaluation of lines.

4. RESEARCH METHOD

In this section, we discuss about the research setting, the research strategy and design and data collection and sources.

4.1 Research setting

Embrapa was created in 1973, and with it the Cooperative System for Agricultural Research (CSAR), which included federal and state agencies, beyond universities and the private sector. The CSAR aimed to contribute to the modernization of Brazilian agriculture starting from various fronts. Among them (and certainly one of the most important), it was the generation of technologies for using of barren land, including the Cerrado. There was also the intention to increase the productivity of land through the replacing of the extensive by intensive livestock, farmings and forests. In 1975, the National Center for Soybean Research (NCSR) – or Embrapa Soja – was created. At that time, the soybean producing region in Brazil covered the states of Rio Grande do Sul, Santa Catarina, Paraná, São Paulo and southern of Mato Grosso (Embrapa, 1984).

A great amount of actors compound the Brazilian seeds sector: R&D organizations (agents of technological innovation), comercial organizations of seeds (agents of commercialization), multipliers of seeds (producers of seeds), agricultors and the final market (consumers). The agents of technological innovation involve both public and private organizations (national and

international ones). Beyond these actors, other stakeholders are organizations of fostering and education sectors and foundations, which gather producers of seeds mainly.

Embrapa interacts with all of the different kind of actors. In fact, nowadays Embrapa coordinates the national network of agricultural research, which includes 18 state agricultural research organizations (Oepas), universities, and federal or state-level research institutes, private companies and foundations. As may be observed, the organizational model of Embrapa since its conception has been structured as networks. Embrapa also invested heavily in learning.

4.2 Research strategy and design

Based on Davis and Eisenhardt (2011), Yin (1984) and Pettigrew (1990; 1997), we chose the research design: a longitudinal single-case study. As suggested by Dantas e Bell (2011), the nature of the research question, focused on the technological *trajectory*, requires a longitudinal study that covers, at least, a long period enough that enable that significant changes in the degree of technological capabilities take place. We found two distint periods in the trajectory driven Embrapa' technological to conquest of Cerrado.

In order to investigate the trajectory, we drank from the source of the model of technological and market catching-up developed by Lee and Lim (2001). In the process of examining the technological capability building, we used three different levels of innovative technological capabilities. The "level 1" is the basic level and refers to technological capabilities enough not only to imitate, but to innovative. This level must allow the company to sustain competitive advantage at local or regional level. The "level 2" refers to innovative technological capabilities at national level, that is, the company is not at the global technological frontier, but at national one. The "level 3" means that the company is at the global technological frontier, that is, it has the same level of technological capabilities of the global leaders (in terms of market share) and that it is able to open new market segments or to developd disruptive technologies.

We made use of two types of catching-up – technological catching-up and market catching-up –, which, although different, are related to each other (Lee & Lim, 2001).

We first measure the market catching-up (at global and national level) based on two important indicators: production[24] and export. We also measured the market share of Embrapa in the same period.

Next, we examined the interaction knowledge networks-technological capabilities, considering the role of the actors in technological catching-up. We also examined the learning mechanisms used by Embrapa in order to catching-up.

Finally, we examined the technological catching-up of Embrapa. We agree with Lee and Lim (2001) that it is not easy to measure and compare the level of technological capabilities. In their words: "There is no single good quantitative measure, including patents, and thus commonly adopted alternatives are qualitative ones... In discussing the rapid catching up by the NIEs, OECD (1992) and World Bank (1993) used "export of manufactures" as an indicator of industrial growth. However, as you notice, they do not specifically refer to technological aspect of catching-up" (Lee & Lim, 2001). Thus, for measuring the Embrapa's technological capability we follow the precepts of the authors, that is, consider technological capability as function of both technological effort and the existing knowledge base. Since technological regimes of the industry – specially their predictability – also affect the innovative activities of catching-up firms, the capability is measure from them.

Similarly to Lee and Lim (2001) that used patents as a indicator of frequency of innovation, we decided to also use a quantitative measure – the number of protected cultivar in SNPC – to verify how the indicator behave in the industry.

4.3 Data collection and sources

We sought evidences from diverse data sources, but predominantly in different areas of Embrapa and Embrapa Soybean. As mechanisms of data collection, we conducted about 35 semi-structured interviews with around 40 people over a year period, which generated over 488 transcribed single-pages of primary source material from these interviews.

[24] It is important to consider "production" in this case, since its increase has arosen from technological innovation when transforming barren land into productive land.

Embrapa headquarters in Brasília was the fist company we visited. The reason was our interest in getting a broader vision about the company and its strategies. Next, we visited Embrapa Soybean. At that time, our intention was to understand in detail the decisions and actions of the company. Then, to check the existence or not of other visions, we went to the other organizations. We yet came back to Embrapa and Embrapa Soybean to confirm our evidences and to solve some doubts.

In order to select the interviewees, we confronted initially the research goals and the functions exerted by the Embrapa professionals in areas previously selected. Both professionals from the directive board, managers from middle level and supervisors, analysts, engineers, assistants, technicians, experts and researchers made part of our sample. Next, we used the snowball strategy to select other professionals to be interviewed.

We also interviewed professionals from other organizations of the sector that somehow interact with Embrapa and Embrapa Soja: Brazilian Association of Seeds and Seedlings (Abrasem), Agronomy Institute (IAC), Meriodional Foundation, Integrated Agroindustrial Cooperative, MT Foundation, Agribusiness Center at the Getulio Vargas Foundation, Center of Management and Strategic Studies (CGEE) and Kleffmann Group. As secondary data, we made use of many company reports and other materials provided by interviewees, beyond newspapers, data from web sites, among others.

4.4 Procedures for the analysis of the empirical evidence

We follow Miles and Huberman (1994) for the analysis of empirical evidence collected. First, we carried out the data cleaning activity. In this phase, we transcribed, coded and prepared in a common format in defined categories the data collected. Then we performed the data reduction. Later, the data were organized in narrative texts, matrices, charts, etc. schemes to allow conclusions. Finally, we seek to identify patterns of answers, explanations and possible relations of cause and effect between the variables investigated (data interpretation).

In section 5, we present the data analysis concerned marketing and technological catching-up, beyond the interaction knowledge networks-technological capabilities.

5. DATA ANALYSIS

5.1 Marketing Catching-up

According to Brazil (2016), "since the late 1990s, few countries have grown so much in international agribusiness trade as Brazil". Currently, Brazil is the second largest grain producer, behind the United States only (Table 1).

Table 1 - World's largest grain producers - Harvest 2014/15

	USA (world's largest grain producer)	Brazil (world's second largest grain producer)	World
Production (million of tons)	108,014 (34.05%)	95,070 (29.97%)	317,253
Planted Area (million of hectares)	33,614 (28.45%)	31,573 (27.73%)	118,135
Yields (kg/ha)	3,213	3,011	

Source: USDA (2015), Conab (2015), Embrapa (2015)

The Economics (The Economics, 2010) highlighted the stunning increase in Brazil's farm production.

> In less than 30 years Brazil has turned itself from a food importer into one of the world's great breadbaskets...It is the first country to have caught up with the traditional "big five" grain exporters (America, Canada, Australia, Argentina and the European Union). It is also the first tropical food-giant; the big five are all temperate producers.

Regarding the soy complex (grain, meal and oil) - the main generator of foreign exchange for the country (BRAZIL, 2016) -, the country leads the ranking of foreign sales. In the 2014/15 harvest, Brazil reached the mark of 45.7 million tons of export of soy, which amounted to 31.4 billion dollars (Table 2).

Table 2 - World's largest grain exporters - Harvest 2014/15

	In millions of tons	In US$ billion
Export of grain	45.7	23.3
Export of bran	13,7	7.0
Export of oil	1,3	1.1
Total export	n.a.	31.4

Source: Agrostat (2015), Embrapa (2015)

The evolution of the Brazilian production of soybean happened in an expressive way both between 1973-74 and 1997-98 harvests (Table 3) and between 1998/99 and 2015/16 harvests (Table 4), after the Plant Variety Protection Act and the arrival of the transnational companies.

Table 3 - Evolution of the production and exports from 1973/74 to 1997-98 (in million tons) – Brazil and World

	Production (MT)			Exports (MT)		
Year	Brazil	World	Share (%)	Brazil	World	Share (%)
1973/74	n.a.	54,007	n.a.	n.a.	15,224	n.a.
1974/75	n.a.	44,246	n.a.	n.a.	12,061	n.a.
1975/76	n.a	53,633	n.a	n.a	15,781	n.a
1976/77	n.a.	45,463	n.a.	n.a.	15,927	n.a.
1977/78	9,541	72,148	13,224206	830	22,509	3,6874139
1978/79	10,24	77,408	13,228607	638	24,671	2,5860322
1979/80	15,156	93,389	16,228892	1,155	28,266	4,0861813
1980/81	15,2	80,926	18,782592	1,798	25,342	7,0949412
1981/82	12,835	86,083	14,910029	858	29,316	2,9267294
1982/83	14,75	93,455	15,782997	1,307	28,617	4,5672153
1983/84	15,541	83,104	18,700664	1,591	26,221	6,0676557
1984/85	18,278	93,063	19,640459	3,476	25,249	13,766882
1985/86	14,1	97,006	14,535183	1,187	26,061	4,5546986
1986/87	17,3	98,049	17,644239	3,294	28,552	11,536845
1987/88	18,02	103,654	17,384761	2,710	30,114	8,9991366
1988/89	23,6	95,857	24,620007	4,839	23,558	20,540793
1989/90	20,34	107,192	18,975297	3,933	27,275	14,419798
1990/91	15,75	104,29	15,102119	2,478	25,392	9,7589792
1991/92	19,3	107,297	17,987455	3,872	28,098	13,78034
1992/93	22,5	117,206	19,196969	4,056	29,296	13,844894
1993/94	24,7	117,582	21,006617	5,434	27,729	19,596812
1994/95	25,9	137,646	18,816384	3,566	31,982	11,150022
1995/96	24,15	124,699	19,366635	3,458	31,643	10,928167
1996/97	27,3	131,943	20,690753	8,424	36,764	22,91372
1997/98	32,5	157,95	20,576132	8,760	39,314	22,282139
Growth rate (1973-1997)	240,64	192,46		955,42	158,24	

Note: the growth rate of Brazilian production and Brazilian exports refers to the interval between 1977/78 and 1997/98
Source: USDA (2015)

While in the 1977/78 Brazilian soybean production represented 13.22% of world production, in 1997/98 it went on account 20.57%, increasing 7.35 percentage points. If we consider data from 1973/74 (based on Conab) when Embrapa was created, this difference is magnified for 11.29 pp.

While the growth rate between 1973 and 1997 in the world was 192.46%, in Brazil between 1977 and 1997 was 240.64. This number is bigger yet if we considered the whole period. The numbers are more impressive yet when we talk about export. While the growth rate of the world export was 158.24% (between 1973/74 and 1997/98), the rate of Brazilian export (between 1977/78 and 1997/98) was 955.42%.

The same pattern continued after 1997. Nowaday the Brazilian production of soybean account for more than 31% of the world production and the Brazilian export for almost 44%.

Table 4 - Evolution of the production and exports from 1998/99 to 2015/16 (in million tons) – Brazil and World

	Production (MT)			Exports (MT)		
Year	Brazil	World	Share (%)	Brazil	World	Share (%)
1998/99	31,3	159,827	19,583675	8,932	37,928	23,549884
1999/00	34,7	160,307	21,645967	11,101	45,634	24,32616
2000/01	39,5	175,844	22,463092	15,469	53,817	28,743706
2001/02	43,5	184,922	23,523432	14,504	53,012	27,359843
2002/03	52	196,952	26,402372	19,629	61,321	32,010241
2003/04	51	186,787	27,303827	20,417	56,046	36,429005
2004/05	53	215,905	24,547834	20,137	64,754	31,097693
2005/06	57	220,86	25,808204	25,911	63,852	40,579778
2006/07	59	236,3	24,968261	23,485	71,137	33,013762
2007/08	61	219,011	27,852482	25,364	78,321	32,384673
2008/09	57,8	212,081	27,253738	29,987	77,212	38,837227
2009/10	69	260,555	26,481933	28,578	91,44	31,253281
2010/11	75,3	264,345	28,485502	29,951	91,702	32,661229
2011/12	66,5	240,427	27,659123	36,257	92,186	39,330267
2012/13	82	268,824	30,503229	41,904	100,802	41,570604
2013/14	86,7	282,865	30,650664	46,829	112,769	41,526483
2014/15	96,2	318,801	30,175564	50,612	125,962	40,180372
2015/16	100	319,008	31,347176	57	129,785	43,918789
Growth rate (1998-2015)	219,49	99,60		538,15	242,19	

Source: USDA (2015)

The Economist resume the stunning evolution of the crop in Brazil in this way:

> Since 1990 its soyabean output has risen from barely 15m tonnes to over 60m. Brazil accounts for about a third of world soyabean exports, second only to America. In 1994 Brazil's soyabean exports were one-seventh of America's; now

> they are six-sevenths. Moreover, Brazil supplies a quarter of the world's soyabean trade on just 6% of the country's arable land (The Economist, 2010).

The forecast for 2024/25 suggests that the world will need even more Brazil, at least regarding the production of soybean.

Table 5 - Largest exporters of soybean in the world – Forecast 2024/25

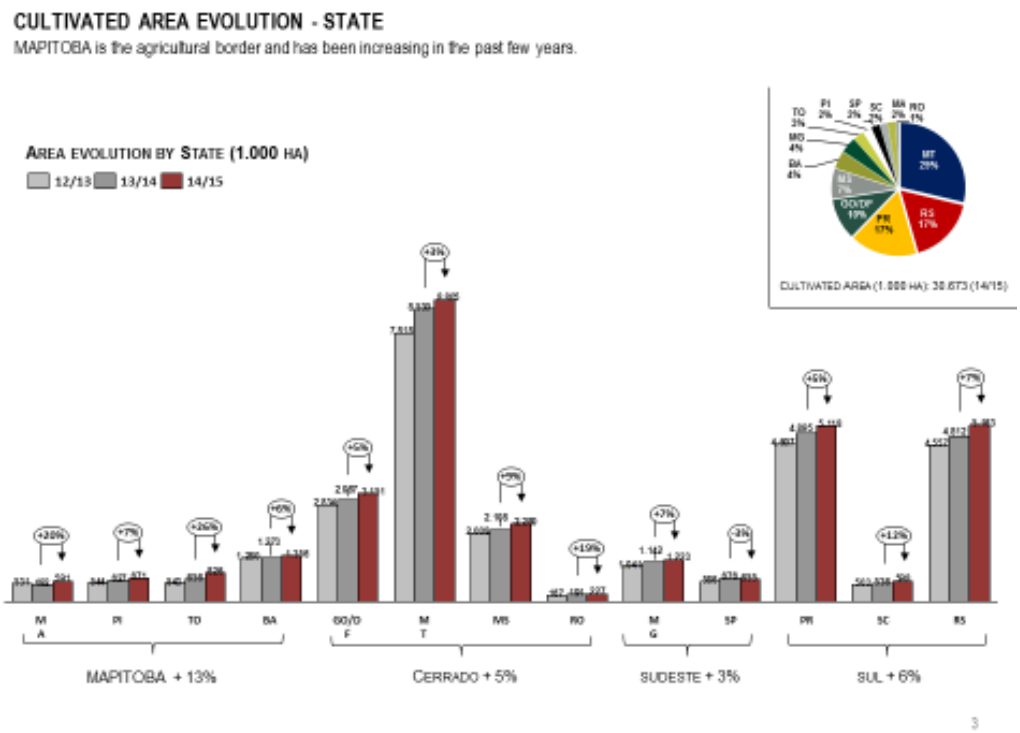
Countries	Exports (million tons)	Share of world trade
Brasil	69	45.9
USA	50.2	33.4
Argentina	12.4	8.2
Other South American countries	11.2	7.4
World	150.4	100.0

Source: USDA (2015)

Such numbers could only be achieved due the conquest of cerrado, which in turn was just possible due technological innovations carried out by Embrapa and partners. Moreover, technological advances have enabled the increase in average productivity per hectare in the cerrado, reaching the major world indices (Brazil, 2016).

Cerrado areas in Brazil cultivated with soybean continued to grow year after year and currently represent 47% of the total ared cultivated with the grain, as may be observed in Figure 2. Thus, the conquest of Cerrado, despite having started yet in the 70, has much important consequences to the country until now.

Figure 2 - Cultivated Area Evolution



Source: Kleffman Group (2015)

Let us understand how Embrapa developed its knowledge networks and the role of each actor in the process of technological catching-up.

5.2 Knowledge Networks and the Role of the Actors in Technological Catching-up

The Brazilian seeds industry, since the year of creation of Embrapa (1973) until now has passing through a dynamism of such proportions that, due to its large different features, may be easily distinguished into two main periods: before and after the PVPA. However, we decided to divide the first period in two sub-periods, since its goals, the actors involved on the main activities, the direction of the knowledge flow, among other features are very different among them. The first period refers to the begining of Embrapa Soja's life, when researchers from abroad, especially from the USA came to Brazil. The second one covers the period between around 1981 and 1997 (shortly after the PVPA, or the early 2000s). And the third refers to around 1998 or 2000 until now, and the industry presents a configuration completely different.

Since its creation, Embrapa made partnerships in order to advance its technological capabilities and to spread the developed technologies. The partnerships have been signed with different kind of actors: international and national universities, international organizations, research centers (including state research institutes) and private initiative.

5.2.1 First period (1973-1980): knowledge transfer from abroad and establishment of networks

In the beginning of Embrapa life, the company made a strong partnership with international organizations, american universities and ARS/USDA mainly. As mentioned by a respondent of the Directive Board of Embrapa Soybean, the first period of Embrapa Soja was marked by the arrival of great consultants, great american researchers, together with the staff of the ARS / USDA in order to basically introduce the soybean crop in the most economical way in Brazil. In his words: “Since the culture of soybeans was already at an advanced stage in the USA and here it was not, they brought from there the cultivars that have been selected and adapted to our conditions, management practices and condition of culture, and that helped us to give the first step”.

In addition to bringing top researchers from abroad, Embrapa invested heavily in the training of its human resources mainly through postgraduated program, in-service training and trips abroad. Until 1980, the postgraduate program of Embrapa, supported by International Bank for Reconstruction and Development (BIRD), Interamerican Development Bank (BID) and Financier of Studies and Projects (Finep), had already benefited about 1,835 researchers, including 518 professionals of the states (Alves, 1980). Many professionals of Embrapa got their master and PhD degrees in american and other international universities, especially in the Mississipi State University, which was considered ‘the mecca of seed technology’ at that time. As exalted by an interviewee, “more than 20 professionals of Embrapa passed through there, which influence a lot the seed program in Brazil”.

At that time, Embrapa had a clear vision about the catching-up possibilities that could arise from the partnerships with countries and its organizations that were at the technological frontier. Alves (1980) explained this idea in this way:

> Scientific knowledge and research methods that guide the generation of technology have universal application. The training of our technicians at universities and other research institutions as well as the short or long-term assistance of foreign experts helps us to leapfrog, leading our young people quickly to the frontier of knowledge (Alves, 1980, p. 11).

Since before the PVPA, there was no way to charge by the seeds due the lack of mechanisms of appropriation of innovation efforts, they were freely exchanged and thus the USA and other countries transferred technology without restrictions to Brazil (in the case, to Embrapa).

In addition to the initiatives of Embrapa to investe on learning, other factor that contributed greatly to the technological catching-up of the Brazilian seeds sector was the decision of the company to work in a cooperative way, in network format since its begining. Major contributions also arised from international organizations such as *Instituto Interamericano de Cooperación para la Agricultura* (IICA) and *Food and Agriculture Organization of the United Nations* (FAO). There were also mutual interest between Embrapa and countries of the so called "Third World" in order to transfer technology and exchange genetic material. In 1980, Embrapa had eleven contracts of multilateral cooperation and bilateral relations with the following countries: Canada, United States, France, Japan, England, Germany, Argentina, Ivory Coast, Costa Rica, Guinea-Bissau and Cape Verde, India, Israel, Italy, the Netherlands and Poland (Alves, 1980).

Specifically regarding the research and development for Cerrado agriculture, it is noteworthy the contribution of EMBRAPA's Cerrado Agricultural Research Center (CPAC, also called "EMBRAPA Cerrado"), which realized both technological innovations for soil management and the improvement of crop breeding.

The government also invested in the creation of special programs, such as POLOCENTRO, established in 1975. The program aimed at "the development and modernization of agricultural activities in the Midwest Region and the western state of Minas Gerais, through the rational occupation of areas with characteristics of Cerrado and their exploitation in enterprise scale". According Roessing and Guedes (1993), its main instrument of incentive was the favored credit to whom wished to invest in agricultural business operating in selected areas. Other major program resulted of the Japan–Brazil cooperation for Cerrado agriculture development, which started at the CPAC by Embrapa and the Japan International Cooperation Agency (JICA) in 1977 and which

consisted of financial and technical cooperation programs. Actually, the Japanese–Brazilian Cooperation Program for Cerrados Development (PRODECER) played a crucial role in the development of Cerrado (Hosono et al., 2016).

Moreover, also deserves to be highlighted the contribution of many research institutes, universities and other organizations. Among them, there are Agricultural Research Company of Minas Gerais (EPAMIG), Baiana Company of Agricultural Development (EBDA), Federal University of Viçosa (UFV), Federal University of Lavras (UFLA), University of Brasilia (UNB), Goias Federal University (UFG), and Mato Grosso Foundation (FMT) (Hosono et al., 2016).

5.2.2 Second period (1981-1997): the role of State and the rural extension

According our field research data, the second period of Embrapa – which lasted until the early 2000s - was marked by a very large partnership with national state research institutes, as well as with other national state agencies and national universities. Soon after also emerged the cooperatives.

5.2.2.1 State research institutes, state agencies and cooperatives

According respondents, “while state research institutes actively participated in the development of cultivars, the state agencies - Emateres - worked in technical assistance and rural extension”. The work of research and extension was considered inseparable part of the process of generating knowledge. The extension agent helped Embrapa to identify the difficulties afflicting farmers and translate them into research projects. Thus, the close contact between researchers and farmers and extension agents ensures that Embrapa focus on the relevant problems and that the solutions arrived to the destiny rapidly. As mentioned by Alves (1980, p. 12), “the rural extension adds to research results the information content which makes them assimilable by farmers. The generation of knowledge is therefore a *continuum*. It begins with a farmer’s problem and ends when the same solution enriches rurícola's ability to produce more efficiently”.

The role of cooperatives was mainly technical assistance to bring the technology to the producer. One way to transfer technology was through new cultivars, as well as new management. Embrapa counted on a wide range of cooperatives, which greatly helped in this process in the South. However, the cooperatives did not played an important role in the Central region, thus they were not important in the conquest of Cerrado.

5.2.2.2 National Universities

The partnerships between the National Agricultural Research System (NARS) and national universities were also strong, involving inclusive, exchange of human resources (including occupation of management positions). Among their diverse goals, it can be mentioned: the training of technicians of the NARS, the harnessing of students to develop theses dedicated to investigate problems faced by the system, and the developing of diverse integrated projects in order to solve agronomic national problems. One of the main important was the nitrogen fixation program. In this sense, UFRGS played a prominent role, as well as IPAGRO and MIRCEN. Agricultural Research Company of Minas Gerais (EPAMIG) also helped Embrapa with its cooperation program with universities (Alves, 1980).

The activities developed in partnerships between educational institutions and Embrapa Soja involved stages and special classes basically, involving the State University of Londrina (FUEL) mainly. In addition to it, many other educational institutions that sent students for internship at Embrapa Soja were: Federal University of Viçosa, Foundation Faculty of Agriculture “Luiz Meneghel” (Bandeirantes), Federal University of Paraná (Curitiba), Londrinense Institute, Agricultural School of Lavras (Escola Superior de Agricultura de Lavras), Agronomy School of Paraguaçu Paulista (Escola Superior de Agronomia de Paraguaçu Paulista), Agronomic Institute of the State of São Paulo, Campinas (IAC), Agronomic Institute of Paraná (IAPAR) and Agronomy School Eliseu Maciel UFPEL (Pelotas), among others (Embrapa, 1984).

5.2.2.3 Private companies

The Cooperative System for Agricultural Research intensified its relationship with the private sector during this period. The main objectives were, among others, the provision of search services, the conducting of cooperative research projects, technological support to agriculture, especially in pioneer regions and dissemination of research results. Regarding the 'provision of services', in addition to conducting research to meet the specific demands of private clients, Embrapa also held product behavior testing, both new or developing in the country, as foreign products to be suitable to our conditions. Demand for services of product behavior testing came mainly from the industrial sector of agricultural and agro-industrial inputs (machinery, fertilizers, chemicals etc) (Alves, 1980). All services provided to private companies were formalized through contracts. In the case of 'cooperative research projects', the private entities (alone or associated with cooperatives) looked for Embrapa in order to solve specific problems of the sector or represented group. In addition to engaging directly in the research process, private companies provided finantial support, covering part of the burden of research (Alves, 1980). The task of dissemination of research results and technology transfer to farmers was was under the responsibility of the Brazilian System for Technical Assistance and Rural Extension (SIBRATER) mainly, which were coordinated by the Brazilian Technical Assistance and Rural Extension (EMBRATER) (Alves, 1980).

5.2.3 Third period (1998-2015): the domain of the private sector

We can consider the third period of Brazilian seeds market featured by the entry of the private companies oriented to obtain large profits in the industry. Of course, at this time, laws on intellectual property rights – such as the plant variety protection law - and mechanisms for appropriation of investments in innovation were already in force. The irruption of the modern biotechnology – transgeny and genetic engineering mainly - also contributed to the interest of transnational companies.

These modern technologies, which involve higher levels of technological complexity, also require expressive investments of financial resources. This fact, allied to the prevalence of transgenic seeds in the Brazilian seeds market and the difficult of Embrapa to reach the local producers, made

Embrapa to change its partners in a certain way. Until 2006, ie before the Biosafety Law, the main partners of Embrapa were, beyond actors who constituted the NARS, universities, private foundations and some international agencies, such as INTA, USDA, JIRCAS and NARO. After 2006 and until 2015, we observed that Embrapa extrapolated this scope of its partner group, which now includes the Big Six or Gene Giants.

5.2.4 Learning Mechanisms

It can be said that the two major mechanism of learning used by Embrapa in its two first phases were consulting and capacitation. The evolution of the researchers of Embrapa until 1981 was presented in Table 6. In 2005, Embrapa had already achieved the number of 2,214 researches (Alves, 2005). Embrapa Soja had also expanded the number of researchers, despite its staff has not changed so significantly since its inception. In 2003, 300 professionals made part of the Embrapa Soja workforce. Today the number is 312, of which 70 are researchers. Around 180 students also contribute to Embrapa researches. The investment of Embrapa Soybean in capacitation may be observed through the evolution of the number of researchers with master or PhD degree. In 1975, from the total of 14 researchers, 8 possessed title of master or PhD degree. In 1978, out of 36, which number jumped to 25 and in 1981 from the total of 51 researchers, 47 were masters or doctors, or about 92.2%. Only between 2008 and 2013, 14 professionals had performed postgraduate courses, *lato sensu* or *stricto sensu*. Regarding the knowledge networks, partnerhips were done with different kind of actors, both to national and transnational ones.

Table 6 - Evolution of the number of Embrapa researchers

Year	Total of Embrapa reserchers (T)	Year	Total of Embrapa reserchers (T)
1973	12	1990	2.146
1974	872	1991	2.105
1975	1.037	1992	2.088
1976	1.328	1993	2.068
1977	1.311	1994	2.099
1978	1.336	1995	2.199
1979	1.448	1996	2.092
1980	1.553	1997	2.096
1981	1.576	1998	2.063
1982	1.597	1999	2.064
1983	1.610	2000	2.045
1984	1.619	2001	2.104
1985	1.650	2002	2.198
1986	1.724	2003	2.209
1987	1.870	2004	2.211
1988	1.911	2005	2.214
1989	2.166		

Source: Alves (2005).

5.3 Technological Catching-up and Technological Capabilities of Embrapa

Let us try to spell out how the industry gave opportunities to latecomers catching-up, while we make explicit the technological trajectory of Embrapa. In order to make the explanations clearer, we examined the two phases of the conventional plant breeding programs – pre-breeding and breeding –in different period over times.

5.3.1 The nature of the seeds sector

Although being an industry based on natural resources, due the fact that the seeds sector is increasingly science-based, it may be surely considered high-tech. However, this is truest yet to the modern technological route (or the so-called traits industry) – that one which includes transgeny – than to the conventional route (or the so-called genetic industry).

In line with Kim (1994, 1997), and Lee and Lim (2001), the technological regime of the seeds industry - particularly in the genetic industry, which envolve conventional plant breeding programs - has two main features. The first one is the high frequency of innovation. Due the adaptive feature

of the nature (for example, insect resistance to insecticides) and changing environmental conditions (more or less rain or drought), the frequency of technological innovations is necessarily high. In other words, the low degree of standardization requires constant investments in R&D. The second feature is the more predictability path of technological trajectory (than in traits industry), and so there are less frequent concepts changes.

If on the one hand, the predictability of innovation paths is favorable to latecomers, on the other, the high frequency of innovation tends to make more painful the caching-up for them.

Moreover, we confirmed in our interviews the feature of tacitness of the knowledge base associated with the development of activities. In our opinion, this is mostly due the fact that the outcomes of innovations depend directly on the edaphoclimatic (soil and weather) conditions, not being possible to give up field tests and phenotypic analysis of plants, despite technological advances.

However, it is important to highlight that this relative dependence on the environment and therefore on the regions of each country does not change the global nature of the industry. In fact, we observe a growing movement of seeds across national borders, which allied with the use of genetically engineered varieties, adds complexity to the sector. This requires investments by the government in regulatory issues related not just to specific technology aspects (ISF, 2013), but also to intellectual property, trade rules and sustainable agriculture aspects.

Next, we present the technological trajectory of Embrapa in each period, highlighting the major technological aspects in which the R&D programs of Embrapa were majority focused at that time.

5.3.2 First period (1973-1980): the consolidation of the crop in Brazil and the conquest of Cerrado

Embrapa Soybean's initial strategy early in his life was to establish partnerships with foreign market leaders - american universities and the Agricultural Research Service (ARS) of U.S. Department of Agriculture (USDA) mainly – in order to introduce the soybean crop in Brazil. In addition to bringing selected cultivars adapted to Brazilian edaphoclimatic conditions, big consultants and american researchers have brought the knowledge base and crop and soil

management practices. As mentioned by some respondents, “the varieties that existed in Brazil, until almost 1980, were american varieties”.

Thus, first Embrapa and other Brazilian companies were involved just with multiplying and adaptation of seeds, which is compatible with innovative capability of basic level (Level 1).

Shortly thereafter, Embrapa Soybean invested strongly in capacitation. A great group of Embrapa’s researches was study abroad, many of them in Mississipi University, considered one of the best universities in seeds technology. In fact, evidences about the investment in knowledge by Embrapa may be observed by the evolution of the number of researchers - which jumped in 1975-1981 period from 14 to 51 – and of researchers with master or PhD degree, which increased from 8 to 47 in the same period. The strong investment in learning, allied with international consulting, were the base to significant technological catching-up of Embrapa. In consequence, Embrapa Soybean began not only to adapt the american seeds, previously acquired, but to develop, itself, its own cultivars. Thus, Embrapa Soybean has evolved, in around 6 years, from innovative capability of basic level (Level 1) to innovative capability of national leadership (Level 2). In this period, Embrapa Soybean adopted the “following-path” trajectory.

Let us see in detail how this technological catching-up has evolved in activities developed in both pre-breeding and breeding phases.

5.3.2.1 Pre-breeding

Regarding the determination of the comprehensiveness area, the American varieties were most well adapted to the South, which justified why before 1980 around 80% of the total planted area with soybean in Brazil was in South.

However, motivated by the price of soybean in international market, the farmers intented to transform the great extension of land of Brazil (which was considered barren land) in productive land. Around 1980, the soybean was developed in two distint regions: traditional and ‘in expansion’ regions. The first one encompassed the states of Rio Grande do Sul (RS), Santa Catarina (SC), Paraná (PR) and São Paulo (SP). The second englobed the states of Mato Grosso do Sul (MS) and

part of Mato Grosso (MT), Goiás (GO), Minas Gerais (MG), Distrito Federal (DF), Bahia (BA) and Maranhão (MA) (Embrapa, 1984). Despite progress, great extensions of land in Brazil remained unproductive.

Thus, the development of new cultivars in Brazil were mainly oriented towards: (i) to adapted them to various ecological regions and different production systems; (ii) get tolerance to the complex of acidity, and with high capacity of soil phosphorus extraction; (iii) to obtain high quality seeds; (iv) to be resistant to major diseases, nematodes and insects; (v) to be used *in nature* and in food industry. Moreover, the Embrapa's breeding program had also as main goals: (vi) the development of the active germplasm bank[25]; (vii) the improvement of recurrent selection and (viii) the development of methodology for soybean breeding (Embrapa, 1984). These were the characteristics of interest of the soybean breeding programs of Embrapa.

Among the various ecological regions of interest were the cerrado. Thus, since the american cultivas had been developed for latitudes above 35°N, a challenge for Brazil was to develop varieties adapted for latitudes of up to 22°N. The challenge was huge, as may be highlighted in The Economist (2010):

> When Embrapa started, the '*cerrado'* was regarded as unfit for farming. Norman Borlaug, an American plant scientist often called the father of the Green Revolution, told the '*New York Time'* that "nobody thought these soils were ever going to be productive." They seemed too acidic and too poor in nutrients. Embrapa did four things to change that.

Thus, after the determination of the comprehensiveness area by Embrapa researchers, there was a great effort to develop not only varieties, but mostly a package of technologies for soil managements. The four things were: (i) Embrapa reduced the levels of acidity through pouring of industrial quantities of lime (pulverised limestone or chalk) onto the soil; and bred varieties of rhizobium, a bacteria that helps fix nitrogen in legumes and which works especially well in the soil of the cerrado, reducing the need for fertilisers[26]; (ii) Embrapa brought from Africa a grass

[25] "The Active Germplasm Bank (BAG) aims at the collection, characterization, evaluation and conservation of soybean genotypes, which represents wide genetic variability" (Embrapa, 1985). The BAG was established in 1975/76 in order to maintain and facilitate the distribution of a larger amount of soybean genotypes. Until 1981, the BAG had 2,000 genotypes (Embrapa, 1984).

[26] In this sense, it is important to highlight the role of Embrapa Cerrados in making productive the Cerrado soils.

called *brachiaria*. "Patient crossbreeding created a variety, called *braquiarinha* in Brazil, which produced 20-25 tonnes of grass feed per hectare, many times what the native *cerrado* grass produces and three times the yield in Africa. That meant parts of the *Cerrado* could be turned into pasture, making possible the enormous expansion of Brazil's beef herd"[27]; (iii) Embrapa turned native soybeans from the north-east of Asia, temperate-climate crop, which were sensitive to temperature changes and that required four distinct seasons into a tropical crop and also created varieties of soya that are more tolerant than usual of acid soils and (iv) "Embrapa has pioneered and encouraged new operational farm techniques. Brazilian farmers pioneered 'no-till' agriculture, in which the soil is not ploughed nor the crop harvested at ground level. Rather, it is cut high on the stalk and the remains of the plant are left to rot into a mat of organic material. Next year's crop is then planted directly into the mat, retaining more nutrients in the soil".

All these observations are in line with our research findings. The soil of the cerrado is truly poor; for example, it contains traces of phosphorus and very high aluminum. Aside from high acidity, other problems of cerrado are low (micro and macro) nutrient availability; recurrent drought spells; extreme temperatures; pests' attacks and diseases. Thus, the features of interest of the breeding program were mainly dedicated to solve problems related to soil characteristics and fertility. An important problem arising from the characteristics of its soil (microflora) is the difficulty of nitrogen fixation, the most required nutrient by soybean (Embrapa, 1984) and, therefore, a main element for high productivity. The liming and fertilization, when carried out in the Cerrado and due the characteristics of your soil (microflora), led to an excessive accumulation of the antibiotic streptomycin. Under these conditions, the majority of inoculants at that time were not capable of producing effects to the antibiotic. Through conducting research on the microflora of the Cerrado, Dr. Johanna Dobereiner and associates, Embrapa researchers, selected a mutant of Rhizobium resistant to the antibiotic even at high levels. The superrace (superestirpe) 29W was later identified as a spontaneous mutant, solving the problem of biological fixation in the cerrado, in the case, of soybeans. In other words, "In the case of soybeans, the problem has been solved with the superestirpe of Rhizobium, which resists to high level of streptomycin existing that exist in the cerrado soils. There is no need, today, of adding nitrogen to the soil. This plant fixes nitrogen that it need, with the help of 'superestirpe' (Alves, 1980, p. 21). CNPq supported the nitrogen fixation

[27] Although here we are talking about pasture, this technological innovation is very important to plant breeding, due the integration of crop, cultivation and livestock.

research, with great interaction between Brazilian and foreign scientists (Alves, 1980). Alves explained the importance of this finding (1980, p. 19):

> Dr. Johanna Dobereiner and his associates opened a promising avenue with pioneering work that showed that grasses also fix nitrogen. These researchs have much potentiality because the area planted with grasses is vast, and therefore, the impact of favorable results will be fantastic. It is not for other reason that scientists around the world have addressed (se debruçam sobre) the issue, after the pioneering work of Brazilian opened their eyes.

Thus, some authors, as Delfim Netto (2015), strengthen the relevance of the conquest of Cerrado by saying that "Embrapa converted our bigger passive into an asset".

Regarding the main diseases that were object of Embrapa´s attention at that period were: frogeye leaf spot, common mosaic of soybean, mildew and bacterial blight, beyond the soybean rust.

Concerning the development of cultivars for using *in natura* and in the food industry, the increasing demand for the crop were justified by the very high quality of soybean protein and its low cost (Embrapa, 1984).

5.3.2.2 Breeding

According our interviewees, the process of breeding, in general, has been the same since the begining. What changed were the methods to promote the advancement of generations and the methods to evaluate and select the plants. Moreover, the partners, which were involved in each phase, has changed over time.

The plant breeding process until the 20th century has been developed almost exclusively by the so-called cross-breding, a conventional process of plant breeding. In this process, it is carried out the sexual crossing (or cross-breeding) between plants of the same species and, when possible, between plants of genetically close species. In line with our findings, Andersen et al. (2015) afirm that the process of seed improvements through cross-breeding until 20th century was mostly developed based on a process of 'trial and error', which features a tacit knowledge. During the process,

through the observation of the phenotype of the plants, those that present the characteristics of interest are selected.

Among the various existing methods to promote the advancement of generations, the genealogical method, the modified genealogical method (Single-seed descent or SSD), the method of population ("bulk") and the method of backcrossing, which may be used alone or in combination, were the most commonly used (Embrapa, 1984; Pípolo et al., 2007).

The main feature of genealogical method is the control of the historic of each advanced lineage during the process of advancing of generations. Since it involves a laborious process of labeling and annotations about the selected plants and progenies, the method requires investment in supporting staff. In this method, plants are selected based on its phenotype only (phenotypically superior plants) and therefore is effective only for characters of high heritability.

The SSD method ensures that each advanced lineage is derived from a different F2 plant previously selected. As advantages, it accelerates the advancement of generations in restricted spaces and maximizes genetic variance among advanced lineages. Since no selection takes place during the process, this method becomes interesting to obtain advanced lineages for genetic studies and with molecular markers.

The "bulk" is one of the most used methods in breeding programs of soy. In it, the F2 plants are threshed together to produce the generation F3. This process is repeated until a high degree of homozygosity is reached. The big advantage of this method lies in the fact that he allows that natural selection acts on populations. By way of example is mentioned the possibility of these populations being placed "under attack by insect pests or in conditions of high severity of diseases, such as rust, in order that the more susceptible or less tolerant genotypes leave fewer descendants to future generations" (Pípolo et al., 2007, p. 5). In addition to this advantage, the method is practical because all the work of sowing and harvesting is mechanized and it still requires a few notes.

Pípolo et al. (2007, p. 5) teach us that "the method of backcrossing also promotes increased of homozygosity over the generations of backcrossing, but is not really a method of advances of generations. In this method, the goal is to insert a particular gene of interest (usually a gene with larger effect in the parental donor) in a suitable cultivar (recurrent parental)" through successive

crossings with the recurrent parental (Pípolo et al., 2007, p. 5). The method was used to insert the gene imparting glyphosate tolerance in soybean cultivars adapted. Perhaps it is main drawback is that it do not promote genetic gain. At the end, the cultivar produced will have the same qualities and defects of the recurring cultivate (Pípolo et al., 2007).

Concerning the phase of evaluation of lines, in that period the soybean-breeding program performed three types of evaluation (Embrapa, 1984, p. 51):

> First individual plants and progeny are selected for quality characteristics (disease resistance, growth habit, etc.). After this initial selection phase, we follow a detailed review in which the factors of production and quality seeds are taken into account to reduce the number of genotypes. Finally, in a third step, the selected lines are subjected to regional testing for assessment in different environmental conditions.

Partners of Embrapa, such as Emgopa (GO), Epamig (MG), Epaba (BA) and Emapa (MA) helped Embrapa in the final evaluation (Embrapa, 1984). As result of these partnerships, in the process of developing new cultivars, an aspect much relevant was “the introduction of genes of late flowering under conditions of short days in lineages of various groups of maturation” (Embrapa, 1984, p. 52).

In sum, Embrapa used in this period (1973-1980) the most modern technologies and methodologies that were available in the world in each activity of its breeding programs, both in pre-breeding and breeding phases, for example to develop segregating population and to promote the advancement of generations. In 1980, the technological catching-up of Embrapa had already reached the level of world leadership (Level 3), which can be observed by the conquest of the Cerrado and the achieved level of productivity. Since Embrapa followed new paths in order to conquest the cerrado, we may say that Embrapa adopted a “path-creating” trajectory.

Hosono et al. (2015) suggest that the model adopted by Embrapa in this period was effective by the point of view of management and organizational theories, since it included the conditions considered essential for an organization to be effective. For the authors, the following conditions were met: “clear strategy (mission, objectives, and goals), staff incentives, group cohesiveness, organization structure, internal communication, leadership, and culture”. In addition, the company

had "autonomy of management, insulation from political influences, transparency, and good relationships both with stakeholders and the general public were also crucial for Embrapa's effectiveness in the political economy of Brazil" (Hosono et al., 2016, p. 22). Regarding the public goods and services provided by Embrapa, the authors said that:

> The public goods (and services) EMBRAPA produced and delivered to the beneficiaries – knowledge and technology – are different from normal goods and services. This unique aspect of the organization is closely related to the issue of technological innovation and dissemination, or a national system of innovation...

In the period 1973/80, the high level of increase of production (which was multiplied for tree times) were accompanied by an increase of planted area with the crop, but in smaller proportion than the production. Meanwhile, there was also increase in average yield, reaching 1,727 kg/ha in 1980, an increase of 24.51% when compared with 1973 (see Table 7).

The same idea is presented in Embrapa (2000), in which is affirmed that in the 70s:

> Soybean has consolidated itself as the main Brazilian agribusiness culture, rising from 1.5 million tonnes (1970) to over 15 million tonnes (1979). This growth was due not only to increased acreage (1.3 to 8.8 million hectares), but also to the significant increase in productivity (1.14 to 1,73t / ha) thanks to new available technologies to producers by Brazilian research. More than 80% of the volume produced at the time was still concentrated in the three southern states of Brazil.

Table 7 - Area, Production and Yield from 1973 to 1980

Year	Area (1,000ha)	Production (1,000t)	Yield (kg/ha)
1973	3,615.2	5,011.6	1,387
1980	8,774.0	15,155.8	1,727

Source: Embrapa (1984)

5.3.3 Second period (1981-1997): advancing in the Northeast and preventing diseases

Due the progress made in recent years by Embrapa, the basic types of soybeans, to diverse regions, were established (Embrapa, 1985). This does not mean, however, that Embrapa had changed its goals in relation to the previous period (see section 5.3.1). In fact, they were almost the same, but some of Embrapa's goals acquired more relevance, such as the introduction of the crop in other regions of Brazil, beyond the development of new cultivars mainly oriented towards to become resistant to major diseases, nematodes and insects.

5.3.3.1 Pre-breeding

Regarding the determination of the comprehensiveness area, after the conquest of cerrado and the enlargement of planted areas with soybean in the Midwest Brazil, Embrapa decided to expand its agricultural frontier to other regions of the country, such as the Northeast.

Other important strategic decision was to invest on prevention of phytosanitary problems, in line with its long-term thoughts and care about the sustainable development of the sector. We should remember that the plant breeding programs must also include in their goals the development of cultivars which are resistent to the major diseases. Pests, diseases (whether they are bacterial, fungal and caused by viruses) and also nematodes are important risks to soybean crops, which can not only reduce productivity, but in some cases, even decimate it. As mentioned by Almeida et al. (1999), depending on the severity and the potential for large losses due some diseases, pests and some types of nematodes, the recommendation of cultivars susceptible to these problems become no more permitted, as happen with the frog eye spot disease.

According Embrapa (2000), phytosanitary problems were not much cause of concern to the researchers until 80s.

> It was just from 80 that disease resistance as Wildfire and Eye-of-frog' spot became to constitute necessary features for recommending of new cultivars. Subsequently, major phytosanitary problems have emerged, such as Stem Canker, the nematode

> cyst and Powdery Mildew, expanding the list of demands to the recommendation of new cultivars (EMBRAPA, 2000).

Thus, among of the major characteristics of interest of the soybean breeding programs of Embrapa between 1981 and 1997 were the development of new cultivars that were resistents to dangerous diseases caused by numerous phyto pathogens, such as fungous, bacteria and nematodes. For example, we may mention the fungous *Sclerotinia sclerotiorum* (mold white), *Rhizoctonia solani* (soil fungus), *Macrophomina phaseolina* (charcoal rot), *Septoria glycines* (brown spot), the bacteria *Pseudomonas syringae pv.glycinea* and the nematodes *Meloidogyne incognita* and *M. javanica* (Nematode-of-galls) (Embrapa, 1985). The stem canker and the nematode cyst are important diseases that also emerged in this period.

Moreover, Embrapa invested on its germplasm bank. In 1984, the BAG of Embrapa had 1,183 genotypes of soybean (Embrapa, 1985).

5.3.3.2 Breeding

Embrapa invested on the development of numerous cultivars driven to the characteristics of interest. Only in 1983/1984, Embrapa performed crosses involving 220 hybrid combinations; 393 populations were conducted through the “bulk” and were tested 92 lineages. Embrapa also gave several lineages for numerous organizations in different regions of Brazil. In 1984, the total of cultivars recomended to the different regions of Brazil achieved the number of 98 cultivars (Embrapa, 1985).

In sum, Embrapa had already reached the level of world leadership (Level 3) in 1981. The company continued to invest heavily in R&D and in making partnerships with numerous partners. Thus, Embrapa continued to use the most modern technologies and methodologies that were available in the world.

As a result, in the period 1981/97, the crop growth registered an annual rate of approximately 9%, that is, the production was multiplied by around 2.4. The cultivated area had also increased, accompanied by a gradual increase in average yields gain, reaching 2,384 kg/ha in 1997, an increase of 55.21% when compared with 1981 (see Table 8).

Table 8 - Area, Production and Yield from 1981 to 1997

Year	**Area (1,000ha)**	**Production (1,000t)**	**Yield (kg/ha)**
1981	8,393.20	12,890.90	1,536
1997	13,157.90	31,369.90	2,384

Source: USDA (2015), Conab (2015)

5.3.4 Third period (1998-2015): the modern biotechnology and the paradigm of sustainability

The global demand for food, especially animal protein, continued to increase significantly and, thus, the demand for soybean for feed composition (Embrapa, 2008).

In this period, after the Plant Variety Protection Law have entered into force in 1997, which allowed the appropriation of innovation efforts, important changes were observed in the commodities market. These changes included the accentuation of the market segmentation and the especialization, beyond the incorporation of new quality attributes to products. Technological changes included the increased of application of modern biotechnology, which were followed by works related to biosafety and the concern for the conservation of the environment, giving robustness to the paradigm of sustainability (Embrapa, 2008). Other important changes were the tendendy of traceability, safety and certification of food. According Embrapa (2008, p. 7), “It was also verified the maintenance, by developed countries, of instruments of protecting to their agricultural sectors, which also included environmental requirements or other instruments to establish new non-tariff barriers”.

The much higher competition resulted in the necessity of some adjustments by Embrapa, such as better management skills, articulation of networks of economic interests, agility in launching differentiated products and technological intensification of agribusiness (Embrapa, 2008).

5.3.4.1 Pre-breeding

Concerning the determination of comprehensiveness area, Embrapa continued to advance in its goal of enlarge the agricultural borders, in special to plant soybean. MAPITOBA, which refers to the states of Maranhão, Piauí, Tocantins and Bahia, were regions whose plantations of soybeans became consolidated.

Embrapa also invested strongly in its germplasm banks, since the breeding researchers have in the germplasm banks their main source of raw material. Although the soybean is native to China, the company has the largest seeds bank of Latin America and one of the largest worldwide (Embrapa Soybean, 2016); around 35,000 of the samples are of different species of soybean.

Fulfilling its role as a public company and since private companies began to offer to the Brazilian producers seeds with high level of quality, Embrapa repositioned itself in order to ensure the sovereignty of Brazil, that is, to continue to develop cultivars with the same quality as private companies in order to be ready to offer them to the producers, in case of high prices or a very high level of verticalization, as affirmed by some respondents. In addition to this, Embrapa should be strict with the requirements in relation the diseases of the plants. In other words, the Embrapa's cultivars should be resistents to the major diseases, which actually happens.

Moreover, Embrapa, by including in its goals of their breeding programs the preservation of the environment, has innovated through new technologies, for example, the livestock, farming and forests integration (crop-livestock-culture integration). The relevance of this kind of technological innovation is elucidated by Nass (2011, p. 31), when he affirmed that "the search of functions with a positive impact on processes such as regulation of chemical composition of the atmosphere,

climate regulation, absorption and waste recycling, water supply, nutrient cycling, pollination and biological control, among others, will become more intense as the impact of the activities of the man on the physical environment grows, with a consequent reduction in the availability of resources". Embrapa is also involved with prospection of biological functions of interest such as drought tolerance, which is one of the priorities nowadays.

5.3.4.2 Breeding

In order to move forward in achieving this goal, the company make use of the most advanced techniques, suas as the molecular biology and genomics (Nass, 2011).

Specifically regarding techniques related to activities of the breeding phase, Embrapa is involved with the most modern ones for select plants and lineages, both those that perform selection based on phenotype only and those that also use genomic selection. The phenotypic analysis encompasses since of phenotype determination through an infinite number of genes of small effect in interaction with the environment (quantitative characteristics) until Spectral Reflectance of Plant Canopy, which according Ferreira and Rangel (2011, p. 79) is another technology with great potential for phenotyping in scale.

The genomic selection, for its part, "is a new method of breeding that incorporates to the classical model the use of markers densely distributed throughout the genome to estimate the so-called genomic breeding value (EGBV - estimated genomic breeding value) of individuals from one population to a characteristic of quantitative inheritance" (Ferreira & Rangel, 2011, p. 79). The authors explain that "methods such as StepWise Regression, Ridge-Regression Best Linear Unbiased Prediction (Blup), Bayesian estimates, semiparametric and nonparametric methods" are used to estimate the genomic breeding value (Ferreira & Rangel, 2011, p. 79). R&D in genome, for example, may identify data in sequencing of genome, which may also includes the investigation of proteomics. All of these techniques make part of the Embrapa's life.

It also deserves to be exalted the feature tacit of the knowledge involved in most of activities. For example, the genetic selection - which allows selecting plants based on their genotype information -

was a great technological advance that benefited greatly the breeding programs, since it reduces the time of the development of the cultivars. As mentioned by Andersen et al. (2015), the genotype information made possible that plants' characteristics, such as lenght or resistence to pests or diseases, be known before the plant be fully developed. However, due the interaction of the plants with the environment, it is not possible to leave aside the phenotype selection, that is, it must be included in the analysis characteristics observed in the field.

Regarding the major diseases that were (and still is today) motive of concern by soybean producers at this period, we may mention the charcoal rot, caused by the fungus *Macrophomina phaseolina* (Embrapa, 2016) and the soybean rust, caused by the fungus *Phakopsora pachyrhizi*. "Diseases that affect the soybean crop can cause annual production losses ranging from 10% to 70% depending on the pathogen that caused the disease, region, climate conditions and management strategies chosen by the producers" (Embrapa, 2016).

The *Phakopsora pachyrhizi* (soybean rust) – perhaps the greatest danger of Brazilian agribusiness nowadays - was first diagnosed in Brazil in 2001. It is unknown how this occurred. However, due the easily of spread of the fungus by the wind, the disease occurs in virtually all producing regions of soybean in the country nowadays. The main damage is the premature defoliation, preventing the complete formation of the grains, resulting in the reduction of the productivity. The level of damage that the disease may cause can reach about 70% (Embrapa, 2016).

Embrapa registered a big number of cultivars in this period, lot of them of great sucess. As an example, it may be mentioned the MGPR45-Conquista, a soybean variety that was the most cultivated worldwide until seven or eight years ago, according our interviewees. This variety could be planted in different regions of the country from Rio Grande do Sul to Roraima, including Goiás and Bahia, but the cultivar were also planted abroad, such as in Cuba. Other good example was the Cultivance, the transgenic variety developed by Embrapa and BASF.

Thus, although Embrapa have had its share in the variety market been reduced in a significant way, the company operates throughout the whole production chain of soybean, generating value in each link of the chain. Actually, the company has innovated in technologies, among them cultivars. As mentioned by an interviewee:

> Embrapa is not only variety, it is much more than that, it is technology. Embrapa supports everything. When happens a new disease, as happened with soybean rust years ago, who provided support for genetic improvement? It was Embrapa. When emerged a new plague in two, three years ago, Helicoverpa, all the staff came around to Embrapa in order to solve the problem. Technology of seed production, who has the technology? It is Embrapa. The training we give here ... since the 80s until today, exactly 1,798 people were trained here at Embrapa Soybean in technics of analysis and seed production. And the work we do here is not only for Embrapa, but we also have trained professionals from Bayer, Syngenta and other companies.

In line with this thought, The Economist in the article "The miracle of the cerrado" mentioned technological innovations developed by Embrapa since its begining until now, which made Brazil the first tropical food-giant, since the big five are all temperate producers. Among these technologies are: (i) varieties of soya that are more tolerant than usual of acid soils (even after the vast application of lime, the cerrado is still somewhat acidic); (ii) the speeded up of the plants' growing period and the "short cycle" plants, which made possible to grow two crops a year, revolutionising the operation of farms; (iii) new operational farm techniquest, such as "no-till" agriculture, "in which the soil is not ploughed nor the crop harvested at ground level"; (iv) forest, agriculture and livestock integration, in which the fields are used alternately for crops and livestock but threads of trees are also planted in between the fields, where cattle can forage (The Economists, 2010).

The article also highlighted that "Brazil has done all this without much government subsidy"[28] and mentioned Embrapa as the primary reason for the extraordinary growth in Brazilian agriculture. Moreover, it is strengthened that how the country manage this astonishing transformation "do not matters not only to Brazil but also to the rest of the world" (The Economists, 2010), especially if we consider the future. In its words:

> So if you were asked to describe the sort of food producer that will matter most in the next 40 years, you would probably say something like this: one that has boosted output a lot and looks capable of continuing to do so; one with land and water in reserve; one able to sustain a large cattle herd (it does not necessarily have to be efficient, but capable of improvement); one that is productive without massive state subsidies; and maybe one with lots of savannah, since the biggest single agricultural failure in the world during past decades has been tropical Africa, and

28 "According to the Organisation for Economic Co-operation and Development (OECD), state support accounted for 5.7% of total farm income in Brazil during 2005-07. That compares with 12% in America, 26% for the OECD average and 29% in the European Union" (The Economists, 2010).

> anything that might help Africans grow more food would be especially valuable. In other words, you would describe Brazil.

As result of the investments in technological innovation, we observe in the period 1998/2015, growth not only in production and planted area, but also in the yield. The annual rate of the crop growth registered was approximately 13.62%. The forescast for 2015 of the planted area reached 33.040,95 ha, an increase of 154.26% when compared with 1998 and of 30.41% regarding the yield (see Table 9).

Table 9 - Area, Production and Yield from 1998 to 2015

Year	Area (1,000ha)	Production (1,000t)	Yield (kg/ha)
1998	12.995,20	30.765,00	2,367
2015	33.040,95	101.997,10	3,087

Source: USDA (2015), Conab (2015)

In sum, first Embrapa introduced american cultivars that were adapted to the South of Brazil. The Embrapa's next step was to develop itself its own cultivars with similar quality with the best ones in the world. In other words, Embrapa was able to reduce the gap in genetic breeding technologies in a very short period of time. The rest of the history is the conquest of cerrado and the stunning evolution of Brazilian production, planted area and yield.

Thus, we can say that Embrapa initiated its technological trajectory through a process that may be classified according the framework as stage-following, which quickly evolved into stage-skipping. The path-creating emerged when Embrapa looked for other technologies that could help to develop cultivars to different regions of Brazil with very different edaphoclimatic conditions. The conquest of cerrado is a good example that makes evident the arrival of Embrapa into the technological frontier. In fact, we advocate that since that time the company is able to implement innovations (and, in fact, it did) that were new to the world, pushing the existing world technology frontier and/or open new segments internationally.

We resume the evolution of the technological capabilities of Embrapa in Figure 3.

Figure 3 - Evolution of Embrapa's innovative technological capabilities from 1973 to 2015

		1973-1980	1981-1997	1998-2015
World Leading Innovation Capability - Level 3	**Breeding**	Advanced techniques (e.g., genealogical method, SSD, "bulk" and backcrossing) / Package of technologies for soil management / Increase of 24.51% of yields (1973-1980) / Conquest of Cerrado	Expansion of agricultural borders in some regions of the Northeast of Brazil / Cultivars resistent to major diseases / Early, semi late and medium cycle cultivars / Technologies, such as crop-livestock-culture integration / Increase of 55,21% of yields (1981-1997)	Expansion of agricultual borders, such as in the region know as MAPITOBA / Use of the most advanced techniques, such as the molecular biology and genomics / Increase of 30.41% of yield from 1998 to 2015
	Pre-breeding	Interest on development of its own cultivars to other regions with diferent edaphoclimatic conditions	Interest on expansion of agricultural frontier to other regions of the country, such as the Northeast	Largest seeds bank of Latin America and one of the largest worldwide / Advanced techniques (e.g. molecular biology and genomics) / Preservation of the environment (livestock, farming and forests integration) / Prospection of biological functions of interest (drought tolerance)
National Leading Innovation Capability - Level 2	**Breeding**	Own cultivars to the South or other regions with similar edaphoclimatic conditions		
	Pre-breeding	Prevention of phytosanitary problems / Investment on the BAG, reaching 1,183 genotypes of soybean in 1984		
Basic Innovation Capability- Level 1	**Breeding**	National state research institutes / development of cultivars		
	Pre-breeding	Interest on expansion of agricultural frontier, such as the states of MS and part of MT, GO, MG, DF, BA and MA / Development of the active germplasm bank		
	Partners: goals	International organization (american universities and ARS/USD, mainly): technological capability accumulation	National state research institutes: development of cultivars; national state agencies: technical assistance and rural extension; national universities: training of technicians of the NARS, harnessing of students to investigate problems, development of integrated projects; cooperatives: technical assistance; private companies: provision of search services, including product behaviour testing, conduction of cooperative research projects and technological support to agriculture	NARS: development and testing of cultivars mainly; private foundations: support to agricultural research; universities: training, development of integrated projects; international agencies: joint research projects; Gene Giants: obtaining financial resources and the exchange of knowledge (genetics and modern biotechnology).

Source: elaborated by the author

5.3.5 Quantitative measure to technological catching-up

We consider very important to examine a quantitative measure of technological innovative widely used in the agricultural seed industry, the number of protected cultivars.

According many authors, including Lee and Lim (2001), patent statistics reveal some important characteristics of the industries. Due the industry uniqueness, particularly the genetic sector, which is related to natural resources, and since the patenting of living organisms is prohibited in Brazil, the protected cultivars in SNPC would be the indicator that is closest to patents. Just to use a similar method as the authors, we examined the annual increase rate of protected cultivars in SNPC (total) and the annual increase rate of protected cultivars in SNPC by Embrapa and measure what could be mistakenly called as "*catching-up*". Table 10 shows these data; a superficial analysis of them, however, could easily lead us to wrong conclusions. For example, between 1999 and 2014, although there is a trend of growing concerned the number of protected cultivars, we may observe many alternations - either positive or negative - in the annual increase rate of protected cultivars in SNPC both by Embrapa and generally. Our interpretation is that this reflects the dynamism of the industry, which is not yet in a mature stage (stage of maturity). Other important information to be considered is the number of actors operating in the sector. While in 1999 there were only cultivars developed by Embrapa - which reflect the small number of companies in the industry - in 2014, according our interviewees, there are around 30 or 40 companies operating in the genetic sector. Even considering that few companies have large market share, we interpreted this as a result of complex interactions between the so-called genetic sector and the so-called traits sector, as well as hard-hitting commercial approaches to the local producers. Thus, the speed of catching-up (and also percentage reductions (share) and decreasing of annual rate) must not be interpreted as a "truncation". Moreover, the positioning of Embrapa as public company is to fill the gaps not occupied by the private sector in order to ensure the supply of quality seeds to local farmers, as well as protect the country from possible risks that could jeopardize the sustentability of the sector. For all this, we advocate that the rate of cultivars is not a good indicator to measure technological catching-up, at least in the Brazilian seeds sector. Conversely, we advocate that production reveal much more about the industry.

Table 10: Total and Brazilian Protected Cultivars in National System of Plant Variety Protection (SNPC): annual increase rates between 1999 and 2014

Year	Total of Protected Cultivar in SNPC	Protected Cultivars by Embrapa in SNPC	Share (%)	Annual increase rate of protected cultivars in SNPC (a)	Annual increase rate of protected cultivars in SNPC by Embrapa (b)	Speed of Catching-up = b-a
1999	4	4	100.00			
2000	17	5	29.41	325%	25%	- 300.00%
2001	29	16	55.17	70.59%	220%	149.41%
2002	19	4	21.05	- 34.48%	- 75%	- 40.52%
2003	38	12	31.58	100%	200%	100%
2004	27	16	59.26	- 28.95%	33.33%	62.28%
2005	38	18	47.37	40.74%	12.5%	- 28.24%
2006	50	14	28.00	31.58%	22.22%	- 9.36%
2007	29	7	24.14	- 42%	- 50%	- 8%
2008	41	9	21.95	41.38%	28.57%	- 12.81%
2009	46	8	17.39	12.20%	- 11.11%	- 23.31%
2010	33	9	27.27	- 28.26%	12.5%	40.76%
2011	46	7	15.22	39.39%	- 22.22%	- 61.61%
2012	51	7	13.73	10.87%	0%	- 10.87%
2013	93	12	12.90	82.35%	71.43%	- 10.92%
2014	81	10	12.35	- 12.90%	- 16.67%	- 3.77%
2015	n.a.	n.a.	n.a.	n.a.	n.a.	n.a

6. CONCLUSION / IMPLICATIONS

We examined in this paper the *characteristics* of the technological trajectory of Embrapa Soja in its process of catching-up and some outcomes of technological innovations which arised from it. Our focus is on the breeding process, particularly on the genetic seeds sector aimed at the conquest of the Cerrado. In the process of addressing the research question, we gave special attention to the knowledge networks and learning mechanisms used by the firm.

As features of the sector, we verified two major ones: its low degree of adaptability, which requires constant technological innovations and the relative predictability path of technological innovation, at least in the genetic plant breeding.

We concluded that the technological trajectory of Embrapa began through a path-following stage and, after have gone through path-skiiping stage, fast forward to path-creating stage. Regarding time to catching-up in plant-genetic breeding, Embrapa took only 7 years to reach the level of world leading. After this, Embrapa remained at this level until nowadays.

The conquest of Cerrado, which exemplifies path-creating stage, contributed greatly to Embrapa reach the rank of the world's second largest soy producer and the largest exporter of the crop. Although this conquest have happened much before 1997 (year of the PVPA), the outcomes of the technologies developed at that time are felt until now. However, the high level of production and export of Embrapa is only possible due new technologies that are continuously developed by Embrapa and its partners.

Embrapa has gone through very diverse periods, along which different actors have exercised different roles. As a public company, it seeks to adapt itself to the spaces not occupied by the private sector, but without forgetting its role as regulator, i.e., the main actor responsible for the sector's sustainability. This seems to include both the development of varieties and other technologies, at least nowadays. Thus, although we believe that some of previous solutions - such as the networks of knowledge and learning mechanisms that have been used and that were successful - are no longer pertinent to the present moment, we advocate that some findings of the study lead us to important conclusions. First, the contribution of the production and export of soybean to Brazil

deserve to be valued, as well as Embrapa contribution to such results. Second, despite the number of new cultivar theoretically be an indicator of technological innovation (more precisely, its utilization rate), due to the dominance of transnational companies and the complexity of the sector, it does not seem to be the most appropriate indicator to measure innovation or even the degree of technological capacity of the companies. Conversely, the production and export denotes both the effectiveness of other technologies that contribute to its increase, but also the inclusion of relevant characteristics that should be considered in the breeding program by all companies operating in the sector.

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GENERAL CONCLUSIONS

The three articles complement each other. Through their results, we believe it was possible to give important contribution to theories - such as the recent theory of catch-up cycles, theories about network structures and about catching-up and therefore, minimize gaps in the literature. Moreover, we think we made possible a deep understanding about the Brazilian seeds industry, which in turn may result in more substantiated public policies.

Articles 1 and 3 address the theme “marketing and technological capabiblities”. However, on the one hand, the article 1 deal with “capabilities” as an element that allows companies to give appropriate responses to deal with windows of opportunities that appear over time and, in consequence, catch-up. On the other hand, the article 3 uses the “capability” variable – particularly the technological capability - as consequence of the firm's efforts to catching-up, such as the establishing of knowledge networks. Thus, we can infer that capabilities are both cause and effect. Similarly, the “marketing catch-up” both affects and is affected by “technological catch-up”. Moreover, the articles 2 and 3 address the theme “knowledge network”, but while the first one is focused on the dynamism of network structures, the second one aimed to understand cognitive aspects of the networks and their relation with (technological and marketing) catch-up. It is also important to highlight that the expected implications of the knowledge network are “catch-up”. Therefore, the variables investigated both in article 1 and article 2 converge to explain an important variable investigated in Article 3, the technological and market catch-ups.

We also found some convergences with regard to results of the articles.

For instance, the propositions suggested in the article 2 are aligned with the theory of catch-up cycles, that is, almost all motivations to establish partnerships stemmed from the necessity to accumulate technological capabilities, which in turn was stimulated by ever-growing demand, and the innovation efforts guaranteed by the institutions. Moreover, we observated the appropriation of the Embrapa responses not only in article 1, but also in articles 2 and 3, especially in the latter, which highlight the trajectory of Embrapa, which made the company one of the biggest success cases of Brazil.

In addition, altogheter, the articles made possible to evidence how innovation has occurred over time in the Brazilian seeds industry, how the innovation drivers have altered in importance from time to time and how the Gene Giants came to possess the strong dominance in the industry nowadays.

Still on the research findings, it is important to highlight some evidences that may possibly demystify some arguments that, in the contrary, may become myths. For example, we may mention these findings: (i) although the significant market share of some private companies, especially in the the genetic industry, the Gene Giants are do the actors that has driven the process of innovation in the Brazilian seeds industry (and perhaps the seeds industry in the Latin America and in the global setting); (ii) there is not a direct relation between the highest amount of launching of new varieties each year and higher levels of technological innovation; (iii) dominant positions in the market do not necessarily mean that the company has higher levels of technological capabilities than other ones with lower market share. Market innovation, such as commercial approach of transnational companies, which includes financing of producers and sales distribution, has played a crucial role in the industry and, most probably, has been the most defining feature of choice of the producers, when compared to quality of seed.

Actually, we can evaluate the seeds industry – including the soy industry – based on different criteria. For example, we may use the “market share of new varieties” or “data of production and export” to evaluate the level of innovative capability, due the fact that the goal of the seeds industry is to increase productivity mainly, which is obtained, among others, through improved seeds. The difference is that they will register different stages of the value chain. However, we advocate that “market share of new varieties” is not a good indicator to measure technological catch-up in the Brazilian seeds sector, but marketing catch-up mainly. If we consider the market share in terms of production or export of soybean, we may classify this sector based on the theory of catch-up cycle as the case of one occurrence of change (from entry to forging ahead) and one occurrence of persistent leadership.

With regard to contributions to public policies, since we saw that partnerships has been increasingly relevant and important trade-offs between public and private organizations, we suggest that the

government helps the Brazilian seeds industry – including Embrapa – with public policies that make easier to public companies to establish partnerships. They should be much more flexible, in a kind of open innovation that allow partnerships in different stages of the productive chain, with diferent actors, especially private ones. Moreover, since we observed that capillarity is a big problem for Embrapa nowadays, and since the private companies take advantage of the greater estrangement of the company, we suggest that the government invest on ways that allow Embrapa to get closer to local producers. New kinds of network, which brings together actors with different types of skills and capabilities, seem to be a good idea. They must be strong enough as those ones at the beginning of Embrapas's life, but much more diversified.

Particularly regarding Embrapa, the company should invest on governance, that is, on learning how to choose their partners and how to ensure returns of investments. In addition, we suggest that, even considering that the company has public interest, we advocate that market professionals may bring many benefits to the company.

To finish, we feel obliged to say that institutions/public policies seem to be the window of opportunity that have more potential both to contribute to the growth of the industry and to harm it, and that it is through it that the sector has suffered most influences that has resulted in major changes. Thus, it is time to discuss about goals, strategies and laws. We need that the scientific and academic community act with scientific substance and less ideological way, what seems to have occurred in earlier stages of Embrapa.