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USING NATURAL RESOURCE INDUSTRIES AS A PLATFORM FOR THE DEVELOPMENT OF KNOWLEDGE INTENSIVE INDUSTRIES IN LATIN AMERICA: THE SEED INDUSTRY IN ARGENTINA, BRAZIL AND CHILE

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ABSTRACT

This paper, explores the extent to which Latin American countries are taking advantage of the new innovation opportunities opened by Natural Resource activities, by analysing the development of technological capabilities and it sources in the seed industry in Argentina, Brazil and Chile. The research is based on an in depth study of a sample of nine private and public companies of the three countries, that were selected to represent the industry structure of each country. Our analysis suggests very interesting insights. First, we found that the agricultural sector in Argentina, Brazil and Chile is not only opening opportunities for innovation in the seed sector. The sector is also engaging itself in innovation in the seed industry through several initiatives of farmers. Second, contradicting most expectations, we found that domestic firms in the region are moving into world leading positions (they are doing R&D in genomics, in second wave GM, and opening new directions for innovation in the sector). On the contrary, the MNCs subsidiaries interviewed, are in less advanced positions, since they draw most of their technological assets from their corporations and are doing very little innovation in the region (with one exception). Third, movements into world leading positions are not all related to the use of transgenesis for the improvement of seeds. The more advanced firms, in effect, in responding to the new opportunities are directing their innovative efforts in more than one direction, including advanced ways of conventional breeding and non- transgenic genetic modification. These face less regulatory restrictions, and are more adequate for certain types of seeds such as fruits and vegetables. Fourth, all firms in the seed industry, independently of the level of capability, perform all forms of internal learning mechanisms. However, only the more advanced firms deploy certain patterns of external learning mechanisms. They do not tap into existing knowledge, they create new knowledge, often registered in publications and patents, and use complex interactive joint R&D projects, which in general include at the same time users, universities and other firms, in the same country or even abroad. There are significant differences across countries regarding capability and structure. Regarding structure, in Argentina, the industry is much more dominated by private companies, both domestic and MNCs, than Brazil and Chile. Private companies carry out most investments in R&D and register most varieties. In Brazil this leading role is played by EMBRAPA (the public research institution linked to the agricultural sector), who seems to be taking advantage of its position as a regulator, to locate itself as an intermediary between the MNCs and the domestic market. In Chile the situation differs according to the market that is served, MNCs dominate the market for exports, that can use GM, while the INIA (the public research institution linked to the agricultural sector) has a leading role in the development of seeds for domestic consume, most for fruits and vegetables.

1) INTRODUCTION

Are natural resource activities inducing the development of technological intensive sectors in Latin America?

Latin American countries are once again heavily specialised on natural resources (NRs). NR activities have become more knowledge and input intensive (Bisang, 2008). It is expected therefore, that they can offer now, much more than in the past, opportunities for innovation and linkages with other knowledge intensive sectors (Perez, 2007, 2008; Marin, Navas-Aleman & Perez, 2010; Marin & Bell, 2010). This paper, explores the extent to which Latin American countries are taking advantage of these new opportunities opened by NRs activities by analysing the development of technological capabilities in the seed industry in Argentina, Brazil and Chile. **Seeds are a key and strategic input for agricultural production.** Argentina, Brazil and Chile are world leaders in agricultural production, and have been the pioneers in the adoption of agricultural technology intensive inputs (e.g. genetically modified (GM) seeds)[2]. The obvious question is thus: are these countries taking advantage of their position as agricultural leaders, to develop technological capabilities in the development and production of seeds, the main key input in agricultural production. These capabilities are crucial for shaping technological change in a direction that is adequate for their contexts.

Seeds have been historically considered public goods. This was because, for a long time, investments in improving them were difficult to recover, with farmers being able to re- use them without paying for this[3]. Public research institutions, accordingly, were central in the development and broad diffusion of seeds, and a full developed market for seeds did not exist. This situation changed dramatically during the last forty years or so. First, during the Green Revolution, with the irruption of hybrids for some crops (e.g. maiz), that loose their main attributes (improvements) after one or two uses, private companies gained interest in the sectors, and a market for seeds emerged [4]. Second, with the irruption of genetics, in the early 1990´s the activity turned highly knowledge intensive, and started to be dominated by a few multinational companies (MNCs)[5], that can afford the genetic technology. Public institutions and domestic firms, however, still

[2] Brazil and Argentina, are the second and third largest producers in the world of biotech crops, after the USA, covering around 40% of the world biotech production. Source?

3 A situation that was accepted, from a moral point of view, since seeds are a necessary input for small farmers to produce their food.

4 The development of hybrid seeds helped companies to recuperate the research and development costs because, contrary to open-pollinated seeds, farmers need to buy new seeds every season to maintain the improved traits of the original seed. Hybrids seeds are rare, however, for some crops such soy, cotton or rice because they are self-pollinating or autogamous. Companies involved in the development of these seeds thus depend on intellectual property regulations (IPR) to recover their investments, and given the problems to enforce these regulations in seeds, companies are developing other approaches, to recover their investments, such as the much discussed terminator gene, which sterilise the seeds but is considered yet morally unacceptable (or specific private agreements between seeds companies and farmers).

[5] These are typically agrochemical MNCs that as well as mastering the new technology are taking advantage of the synergies between the new types of seeds being developed, and the chemical products that go together with the seeds (the typical example is the soy bean resistant to Glyphosate, a seed and herbicide developed by Monsanto that need to go together for them to work).

have a role to play. First, because not all innovations in the industry involve genetic engineering, and second, because GM seeds perform well only when they are introduced in genetic backgrounds (the cultivars where genes have to be pasted) that are adapted to local ecological and socio economic conditions, and these backgrounds are typically owned by local breeders (public institutions of agricultural research and private companies).

In this paper we explore the extent and type of technological capabilities (TCs) being accumulated in Argentina, Brazil and Chile in these three key agents for the seed industry: MNCs, domestic firms and public companies. The research is based on an in depth study of a sample of nine private and public companies of the three countries, that were selected to represent the industry structure of each country. Our main focus of analysis is the firm but we also draw on secondary data to characterise the whole context in which each firm (institution) operates. More specifically, we explore the following two questions: 1) which is the level and type of technological capability achieved by each type of company within the industry in each country and, 2) how different learning mechanisms and knowledge flows with other agents have influenced the levels and types of TCs developed.

The contrast between the three countries selected for the study is very informative because they have adopted a very different approach to the adoption of GM technologies. Argentina, has adopted the more liberal approach, by allowing the adoption of GM seeds for food production, right from the beginning, when the first GM seeds were released by mid 1990´s. Brazil, was more reluctant to adopt the technology, at the beginning. However, already in 2005, reacting to the massive illegal adoption of the technology in the south of the country (brought by Argentinean farmers), this country allowed the use of GM seeds for domestic production. Finally, Chile only allows the use of GM seeds (modified using transgenesis[6]) (TGM) when they are used to produce seeds that are then re-exported. TGM seeds are not allowed to produce food products that will then be commercialised internally or exported.

To conduct the analysis we draw on a very well known theoretical framework about the accumulation of technological capabilities of firms operating in late industrialising countries, and its explicative causes. Our analysis suggests very interesting insights. First, we found that the agricultural sector in Argentina, Brazil and Chile is not only opening opportunities for innovation in the seed sector. The sector is also engaging itself in innovation in the seed industry through several initiatives of farmers. In fact, among the most innovative ventures analysed by our study across countries, are two ventures of farmers, which developed strong links with the local research infrastructure to produce knowledge useful to be used in the development of high tech, highly competitive seeds adapted to the local contexts. Second, contradicting most expectations, we found that domestic firms in the region are moving into world leading positions (they are doing R&D in genomics, in second wave GM, and opening new directions for innovation in the sector). On the contrary, the MNCs subsidiaries interviewed, are in less advanced positions, since they draw most of their technological assets from their corporations and are doing very little innovation in the region (with

[6] Transgenesis is a form of genetic manipulation that seek improvements in the seeds using genes from different species.

one exception). Third, movements into world leading positions are not all related to the use of transgenesis for the improvement of seeds. The more advanced firms, in effect, in responding to the new opportunities are directing their innovative efforts in more than one direction, including advanced ways of conventional breeding and non transgenic genetic modification. These face less regulatory restrictions, and are more adequate for certain types of seeds such as fruits and vegetables. Fourth, all firms in the seed industry, independently of the level of capability, perform all forms of internal learning mechanisms, including training, operational experimentation, R&D experimentation, knowledge sharing or socialization, and knowledge codification. These forms of internal learning mechanisms can, therefore, be considered the minimum threshold to remain in this industry. However, only the more advanced firms deploy certain patterns of external learning mechanisms. All their main innovations include at the same time users (farmers), the knowledge base (researchers in universities) and other seed industries (suppliers and even competitors). Also, they do not tap into existing knowledge, they create new knowledge, often registered in publications and patents, and use complex interactive joint R&D projects, which in general include at the same time users, universities and other firms, in the same country or even abroad.

The paper is structured as follow. Section 2, discusses the theoretical and methodological background of this study. Section 3 analyses the evidence. We first present the analysis of the contexts in which firms operate – institutional and economic framework -, the economic and institutional background, then the evidence regarding levels of technological capabilities at the firm level, and finally discuss the sources of these capabilities. Section 4 concludes.

2) THEORETICAL AND METHDOLOGICAL BACKGROUND

In this section we summarize the theoretical framework and explain the methodology applied to conduct the study. First, we briefly introduce the main concepts supporting the literature to understand the accumulation of technological capabilities in late industrialising countries. Second, we present this framework distinguishing levels and types of technological capabilities in the seed industry and finally we provide details regarding the qualitative research strategy that was implemented for data collection, and devices used for analysis and interpretation.

2.1) The theoretical framework in brief

To conduct the analysis we draw on a very well known theoretical framework developed to understand the accumulation of technological capabilities in late industrialising countries, and its explicative causes. This framework (summarised in Graph 1 bellow) distinguishes different levels of technological capabilities that firms can reach, taking into account the complexity of the innovative activity that firms perform, and then explores how these levels relate to micro decisions of the firm regarding learning efforts and external linkages (see Katz, 1987; Lall, 1987, Hobday, 1995; Ariffin & Bell, 1999; Ariffin, 2000; Figueiredo, 2001, 2003; Ariffin & Figueiredo, 2004; Hobday et al., 2004; Tsekouras, 2006).

Graph 1: A summary of the theoretical framework, linking the level of capabilities with its sources.

In general four levels of technological capabilities are distinguished: 1) Basic, 2) Intermediate, 3) Advanced and, 4) World leading (See Table 1 for a description). In this study however, we do not consider the basic level (which includes firms that do not perform any form of R&D), since this level does not seem relevant in this knowledge intensive industry, where all firms need to perform some form of R&D to participate in the market.

Table 1: Levels of technological capabilities

Level 1 - Basic innovation: being able to introduce very minor technological changes in technologies which are mostly experience-based or reliant on the introduction of new vintages of technologies in production systems.
Level 2 - Intermediate innovation: being able to introduce technological changes which are mostly adaptations to technologies based on design and engineering activities, informal or not systematic R&D.
Level 3 - Advanced innovation: being able to introduce technological changes based on R&D close to the technological frontier, within an existing and established technological trajectory ("along the beaten track").
Level 4 - World leading innovation: being able to introduce technological changes based on world-class R&D that advance the technological frontier and help to establish new directions and trajectories of technological change ("off the beaten track").

Source: own elaboration based on literature of technological capabilities development.

Learning efforts (sources or inputs), include the learning activities oriented to build and deepen capabilities to innovate in a conscious, purposive and costly rather than in a automatic and passive way (Bell, 1984; Malerba, 1992; Lall, 2000). We distinguish two broad types of efforts: internal learning mechanism and external learning mechanisms. Internal learning mechanisms, involve the various forms of knowledge sharing, articulation and codification inside firms (such as: internal training, operational experimentation, engineering and design experimentation, R&D experimentation, knowledge sharing or socialization, knowledge codification). External learning mechanisms, involve the leverage of external knowledge acquisition through various types of mechanisms (e.g. overseas training, technical assistance), including links between firms and innovation system supporting organisations (e.g. network of universities, research institutes, laboratories, technical schools in local communities). They are oriented to use and enlarge capabilities which are distributed outside the firm (for instance, by the exchange of knowledge developed by the different type of agents, recently described) (Coombs and Metcallfe, 2000; Coombs et al, 2003; Acha and Cusmano, 2005; Robertson and Smith, 2007).

The illustration of these mechanisms is presented in more detail in point 2.3) when we link this theoretical framework with the empirical evidence collected during the fieldwork.

2.2) Distinguishing levels and types of technological capability in the seed industry

The technological capability framework used in this study usually distinguishes different levels of technological capability on the bases of the complexity of R&D and other innovative efforts performed by each firm. In this study we complement this, with information about innovative outputs (tangible results of the capability building process), to have a measure of the effectiveness of the efforts. It is also commonly assumed within this framework (though implicitly) that there is only one possible direction of technological change, towards which capabilities should be accumulated, the one followed by industry leaders. So, the evolution of capabilities and efforts are typically evaluated with respect to this direction. In the seed industry, however, this assumption is not adequate. Firms face high market, technological and regulatory uncertainties and, put their efforts and develop capabilities in more than one direction. We incorporate this fact in the framework utilised to evaluate TCs and efforts of firms. In the following paragraphs, we first describe the indicators of output used to complement R&D indications (2.2.1) and, second, we discuss the framework proposed to evaluate innovative capabilities and efforts in the seed industry taking into account the possibility of more than one direction of change (2.2.2).

2.2.1) Innovative outputs

We examine two indicators of innovative output: patents and plant variety protection certificates. They both provide developers of new varieties with exclusive marketing rights for a number of years (around 20 years, but varies across countries). Plant variety protection certificates are the more extended system used to protect new seed varieties, GM and not GM. Patents are mainly used to protect new genes or genetic constructions.

- ✓ Plant variety protection certificates protect breeders that develop new varieties, when they are (novel) uniform, stable, and distinct from all other varieties. They are guaranteed by each National State, and run normally between 15 and 20 years, providing breeders during this time the right to commercialise the new variety. They are regulated internationally by the UPOV (The International Union for the Protection of New Varieties of Plants).
- ✓ Patents grant the owners of new genes or genetic constructions, a similar period of protection. However, most countries in the world, do not allow to patent plants and animals, with the exception of USA, Australia, Korea and Japan. Consequently, firms facing barriers in their own countries to patent genetic constructions go and patent them abroad (through USPTO in the USA or EPO in Europe and even WIPO[7])

These two mechanisms are not of central importance in crops like maize and sunflower, where the bulk of the seeds are hybrids and the production from previous crops cannot be used as seed in future production[8]. They are crucial in the case of varieties of soybeans or wheat, where the production of previous years can be used as input for

[7] UPSTO: United States Patent and Trademark Office; EPO: European Patent Office; WIPO: World Intellectual Property Organization

[8] Without appreciably affecting the yield, germination, vigour and production quality. In these cases the protection is effective in practice even in the absence of regulatory systems, through the mechanism of trade secrets.

future crops of this species almost without affecting its productive quality, at least in the first sowing. Companies, however, patent and register varieties of the two types of seeds, because they use them as a signal to the market, and to be able to negotiate with other companies when their varieties are used for future improvements.

We complement these two main measures of innovative outputs with illustrative examples of the main innovation products developed and technological services provided by each firms under study.

2.2.2) Types and Levels of capability in the seeds industry

Innovation in the seed industry have always been oriented to find the best seeds, so that they are adapted to the agro ecological conditions where they need to be used (water, climate, etc.) and, to the consumers tastes and needs. For many years, almost since the beginning of agriculture, these improvements were obtained using conventional breeding techniques, i.e. sexually crossing plants and selecting the best varieties. However, substantial advances in several of the knowledge bases connected to the production of seeds, such as in genetics, biology, and agronomy, have recently augmented considerably the space of possibilities for improving seeds. Now changes can be done not only at the organism level by selecting the best parents and crossing them, but also by manipulating the genes of the organisms. Reproduction does not need to be sexual, but can also be in vitro. Genetic manipulation can involve the movements of genes between unrelated species or be restricted to only related species, among others. Companies, therefore, can now choose how to improve seeds from a variety of options, and they are doing so taking into consideration issues such as regulations, which are very strict around to the use of: some forms of genetic manipulation; consumer tastes, which still in many cases reject food produced with GM seeds; and the technological and appropriability possibilities open for the specific crops in question[9].Nowadays, the three more used technology options are the following:

1) Based on sexual recombination of parents to introduce improvements, where genetic modifications to obtain better varieties, just as in the conventional breeding techniques, are done at the organism level, i.e. with the normal mating processes, but manipulated through human choice of the parents and selection of their offspring so that evolution is directed towards production of crops with desirable characteristics[10].
2) Based on transgenesis, where genetic improvements are done at the genetic level implanting genes from different species (up to know mostly from bacterias) or engineered genes. This is done typically using genetic engineering techniques,

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[9] It is always more difficult, for instance, to recover investments in seeds which are autogamous or self-pollinating (e.g. soybean, wheat and rice) than for hybrids, because autogamous reproduce themselves without losing their characteristics. So, firms follow different technological trajectories for different kinds of crops, in part based on the possibilities of recovering their investments. They also follow different strategies for crops with different types of markets, given that is more difficult to sell GM seeds with transgenesis in final markets, such as the ones for fruits, wheat or rice.

[10] The genetic mechanisms that drive sexual recombination operate during gamete (egg and pollen) formation via meiosis, and include Gregor Mendel's famous discovery of independent assortment of genes and T.H. Morgan's discovery of crossing-over of homologous chromosomes. The key feature of sexual reproduction is that it allows and assures that all of the traits that differ between the parents are free to re-associate (segregate) in new and potentially better combinations in the offspring.

which use DNA molecules from different sources, and combine them into one molecule to create a new set of genes. This DNA is then transferred into an organism, giving it modified or novel genes[11]/[12].

3) Based on genetic improvements at the gene level, as in transgenesis, but with genes from the same specie, or a sexually compatible partner, as in conventional breeding. There are two forms at least, in which genetic improvements using genes of the same species can be performed: cisgenesis and mutagenesis. With cisgenesis, genes coding for an agricultural trait from the crop plant itself or from a sexually compatible donor plant (cisgenes or natural genes) are artificially transferred between organisms that could otherwise be conventionally bred. With mutagenesis, past knowledge of causes of mutations (such as exposure to radiation or temperature extremes) known as mutagens, are harnessed to generate intentional changes in the genetic make-up of a cell or plant tissue.

The use of transgenesis widens the gene pool from which genes with desired traits can be obtained, and then transferred into organisms lacking those traits[13]. It is common to assume, therefore, that this technology reflects a more advanced level of capability than the others two. There are substantial controversies, however, around the potential unpredictable and unknown long-term effects of unnatural recombination of genes to produce food, which have not yet been adequately investigated. In addition, the technological possibilities open by transgenesis as well as the regulatory costs[14] and the appropriability conditions are not the same for all crops. Several companies are, therefore, concentrating substantial innovative efforts around non transgenic trajectories (such as the ones discussed above) to induce genetic improvements, which can be performed in a more or less sophisticated and controlled way[15]. We do not assume, therefore, that any technique and subsequent trajectory is superior to the others. What we consider instead to evaluate and identify the level of capabilities of firms, is how the trajectory is followed and which outputs have been obtained. The more advanced level of capability is reached when: (a) research is conducted supported by the more

[11] Genetic engineering preserves the integrity of the parental genotype, inserting only a small additional piece of information that controls a specific trait. This is done by splicing a well characterized chunk of foreign DNA containing a known gene into a chromosome of the host species using “restriction” enzymes.

[12] There are two common ways to transfer an engineered gene into a plant chromosome. A) Using a bacteria: Agrobacterium tumefaciens is a plant-pathogenic bacterium that has the ability to transfer a portion of its own genetic information into many plant species through a process called transformation, thereby causing the “crown gall” disease. B) Shooting gold particles: the engineered genes are shot into plant cells using tiny DNA-coated tungsten or gold particles as fine as dust. Although somewhat more expensive in terms of equipment requirements, the “gene gun” approach has the advantage of unlimited range of applicability.

[13] Since the search for useful genes can be performed in related and unrelated species

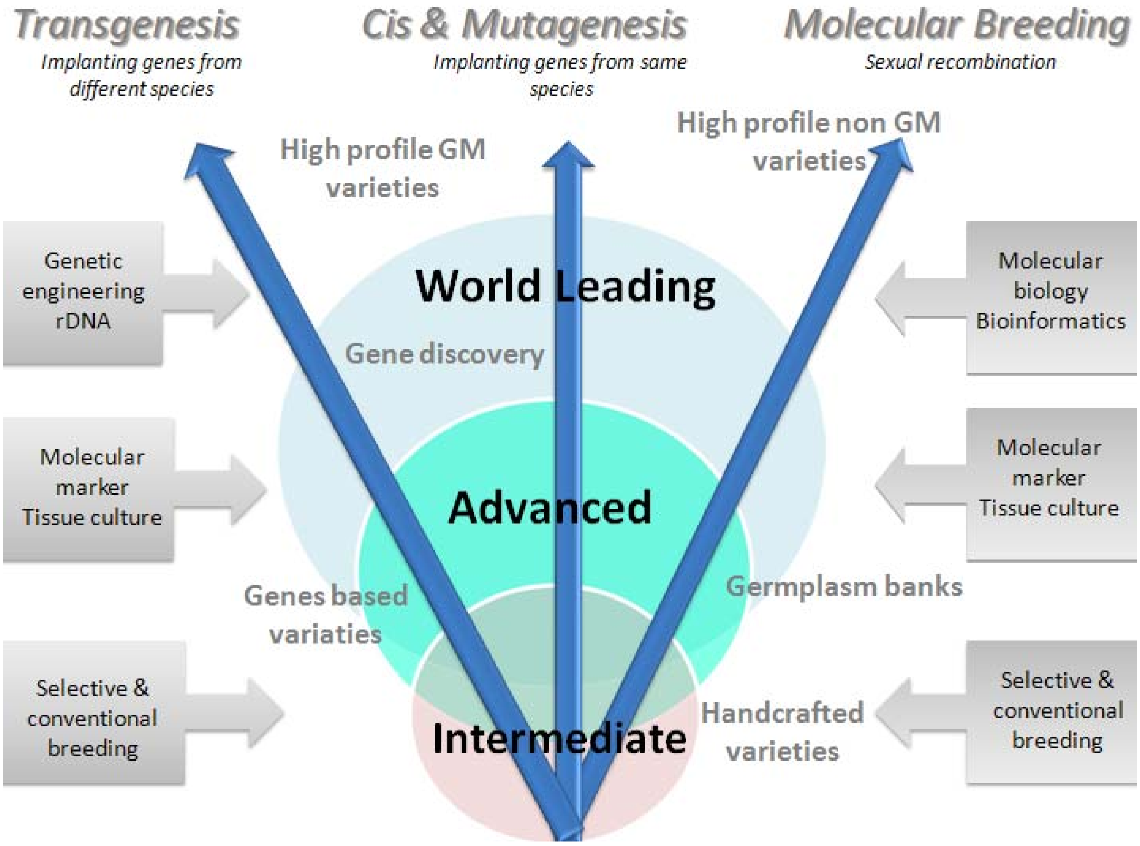
[14] The release of transgenic events requires a long and costly process of testing the safety for human health and the environment.

[15] Mutagenesis, for instance, can be performed naturally, or using genetic engineering (i.e. removing and inserting the desired obtained traits into targeted spots on a DNA strand), based on a technique called rapid trait development system (RTDS). RTDS derives its genetic traits from the very same plant species being altered. It is therefore argued to be less stressful and obtrusive to a seed than genetic engineering because it doesn’t force unnatural recombinations of genes. Once DNA is changed it’s inheritable, and the chemical used to induce mutagenesis can be removed.

advanced level of knowledge available for each technique, and (b) when firms are obtained tangible outputs in association with their research efforts.

Graph 2 describes the three technological possibilities available for seed companies nowadays and how can firms can evolve within each trajectory.

Graph 2: Technological trajectories in the seed industry



Source: own elaboration

In trajectory 1[16] (on the right), improvements are done by sexual recombination. Within this trajectory, firms operate at intermediate level when they work almost in an artisanal way, and they evolve towards at advanced level when they perform their R&D tasks assisted by modern technology, which increases the possibilities of controlling the process, and reduce hazards and time. For instance, they can choose the best parents after years of observation and experimentation or assisted by molecular markers (see

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[16] Whis involves three main steps: a) Generating a breeding population that is highly variable for traits that are agriculturally interesting. This is accomplished by choosing parents that complement each other; b) Combination (sexual recombination allows and assures that all the traits that differ between the parents are free to re-associate in new and potentially better combinations) and; c) Selection among the segregating progeny for individuals that combine the most useful traits of the parents with fewest of their failings.

Box 1 for a definition of the technique). In the first case they will be at intermediate level, but in the second in an advanced level. The same can be said regarding the following step, the combination between parents which can be done using cross pollination of the parents to initiate sexual recombination or using in vitro techniques and tissue culture for propagation (see box 1). In the more advanced level are the firms that perform sexual recombination using molecular breeding.

Something similar can be argued regarding the transgenic (on the left) or cisgenic / mutagenesis trajectories. Firms will be world leaders when they engage in the development of their own genetic events. When they buy these events or genes to obtain their new varieties from other firms, they will be in a less advanced level. If the genes are from the same or related species they will be in trajectory number two (in the middle), and if they are from different species they will be in trajectory number three (left, transgenesis).

In the bottom of the graph we have firms only performing conventional breeding techniques, performed in an artisanal way. These firms, typically provide the genetic background or varieties which are then improved, via transgenesis, cisgenesis or mutagenesis. These varieties however, are unique assets (constituting a germoplasm or collection of genetic resources for an organism) obtained after years of conventional breeding activities in a particular area. So firms, which have managed to obtain well-developed germplasm are considered here to have intermediate capabilities level of capability (not basic), even though they do not use biotechnology to induce genetic improvements.

Box 1 Definitions

Tissue Culture: The propagation of a plant by using a plant part or single cell or group cell in a test tube under very controlled and hygienic conditions is called "Tissue Culture". This is used to regenerate whole plants from plant cells that have been genetically modified.

Molecular Markers:A molecular marker (identified as genetic markers) is a fragment of DNA sequence that is associated to a part of the genoma. They are signs along the DNA trail that pinpoint the location of desirable genetic traits or indicate specific genetic differences. They are used speed up the process of identifying and transferring genes of interest (for instance for selecting plants with desirable combination of genes, for transferring genes into a new cultivar or in testing plans for inheritance of many genes at once).

2.3) Data collection

We use a qualitative research strategy based on multiple-case studies centred on firm level. Since our research is concerned with how capabilities developed and how different learning mechanisms and knowledge flows have influenced this process, a multiple case study strategy seemed to be the most appropriate. Qualitative methods are built around experiential understanding (Stake, 2010) and its analysis made it possible to assess the interaction between variables in a great level of detail and analyse causality in this particular empirical context. The case study strategy is suitable to enlighten those situations in which the intervention being evaluated has no single set of outcomes (Yin, 2009). The multiple-case approach allowed us collecting and analyzing data from several firms and institutions. Within that broad approach, we then draw a single set of “cross-case” analysis and provide an insight about the seed industry technological performance in the studied countries.

Research design was based on a handbook for fieldwork and two main sources of information. On the one hand, we examined secondary evidence from available reports regarding the seed industry in Argentina, Brazil, Chile and in the world. On the other hand, we gathered points of view from experts and well-experienced people in the sector through interviews and a closed seminar conducted in 2009. This preparation work allowed us selecting the nine firms studied. We ensure that the selected firms had experienced significant paths of positive innovation outputs and developed capabilities over reasonable periods of time. We chose to interview nine private and public firms, domestics and multinationals. The firms selected in each country represent the more important groups for each country, so in Argentina, where the private domestic sector is crucial, we select two domestic private firms, and one MNC half Argentinean, and in Chile and Brazil, where the public sector and the multinational sector are more important, we select one public firm, one MNC subsidiary and one domestic firm per country.

The fieldwork of this study was done from August 2010 to September 2011. We collected data from multiple sources within and outside the firms in order to address problems about recollection and other errors among respondents. For collecting primary evidence, we interviewed diverse members such as managers, engineers and R&D personnel in the focal nine companies. In addition, we met and visited key actors from Chambers, Associations, Universities, Research Centres and Government Units.

Regarding the firms, we conducted at least 25 in depth interviews. The main body of data was collected through a questionnaire guideline, the same in the three countries. These interviews provided information about the historical evolution of the firms and current performance, main events or breakthroughs, organizational changes, learning process and its mechanisms, and collaborations. Furthermore, information was collected through informal meetings with key individuals and from documentary sources. We examined specialized documents, reports, accounting sheets provided by firms, web sites and articles published in magazines and newspapers. There was in average two visits per firm, which allowed us complementing the analysis of secondary information with direct observations. Finally, we implemented four different follow up questionnaires about technological activities and learning mechanisms.

The analysis of the data was done by each firm under study individually and fell into two stages. First, as illustrated in Table 2 below, the transcribed records of interviews and other data were collapsed to a number of indicators and associated with each of the capability sources. Second, the data displayed was analysed according with commonalties and discrepancies and converted into the analytical framework explained above regarding levels of capabilities within technological trajectories (see Graph 2).

Table 2: Linking the conceptual framework to the empirical information

Conceptual Framework	*Sources to the building of capabilities*	*Indicators*
INNOVATION CAPABILITY BUILDING Trajectory / Level of capability	Technological Activities	Complexity of the R&D performed
		Use of modern biotechnology, or other new knowledge
		Innovative outputs (plant variety protection and patents
	Internal Learning Mechanisms	Knowledge codification
		Knowledge sharing/socialization
		Learning from formal R&D experimentation
		Learning from engineering and design experimentation
		Internal training
		Learning from operational experimentation
	External Learning Mechanisms + Distributed Capabilities	Establishment of R&D facilities in knowledge-rich locations abroad
		R&D-based interactions with universities and research institutes
		R&D-based interaction with suppliers
		R&D-based interaction with users
		R&D-based interactions with competitors
		Exchanges of knowledge with competitors
		Active participation in scientific and technical conferences, workshops and meetings through the presentation of lectures and papers
		Monitoring competitors
		Searching into specialized knowledge sources
		Learning through feedback or assistance from users or costumers
		Learning from technical assistance, consulting services and license agreements
		Education and training programmes
		Hiring expertise

Source: own elaboration

3) EMPIRICAL ANALYSIS

The empirical analysis is divided in four sections. First, we describe the main institutional and economic features useful to contextualize the seed industry behaviour in the countries under study. Then, we present key aspects of the firms explored during the fieldwork. In third and fourth place, we explain the evolution of levels of capabilities reached by each firm over time and the efforts carried out in terms of learning mechanisms and distributed capabilities to obtain innovative products.

3.1) The context: Argentina, Brazil and Chile

In this section we describe the main features of the institutional and economic framework that could have affected the level and type and the evolution of technological capabilities accumulated in firms, including IP and biosafety regulations, size and vigour of the industry, and biotechnology capabilities.

3.1.1) Institutional and policy framework

Patents

Argentina, Brazil and Chile have a similar patent system. They permit to patent the use of genes for specific constructions, but do not allow patenting of life forms and/or genome (or genes), as found in nature. Brazil and Chile even explicitly reject the doctrine of isolation, according to which isolated or purified products of nature are patentable[17]. The three countries also, exclude from patentability essentially and /or natural biological processes, for the production of plants or animals. The same with life forms, plants and animal, which are not patentable in the three countries (being they varieties or not)[18] (see Box 2 in the Annex 5 for a detailed explanation of the patent system in each case).. In the case of plants, the system allows the countries to respect the *International Convention for the Protection of New Varieties of Plants* of 1978 or 1991

Plant Certificates

The three countries have also adopted a similar system regarding IP protection for plant breeding. They adopted early measures that protect breeders developing new varieties by means of plant certificates for a period of between 15 and 20 years . However, they have adhered to different versions of the UPOV convention, the International Union for the Protection of New Varieties of Plants[19]. Argentina, who joined the club in 1994, adhered to the rules of the convention signed in 1978; Brazil and Chile, who joined in 1998 and 1996 respectively, adhered to the rules of the last convention in 1991.

The UPOV Act signed in 1978 allowed two exceptions to the rights granted to the breeders; the first, to farmers that save seeds for use on their own farm or to sell it to their neighbours[20]; the second to research, which could be conducted using existing varieties without paying royalties. This was supposed to favour the free exchange of germoplasm within the research community, and to develop new varieties based on one previously registered. In the 1991 version, UPOV limited the privileges of the breeder (using existing varieties to develop new ones) using the concept of new variety essentially derivated. Breeders that carry out improvements, introducing for instance new genes to an existing variety, must pay a royalty to the developer of the existing variety from which the new was derivated.

This change equilibrated the situation between conventional breeders and GM producers, since GM constructions are always patented, so in the version of 1978 of the plant certificates, when local breeders used varieties with a new gen that was patented, they had to pay royalties to the owners of the genes (in the patent system). But because of the exceptions of the plant variety protection system, when new varieties registered in the plant variety protection system where used to develop new GM seeds, the owners (in the plant variety protection system) of the variety registered, did not receive any

[17] Brazilian Industrial Property Law, article 10; Law Nº 19.039 of Chile, article 37.
[18] Brazilian Industrial Property Law, article 18; Law Nº 19.039 of Chile, article 37; Decision 486, *supra* article 15.
[19] UPOV is an intergovernmental organisation established by the International Convention for the Protection of New Varieties of Plants, known as the UPOV Convention, adopted in Paris in 1961. The Convention was revised in 1972, 1978 and 1991. The last two revisions, or “Acts” as they are known, are currently in force. By signing the UPOV Convention, countries obtain guarantees that IPR over new varieties will be respected by other signatories and reciprocally undertake to respect the rights of breeders in other signatories. UPOV Convention signatories are required to introduce plant variety protection legislation with certain basic characteristics.
[20] Recent court decisions have defined who is a "farmer" and how much seed can be saved.

retribution. In the 1991 version of the system, this changed, and the developers of GM seeds have to pay royalties to the plant breeders when they use their backgrounds to paste their genes, which obviously favours local breeders.

The 1991 version of the UPOV also tighten up the requirements for protection, new varieties must now be novel in addition to be distinct, uniform and stable (as in 1978) to be susceptible to be protected, and removed the van on double protection that existed before, enabling new varieties to be patented as well as being protected by breeder's rights.

Regulation of biotechnology events

Argentina, Brazil and Chile have adopted different approaches to the approbation of GM technologies. Argentina, has adopted the more liberal approach, by allowing the use of GM seeds for food production, right from the beginning, when the first GM seeds were released by mid-1990´s. Brazil, was more reluctant to adopt the technology, at the beginning. However, already in 2005, reacting to the massive illegal adoption of the technology in the south of the country (brought by Argentinean farmers) allowed the use of GM seeds for domestic production, but with more restrictions. Finally, Chile only allows the use of GM seeds (modified using transgenesis), when they are used to produce animal food (1992) and seeds that are then re-exported (1997). TGM seeds are not allowed to produce food products that will then be commercialised internally or exported.

However, in the three countries exist now a similar set of institutions that regulate biotechnological events, which take between 10 and 15 years to be authorised after the required trials and risks assessments are performed. In Argentina the institution in charge of regulating and authorising biotech events is Conabia, created in 1991, in Brazil the Council of BioSecurity, created in 2005, and in Chile the Technical Commite on GMOs, create also in 2005.

Enforcement

A big challenge for the three countries, but particularly for Brazil and Argentina is the enforcement of all these rules of IP protection. The three countries have put in place several institutions to help enforcement, however these have not yet been very effective. In Brazil, for instance Abrasem and Braspov (the two main associations of seed producers) set up the OriLeg Program, a tool that identifies and certifies whether agricultural production in an specific productive chain is organised using legal seed, bought in the white market. In Argentina, the seeds association create Arpov, the national plant variety protection association, which is in charge of administrating the system of protection. Most of seeds commercialised in the countries, however, still originates in the black market (mostly for autogamous), i.e. has not been certified and has not paid property rights.

Public and private Support

Actions oriented to provide support to the seed industry are organised mainly in two ways, in the three countries. On one hand, through governments and the associations of farmers, seeds and biotech producers. On the other hand, the three countries have several public programmes giving support directly or indirectly to the seed industry (e.g. the Action Plan for Science, Technology and Innovation for Development of Plants and Animal Genome, in Brazil; thee seed cluster in Argentina[21], and the National Commission for Development of Biotechnology in Chile). They have also several and very efficient and well interconnected seeds and farmer associations. These programmes and associations have been relatively successful at encouraging and connecting capabilities and investment in the sector, and at diffusing knowledge, however, they have not been so successful at addressing one of the main problems faced by world leading seed producers nowadays, the economic and regulatory barriers to patenting. Companies or universities that have made an important discovery, in the region, have to seek for external partners and share the benefits of their new knowledge with other partners, which only provide the support for patenting. This is because companies and universities in the countries under study are not able to patent themselves due to the high costs and the complexity of the process.

3.1.2) Industry size, organisation and capabilities

Size of the industry

Argentina, Brazil and Chile are heavily specialised in agricultural production, and are among the greatest food-producing and food-exporting countries of the world[22]. It is not surprising thus that these countries have developed substantial markets for seeds valued among the tops in the world. Brazil has the fourth largest market of seeds in the world (after USA, France and China), with a domestic seed market value of 2000 millions of dollars; Argentina has the 9th largest seed market in the world valued in 600 millions dollars (see Table 3). The domestic seed market in Chile is substantially smaller, valued at 120 million dollars ranks 31st, well bellow Brazil and Argentina. However, Chile is one of the world top leaders of seeds exports (the fifth after the Netherlands, USA, France and Germany). Argentina is 11th world exporter and Brazil the 23th.

Chile has around 70 seed companies registered most of which are MNCs producing seeds for exports (80% maize and soy), however some domestic firms, including INIA produce vegetable and fruit seeds for domestic market (4000 hectares of the total 24000 hectares cultivated with seeds are for the internal market). In Brazil, Abrasem (the seed association) has 560 companies registered, most of which produce soy, maiz and wheat for the domestic market. The total area cultivated with seeds in 2006 was 46 million has. In Argentina there are 800 companies dedicated to seed production, 60 of which are

[21] The Seed Cluster is a project oriented to form a national network of multidisciplinary skills in the use of DNA-based technologies (genomics, molecular markers, genetic transformation) combined with crop ecophysiology, industrial quality and plant pathology to increase the competitiveness and sustainability of the value chain of the wheat grain and barley.

[22] The contribution of the whole chain of agribusiness to the total exports of the countries goes from around 25% in the case of Chile (where the main primary export is copper), to 35% in the case of Brazil to 46% in the case of Argentina. With an estimated 367 million hectares of arable and permanent cropland, and the application of very sophisticated techniques these countries are world leaders in the production of several agricultural products. Brazil's is the world's largest producers of sugar, coffee and orange juice, and second world producer of soybeans, soybean oil and cake of soybeans. Argentina, is the world's largest producer of soybean oil and cake of soybeans, and the second and third world producer of sunflower oil and maize. Chile is more specialised in fruits and vegetables, being a world leader in the exports of grapes (1st), wine (5th) and fruits (apples, avocado, cherries and kiwis). Source?

breeders and 34 of which own their own germoplasm. As in Brazil, most of them produce soy, wheat and maize seeds, and there are around half of million hectares cultivated with seeds only in the Pampean area.

Table 3: Importance of the seed market per country

Country	**SEEDS**		
	Market Value (USD millions)	Total exports (USD millions)	Total varieties registered per year*
Argentina	600	172	136
Brazil	2000	370	153
Chile	120	54	40

Source: International Seed Federation, ASA (Asociacion de Semilleros Argentinos and Catalogo de Patentes sobre biotecnologia en el Mercosur.
*Argentina covers 1979-2011 the total is 4347, Brazil, 1997-2010: the total is 1840, Chile 1994-2009

A good indicator of the importance of the seed market in each country is given by the total quantity of varieties registered. Here we have variations not only in the numbers, reflecting differences in the sizes of the countries and the vigor of the industry (see Table 3, Column 3), but also in the type of seeds registered reflecting differences in the structure and the specialization of the agricultural sector. In Argentina most of the registered cultivars are in crops such as sunflower (16%), maize (40%), soy (16%) and sorgo (19%); in Chile in fruits (60%) and; in Brazil in soybean and maize and tropical fruits and vegetables.

Industry organization: main players

In Argentina, the main three key players in the seed industry are MNCs, domestic companies and INTA. MNCs gained prominent roles after the 1990s, with the concentration and transnaitonalisation of the sector, but domestic firms kept a key role in the market (together with INTA). They typically buy (biotechnological events) and sell (domestic varieties) to MNCs, and compete with them in the final market, with leading positions for some crops such as soy (where two domestic companies Don Mario and Nidera have 60% of the market). INTA, does not sell seeds in the final market, but sell technology to MNCs and domestic firms, as well as buying it from them, when necessary to generate new improved varieties.

In Brazil, the main two players after the 1990´s are MNCs and Embrapa. There are also domestic firms, that develop seeds, but they occupy a more marginal place for new developments. Similarly in Chile, where the main actors are INIA, the public company doing research in agriculture and selling seeds, and the MNCs, which mostly multiply seeds for export. A few domestic firms also occupy a place in the market, however, this is marginal in the market of crops for exports. They are strong in the production of seeds for the main exportable products of Chile, such as fruits, vides, etc..

A substantial difference between Argentina, and Brazil and Chile which explains in part these discrepancies in the organization of the seed market, relates to the status of the agricultural research institutions (Embrapa for Brazil, Inta for Argentina and INIA for Chile). In Brazil and Chile the institutes of agricultural research, Embrapa and INIA are public companies that hold an important share in the seed market. They compete with firms, domestic and MNCs to supply the domestic markets as final providers of seeds.

In Argentina, despite the importance of INTA[23] (the National Institute of Agricultural Technology) for the seed market (e.g. owns 50% of new varieties), this institution is not a company supplying seeds. It is a research institution which produce knowledge useful for the sector, which is then licensed to other firms, domestic and MNCs which commercialize the seeds in final market.

Another difference relates to history. In Argentina private participation in the breeding activity started as earlier as 1919, with the activities of firms such as Klein, Buck (1930) and Relmo which were involved in genetic improvements of wheat and soybean. In Brazil and Chile instead, the activity was almost completely dominated by the public sector. Private activity started in the 1970´s together with the creation of the public companies of agricultural research Embrapa (1973) and INIA (1964). By the 1990´s when there was a substantial process of international concentration and transnationalisation of the activity, lead by a few chemical companies (such as Monsanto, Sygenta, Pioneer, Dupon, etc.), Argentina already counted with a group of strong domestic firms supplying the domestic market (together with INTA, created in 1956) which was not completely absorbed by the MNCs, as it happened in Brazil, and Chile.

Biotechnology capabilities

Regarding biotechnology capabilities, which are crucial for the seeds industry we observed interesting differences across countries (see Tables 4 to 7).

First, Brazil takes the lead clearly regarding efforts. It is both, investing more and dedicating more human resources to research in agricultural biotechnology. (see table 4 and 5: 111million dollars per billion GDP of investments against 31 in the case of Argentina and 41 in the case of Chile).

Something similar happens with patents, Argentina has 1.5 per researchers, Brazil 0.4 and Chile 0.17, and this difference is more marked yet if we only focus on the class 800, the only class patent one strictly related to seed production (See Annex I).

Table 4: Private and public investments in agricultural biotechnology

	Investments in agricultural biotechnology (millions of dollars)					
Country	**Private**	**Public**	**Total**	**Private-Public share**	**Per million of in-habitants**	**Per billion GDP**
Argentina	3463	4816	8279	0,72	218	31
Brazil	13761	55046	68807	0,25	384	111
Chile	268	3049	3317	0,09	207	41

Source: Biotecnologia agropecuaria para el desarrollo en América Latina: Oportunidades y Retos , BID

[23] Created in 1956, much earlier than Embrapa the equivalent in Brazil and INIA in Chile

Table 5: Total researchers, by country and resources in agricultural biotechnology

	Total researchers			Indicator of strength	**Number and distribution of techniques**		
	Private	**Public**	**Total**	**Researchers inhabitants**	**Total[1]**	**Traditional**	**Modern**
Argentina	11	47	58	1.52	239 (76%)	57	43
Brazil	0	358	358	2.17	288 (100%)	75	25
Chile	5	198	203	12.71	180 (94%)	62	38

Source: Biotecnologia agropecuaria para el desarrollo en América Latina: Oportunidades y Retos , BID
[1] In brackets is the share of public sector

Second, however, if we observe indicators of performance it seems that Argentina is accumulating more capabilities than Chile and Brazil. It has more publications and patents per capita and researcher, and it has also more diffused use of modern compared with traditional techniques of biotech (including for instance genetic engineering, recombinant DNA, etc.) (see tables 6 and 7). Argentina has published 42.3 papers per researcher, and 61,3 per million inhabitants, while in Brazil these numbers are 5.2 and 2.8 and, in Chile are 21.1 and 1.7 respectively

Table 6: Publications by country and area

	Biochemistry Genetics and Molecular Biology	Biology and Agricultural Sciences	Total	Total Per Capita per million	Total by researcher
Argentina	2094	357	2451	61,3	42,3
Brazil	891	133	1024	5,2	2,8
Chile	314	45	359	21,1	1,7

Source: Biotecnologia agropecuaria para el desarrollo en América Latina: Oportunidades y Retos , BID

Table 7: Patents (see Annex I for a description for patents class 800 the more adequate for the sector)

	Total Patents	Class 800	Class 435	% MNC in 800	% Private national	Total Patents per millon	Total Patents per researcher
Argentina	87	31	56	80%	6%	2,5	1.5
Brazil	156	46	110	93%	2%	1,0	0.44
Chile	34	2	32	0	0%	2,2	0.17

Source: Biotecnologia agropecuaria para el desarrollo en América Latina: Oportunidades y Retos , BID

Finally, in Argentina private share in the investments and patents is more important than in Brazil and Chile, and these private investments are not only coming from MNCs, as suggested by the origin of patents. In Brazil, MNCs and the public sector seem to be the main actors involved in investments and patents, and in Chile only public institutions play a role. These differences are to a large extent explained by the history and difference in the industrial structure of the sector across countries.

3.2) The companies

In line with the predominant structure of the industry in each country we select the following firms to be explored in the fieldwork:

- In Argentina: two domestic firms: Bioceres and Sursem and one Argentinean Dutch MNC: Nidera.
- In Brazil: the public company Embrapa, one MNC, Sygenta and Coodetec a domestic company run by a cooperative of farmers.
- In Chile: a domestic venture by local farmers, researchers and the government, Biofrutales, a MNC, Monsanto, and the public company INIA.

Table 8 summarises key aspects of each company studied in Argentina, Brazil and Chile.

Table 8: Domestic firms researched in the seed sector in Argentina, Brazil and Chile

Firm	*Trajectory/ies*	*Seed and Other Products*
	DOMESTIC FIRMS	
Bioceres (2001), Private Co-operative of farmers, Public sector involved (Argentina) 50 employees	Transgenesis, conventional	• Varieties: Wheat, soybean • Hybrids: maize, sunflower • Chymosines based on plants
Sursem (1995/2008) Private, Joint venture between two SMEs), (Argentina) 110 employees	Transgenesis, conventional	• Varieties: Wheat, soybean • Hybrids: maize, sunflower
Coodetec (1995), Private Co-operative of farmers (Brazil) 520 Employees	Transgenesis, conventional	• Varieties: Wheat, soybean • Hybrids: maize,
Biofrutales (2006), Private /public partnership , Co-operative of farmers involved (Chile) 50 employees	Transgenesis Cisgenesis	• Fruits: grapes, peaches, cherries, plums
	MNCs SUBSIDIARIES	
Nidera* (1929), Seeds unit (1990) Private, Argentinean Dutch MNC Subsidiary Argentina 1400 Employees	Transgenesis, Mutagenesis, Conventional	• Varieties: wheat, soybean, Hybrids: maize and sunflower • Vegetable oils • Fertilizers • Bioenergy
Sygenta (2000 in Brazil, acquire Novartis) Private, Swiss MNc Subsidiary Brazil 1600 Employees	Transgenesis	• Varieties, soybean, Hybrids: maize • Vegetables, flowers,. agrochemicals
Monsanto (1993 in Chile) Private, North American	Transgenesis,	• Varieties, soybean, Hybrids:

Subsidiary Chile 67 Employees		• Agrochemicals
PUBLIC FIRMS		
Embrapa (Brazil) (1973) Public company of Agricultural research 57 % the country's public agricultural R&D 9000 Employees	Transgenesis, Mutagenesis Mollecular breeding	• Crops: soybean, maize, cotton, wheat, sorghum, vegetables, etc. • Others: coffee, citrus, sugar cane
Inia (Chile) (1964) Public company of Agricultural research	Mutagensis, Cisgensis Mollecular breeding	• Wheat, oats, rice, fruits and vegetables

Source: own elaboration

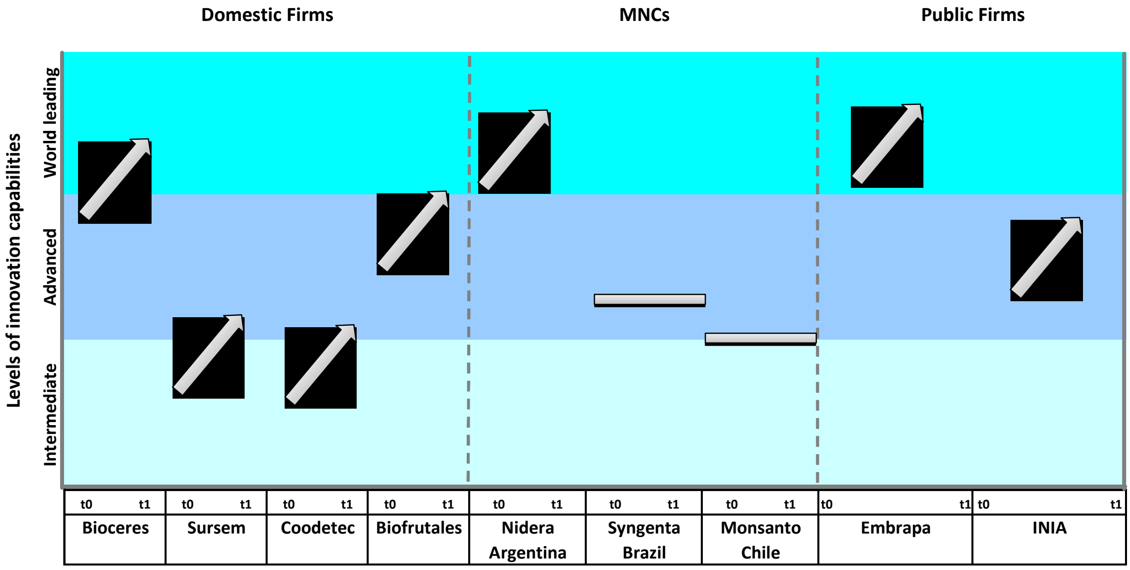
* Among MNCs, Nidera is an exception: created by an Argentinean family, currently high part of the property still belong to domestic owners, they conduct R&D activities in-house, which is mainly located in Argentina.

It is interesting to notice from Table 8 that the four domestic firms were created as a result of some kind of collaborative association between the public and private sector. Also, in all four cases farmers have taken the initiative in the project. Typically, the public sector provides scientific and technologic infraestructure and the private sector plays a key role regarding market needs (farmers) and financing (venture capital, private owners). It is also noticeable that all firms follow more than one trajectory, though domestic firms and institutions seem more concerned in keeping diversity.

3.3) Levels of capabilities

Graph 3 summarizes the levels of capabilities reached by each firm. We classified them in line with the theoretical framework summarized in Graph 2. The vertical axis is divided into three levels of innovation capabilities: intermediate, advanced and world leading. The horizontal axis shows the three broad groups of firms: domestic, MNCs and public firms. Each firm is characterized in terms of the evolution of its technological capabilities with an arrow that start in time zero (t0) and ends up in time time one (t1), the relevant time line for each company.

Graph 3: Levels of capabilities and evolution



Source: own elaboration

Three companies have been classified as world leaders innovators: one domestic Bioceres from Argentina, one MNC from Argentina, Nidera and, one public firm from Brazil, Embrapa.

The main distinctive feature of these three companies is that they are all carrying out substantial R&D efforts in the frontier, supported by the more advanced biotechnology techniques (genetic engineering, rDNA) and other advanced techniques (molecular biology and bioinformatics) to improve seeds, and at the same time they have managed to obtain concrete innovative outputs in association with these efforts.. Nidera, for instance has patented a new variety of hybrid sunflower seed, obtained from mutagenesis, which is resistant to the herbicide Clearsol Plus (Basf), Bioceres has patented the gene Hahb4 which can be used to develop seeds resistant to water stress and salinity and Embrapa, has patented soybean of seeds resistant to herbicides imidazolinonas (see Table 9 for a full description of the type of R&D, innovations and innovative output of each world leader firm and Box 2 for a description of the evolution of each one of these companies towards their leading positions). These innovations have enabled these firms to gain a position of technology providers in the seed market (see Technology Services in Table 9).

These three companies are also actively involved in the development of tools and processes useful for conducting R&D and improving seeds and in the opening up and supporting of different directions of innovation in the seed sector, besides transgenesis. Bioceres, for instance, has several programmes in molecular breeding, Nidera is committed in the use and development of mutagenesis as an alternative to transgensesis in several of its main programmes, and Embrapa has engaged substantial resources to the support of research in non GM soy bean seeds, among others efforts (see http://www.semear2011.com/content/embrapa-launches-program-support-non-gm-soy).

Following the three world leaders, we have classified two companies as pointing (or going) toward world leaders. These are Biofrutales, domestic from Chile, and INIA, the public agricultural research institution of Chile. We have classified them in this level because even though they have not managed to obtain concrete innovative outputs in the form of patents for instance, they are conducting substantial R&D efforts in the frontier, assisted by the more modern biotech (e.g. genetic engineering, molecular markers, selective breeding) and other advanced techniques (e.g. bioinformatics), oriented to the identification of genes responsible for desired traits. They are also engaged in the development of tools and processes to assist the process of R&D and in the opening and supporting of new directions of technical change in the sector. Biofrutales, for instance, has developed bioinformatic and biological tools to apply in genomic and proteomic research and INIA is a leader in procedures for sowing and precision agriculture techniques. They are both also committed to the development and diffusion of cisgenic techniques for seeds improvements which offer an alternative way to genetically improved fruit seed, which can not be altered via transgenisis (for market and regulatory issues (see Table 10 for a description of the R&D efforts and the main innovations of each firm).

The two MNCs subsidiaries from Brazil (Sygenta) and Chile (Monsanto) have not been classified as world leaders but as advanced because they do not conduct advanced R&D in genetics (using for instance genetic engineering or rDNA) oriented to identify genes in the host countries[24], even though they have committed to the transgenic trajectory. Resembling the typical pattern of MNC subsidiaries in developing countries, these companies draw most of their main technological assets from their parent companies (or sisters subsidiaries in advanced countries) limiting their local R&D to efforts to perform adaptations to the local context. We have considered these efforts as advanced, however, because in the case of seeds unlike other products such as computers for instance, substantial adaptations are needed for them to work well in line with the agro ecological conditions of the host context. This requires the MNC subsidiaries to perform substantial local efforts, mostly local alliances to adapt their seeds to the domestic market (see Table 11).

Finally, we have classified the two other domestic firms from Argentina (Sursem) and Brazil (Coodetec) as intermediate going up to advanced, because , but they do not perform R&D efforts oriented to the identification of genes, or have managed results in this field, despite being fully committed to the transgenic trajectory (they sell mostly transgenic seeds). They typically develop varieties adapted to the local conditions, buying biotechnology events (or genes) from other firms (MNCs typically) and pasting them to their varieties (improved by conventional breeding techniques). They are in a lower level of capabilities relative to the subsidiaries because they do not have privileged access to the technological assets of other companies, as MNCs subsidiaries do. The evolution that these domestic firms have experienced from intermediate to advanced is justified because of their increasing use of sophisticated biotechnology tools for developing seeds (their new transgenic varieties are now developed assisted by modern biotechnology techniques such as molecular markers) (see Table 12).

Table 9 to 12 provide examples of the main R&D efforts and innovation outputs of the companies in each level of capability.

[24] This constrasts with Nidera which conducts most its R&D in genomics in Argentina, since the creation of the Seed Unit.

World Leaders

Table 9: Main R&D efforts and innovative outputs of world leaders

Firm Efforts and outputs	Nidera	Embrapa	Bioceres
Main technological assets	•**Own genes** •Licences of genes from other MNCs •Own germoplasm	•**Own genes** •Licences of genes from other MNCs •Own germoplasm	•**Own genes** •Licences of genes from other MNCs •Own germoplasm
R&D supporting efforts	•Genetic engineering •Mutagenesis •Molecular markers •Culture tissue •Selective breeding •Conventional breeding	•Genetic engineering •Molecular markers •Culture tissue •Selective breeding •Conventional breeding •Bioinformatics	•Genetic engineering •Molecular markers •Culture tissue •Selective breeding •Molecular breeding
Patents *	4 in USPTO 1 in WIPO	4 in USPTO 1 in EPO 5 in Wipo Embrapa has not patented in other countries from Mercosur	3 in USPTO and EPO 2 in Brazil
Registered varieties per year	16	15	17
Main Innovations	• First Argentine firm that introduced the soybean with RR gen in the country • Clearfield Plus Soybean: it is a package that includes the hybrid sunflower seed obtained from mutagenesis (Paraíso 1000 CL Plus) and the herbicide Clearsol Plus. The seed is resistant to the herbicide. • New Soybean variety recently launched to the market to be used in the campaign 2012 (4N2V74028).	• Soybean with Bt RR2 gen • Soybean resistant to herbicides of imidazolinonas • Inoculation of biological nitrogen fixers for soybean seeds before planting • Soybeans, beans corns, adapted to the savannah (“Cerrados”) and low latitude regions; tropical soybean. • Approval for its first GM seed which is tolerant to acid soils in 2010 • Electro-chemical sensors and bio-sensors based on nanotechnology	• Gene Hahb4 from which it is possible to obtain transgenic plants resistant to hydride stress and salinity. • Gene COX5c, which is a gene promoter or enhancer and allow increasing the expression level of genes in plant cells. • Gene Hahb-10 for the production of transgenic plants charactarized by short life cycles and tolerant to oxidative stress • Molecular farming platform: diversification to other science based productive process (chymosine based on plants)
Technology services	• Nidera also licence technology to Central Europe, Eastern Europe and Russia (sunflower) and USA and Africa (maize and soybeans).		• License of technology: genes to Advanta India • Gene sequencing (potential service import substitution: biodiversity, bioremediation, bioprospection)

Source: own elaboration

* The four patents of Embrapa in USPTO include: 1) A process for obtaining transgenic leguminous plants (leguminosae) containing exogenous DNA, 2) Sorghum aluminum tolerance gene, SbMATE , 3) Biocontrol for plants with Bacillus subtilis, Pseudomonas putida, and Sporobolomyces roseus , 4) Biocontrol of plant diseases caused by Fusarium species with novel isolates of Bacillus megaterium Nidera has the following four patents registered in USPTO: 1) Soybean cultivar 4N2V74028, 2) Soybean cultivar 4N0S63222, 3) Soybean cultivar 4N2V55022, 4) Herbicide-resistant sunflower plants with multiple herbicide resistant alleles of ahasl1. The patents of bioceres are described in the table above (see details for genes: Hahb4, COX5c and Hahb10

Box 2: Brief history of the world leaders. (Annex II describes the history of all the other companies.

Bioceres

Bioceres was created in 2001 by a co-operative of 23 agriculture producers, associated to two important agricultural institutions, AAPRESID and AACREA with the objective of improving the match between biotechnology projects that, at that moment, were being carried out by research groups working in R&D public institutions (INTA and Universities), and the agricultural needs in Argentina.

The company created the seed unit in 2007, and its own research lab, INDEAR in 2008. The starting point of the seed unit was a technological agreement with INTA (BIOINTA Programme) according to which the public institution developed the wheat seed and Bioceres sold it to the market. For other crops, the company started only buying technological events from MNCs and using them to carry out the activities related to the development and achievement of genetic material (basic or foundation seeds). Over the years, the unit evolved towards the development and production of its own branded seeds and the invention of genes.

The creation of INDEAR has supported this objective. INDEAR is the result of a public private alliance (an alliance with The National Council of Research –CONICET-), fully dedicated to gene discovery, based on a transformation platform (Arabidopsis) and to the test of cultivars of interest. For doing so, the firm employs 25 PhDs in biology, genetics and chemistry. Indear has been investing all its sources into R&D. According to an interviewee “since Indear was created there aren´t revenues from its activities”. As stated by one of the interviewees “INDEAR has pursued the development of our own technological platform. Moreover, it is an alternative for outsourcing R&D programmes in public institutions or universities. The goal was to generate our own transgenic seeds based on our own germplasm and package the product to sell it to the agriculture producers. We consider that this is the way to capture the innovation rent”.

Currently, Bioceres can not introduce its own genes in its germplasm because the patents are under regulatory stages. For this reason, they keep buying biotech events to MNC. However, as it was stated by the interviewee The company moved up towards world leading level of capabilities when the USPTO granted three patents to Bioceres (together with CONICET and University of Litoral).

Nidera

Nidera Seeds was created in 1991. Its main activities include the research, development and production of agronomic seeds; the procurement, conditioning and export handling of grains and oilseeds; the manufacture and refining of vegetable oils; and the sale and distribution of a wide variety of agricultural inputs to the farm sector. Its creation was based on the interest of the firm in developing their own feedstock (germplasm) for the production of grains and oil. The starting point was the hiring of a group of researchers that were participating in the program of sunflower in an argentine subsidiary of an international company (Continental Seed). At the same time, Nidera bought the Argentine subsidiary of Ashgrow Seed Company. By the mid of the ninety Nidera was the first company that started selling the transgenic soybean with the gen RR in Argentina.

In 2000, Nidera created the division of agricultural chemicals and fertilizers under the objective of increasing the seed business inputs needed by the agriculture producers (seed, fertilizers, agrochemicals). During same year they started also using molecular markers which allow incorporating the interest genes in shorter time. In 2005, through the purchase of Bayer's subsidiary in Brazil, the firm founded Nidera Sementes in this country, in order to come up with products in Brazilian territory.

Regarding milestones, Nidera evolved using more complex technologies and procedures over time. The interviewee explained “from development of our own germplasm, to gene replacement, to development of our own technological event which, nowadays is about to be licensed abroad”. In 1996 the firm launched the soybean resistant to glyphosate (by the incorporation of gen RR). In 1999, they produced new maize material with American blood which allow increasing yields of the hybrid (the interviewee explained that at that moment, the maize produced in Argentina were very basic). During the first years of 2000, they replaced the traditional Argentinean wheat germplasm by the European one because of its better performance. The firm imported French wheat genetic and developed its own germplasm. The result is the well known product of the Nidera that is named “Baguette Seed”. In 2010, one of the strongest working lines is based in sunflower for developing a new gene.

The interviewee comments “We developed a mutant conferring resistance to a specific of herbicide. It will be the first biotechnological event of the firm and it is in the stage of patenting. It will be a whole technological package: sunflower seed resistant to herbicide and the herbicide developed by the firm”. One interesting aspect of this new development is the use of mutagenesis instead of transgenesis, which in the case of sunflower is important, and also mark a potential new direction in the industry for cultivates that are more sensitive to the use of transgenics (consumers are more sensitive).

Embrapa

Embrapa was created in 1973 by the Brazilian Government, the World Bank and IDB. The public corporation would be dedicated to agricultural research, and the idea was to encourage a division of labor in the public sector whereby basic research would be the responsibility of universities and applied research would be conducted by Embrapa itself.

In 1998, Embrapa created the Intellectual Rights Property Unit (Secretaria de Propriedade Intelectual, SPRI). The aim of this unit was to promote the transferring of technology and the valorization of the intellectual assets generated by Embrapa. In 2003, the functions accomplished by the SPRI were transferred to the unit named Technology Transfer Embrapa (Embrapa Transferência de Tecnologia). With the support of this unit, Embrapa achieved a portfolio of protected technologies in Brazil comprised of the following: 129 patents, 168 brands, 30 software, and 230 protected cultivars. Abroad, Embrapa achieved a portfolio that includes 89 patents, 1 brand and 19 protected cultivars. .

Recently, Embrapa constituted a Work Group in Agro Ecology and launched the Referential Mark for Research in Agro Ecology (in 2006). This document identified the need of systematizing the innovative practices and experiences of agriculturists and to develop participative process of research with a systemic perspective. The solutions developed by Embrapa are internationally recognized.

Currently, Embrapa is the main Brazilian Public Institution of Agricultural Research (Instituições Públicas de Pesquisa Agrícola, IPPAs). It is comprised of 38 research units, 3 services and 13 administrative units. The firm embraced research models that can be differentiated as follows:

- Concentration on Research Model. This model was based on the creation of integrated centers of R&D with a focus on broad national issues. Priorities and the development of research were conducted by decentralized units, which adopted a National Plan of Research. The aim was to substitute a previous research model, which was based on diffuse research.
- Circular Programming Model. This model was established at the end of 1980’s. The aim was mostly to enable the participation of diverse areas in defining the research programs.
- Embrapa System of Planning (Sistema Embrapa de Planejamento, SEP). This model made more concrete the commitment of Embrapa in including diverse areas in the definition of the research programs.
- Embrapa System of Management (Sistema Embrapa de Gestão, SEG). This research model was established in 2002. It reflects a significant change that was made in the scope and focus that has been used in the management and organization of research. This system encompasses the planning, execution, monitoring, assessment, feedback and time plan of funds releasing. The allocation of financial resources occur by Macro Programs (MP) and the aim is to manage a set of projects and processes in Embrapa and also to achieve institutional objectives, to guarantee technical and scientific quality and the strategic value of the research programs. SEG encompasses 6 MPs and the MP1, which is named as the ‘Big National Challenges’ and comprises 18 projects (regarding agro environment, bio security, organic agriculture, and conservation of genetic resources)

Source: own elaboration

Table 10: R&D efforts and innovative outputs of the group pointing to world leaders

Firm	Biofrutales	INIA
Main technological assets	•Own germoplasm	•Licences of genes from other MNCs •Own germoplasm
R&D supporting efforts	•Genetic engineering •Mutagenesis •Cisgenesis •Molecular markers •Culture tissue •Selective breeding •Conventional breeding	•Genetic engineering •Molecular markers •Culture tissue •Selective breeding •Conventional breeding •Bioinformatics
Patents	_____	_____

Registered varieties per year	**N/A**	2.28
Main Innovations	• New varieties through genetic improvements in selected fruits • New varieties through genetic transformation (mostly based on cysgenesis) • Development of biotech tools: models, algoritms, bioinformatic and biological tools to apply in genomic and proteomic research. For example: development of “porta-injertos” and commercial varieties of grapes resistant to viruses (GFLV) and funguses (Oidio y Botritis cinérea)	• New varieties of seeds. For example, the Kumpa – INIA wheat variety (winter bread) and new “premium” vegetables (raw material with outstanding quality and quantity of proteins, fatty acids, soluble fiber, antioxidants) through biotechnology based on genomics and bioinformatics (better adaptation to local environmental conditions: water and saline stress) • Renewed procedures for sowing and precision agriculture techniques
Technology services	_____	_____

Source: own elaboration

Table 11: R&D efforts and innovative outputs of advanced innovators

Firm	**Monsanto**	**Sygenta**
Main technological assets	•Genes from the corporation •Licences varieties from domestic firms	•Genes from the corporation •Licences varieties from domestic firms
R&D supporting efforts	•Molecular markers •Culture tissue •Selective breeding •Conventional breeding	•Molecular markers •Culture tissue •Selective breeding •Conventional breeding
Patents	_____	_____
Registered varieties per year	**N/A**	37
Main Innovations in the local context	•Maize with greater nutritional value and better texture of grains.	• Maize with Bt11 which is simultaneously Bt and resistant to the herbicide gluphosinate of ammonium.
Technology services	_____	_____

Source: own elaboration

Table 12: R&D efforts and innovative outputs of intermediate innovators

Firm	**Sursem**	**Coodetec**
Main technological assets	•Licences of genes from MNCs •Own germplasm	•Licences of genes from MNCs •Own germplasm
R&D supporting efforts	•Molecular markers •Culture tissue •Selective breeding •Conventional breeding	•Molecular markers •Culture tissue •Selective breeding •Conventional breeding
Patents	_____	_____
Registered varieties per year	8	13

Main Innovations in the local context	• New soybean variety: BtRR2 resistant to lepidopteros and gliphosate. RR2 has outstanding performance compared with the previous gen RR1.	• 13 new transgenic cultivars • System for the handling of "buva" resistant in soy production
Technology services	_____	_____

Source: own elaboration

3.4) Innovative efforts

In this section we analyse the efforts implemented by each firm to reach these levels of capabilities. We organize the evidence as follow. First, we describe the internal learning mechanisms implemented to develop capabilities inside the firm. Second, we consider the external learning mechanisms in combination with the distributed capabilities. Both dimensions allow us identifying different ways in which firms access or use technologies and knowledge available outside their boundaries. The internal mechanisms are those implemented inside the company, according with the list of possible mechanisms described in Table 2. The external mechanisms are those applied by the firm interactively with other actors who can be from the country where the organization is located or from overseas. Regarding distributed capabilities we classify them considering a matrix of relationships with four dimensions: domestic, international, private and public. The objective is to describe the exchanges of knowledge carried out by each company with different actors (other firms, universities, institutes research, suppliers, chambers, etc.) for the development of their technological capabilities.

3.4.1) Internal learning mechanisms

Internal learning mechanisms include: internal training, operational experimentation, engineering and design experimentation, R&D experimentation, knowledge sharing or socialization, knowledge codification.

All firms studied utilised all the internal learning mechanisms evaluated, regardless of the level of technological capability achieved. In order words, the set of internal learning mechanisms evaluated here (included in Table 2) should be considered the minimum threshold of learning efforts that firms must implement to be able to operate in the seed industry, independently of the level of capability (world leading, advanced or intermediate levels). The only distinction we observed between firms with different levels of capability was regarding the intensity in the use. The more advanced firms, in world leading positions have engaged in substantial efforts to increase the intensity of use of all mechanisms, but particularly: internal training, R&D experimentation, knowledge sharing and socialization and knowledge codification. Firms in less advanced levels were more passive in this respect. As a general observation among all the firms, the less used mechanisms was engineering and design experimentation.

In the Annex III we provide illustrative examples for each firm grouped by level of reached capabilities with the information collected in the fieldwork.

3.4.2) External learning mechanisms and distributed capabilities

As explained in the framework, in Section 2, firms do not only build up and accumulate innovative capabilities through internal learning processes. They also put substantial efforts to acquire knowledge which is outside the firm (in distributed knowledge or capabilities) or to develop new knowledge together with external partners.

Differently to the case of internal learning mechanisms, in the case of external ones there are substantial differences across firms with different level of capabilities. In particular, we could observe three main differences in the pattern of external learning and use of distributed capabilities between world leaders (WLs) and pointing to WLs (though to a lesser extent), and the rest:

1) **In the number**: world leaders (and firms pointing to world leaders), in general, engage in a larger number of external learning mechanisms than the rest, and they interact with a higher number of actors, doing so for all activities of the firm. See Graphs 4 and 5 for a visual overview[25] and Table 16, in Annex 4 for a description of the main learning mechanisms used by each firm in key selected innovations.

2) **In the scope**: World leaders (and firms pointing to world leaders though less than the world leaders) interact with a higher diversity of actors including both public and private actors, and locals and foreigners. Also, as replicating the recommendations of innovation manuals, they tend to perform their main innovation tasks and learning efforts closely interacting with the three main sources of knowledge for innovation:
    a. Users: multipliers, farmers and/or trading firms
    b. Knowledge institutions: universities and public research institutes
    c. Other firms in the sector: owners of biotechnological events, and of varieties

In the case of Bioceres and Biofrutales, they have both been directly created as initiatives to connect local users of seeds with the local scientific infrastructure. This assures permanent close learning interactions with these two key sources of distributed capabilities: users and the knowledge base. Bioceres also works closely with international companies such as Advanta (India) and SemBioSys (Canada), which assures that the views of other firms are brought into the innovation process as well.

Nidera, is an initiative of a crop trading company which again assures that the views of users are permanently incorporated in the innovation processes, via different mechanisms described by the firms such periodic meetings. The company also develops its main innovations via R&D joint ventures with foreign companies (a good example is provided by the Clearfield Plus Sunflower, which was developed via a joint venture with Basf), and is actively involved in the scientific community via publications,

[25] These graphs show a comparison among the three world leader firms in terms of their linkages with other actors classified in a matrix that considered four dimensions: private – domestic, public domestic, private - international and public international. The direction of the arrows indicates if the knowledge is provided or received by the firm and in those cases of bi-directional arrows there is a knowledge feedback between the firm and its partner.

conferences, and with several Universities in teaching programmes (e.g. the University of Rosario and Córdoba), (see Table 16 in Annex IV).

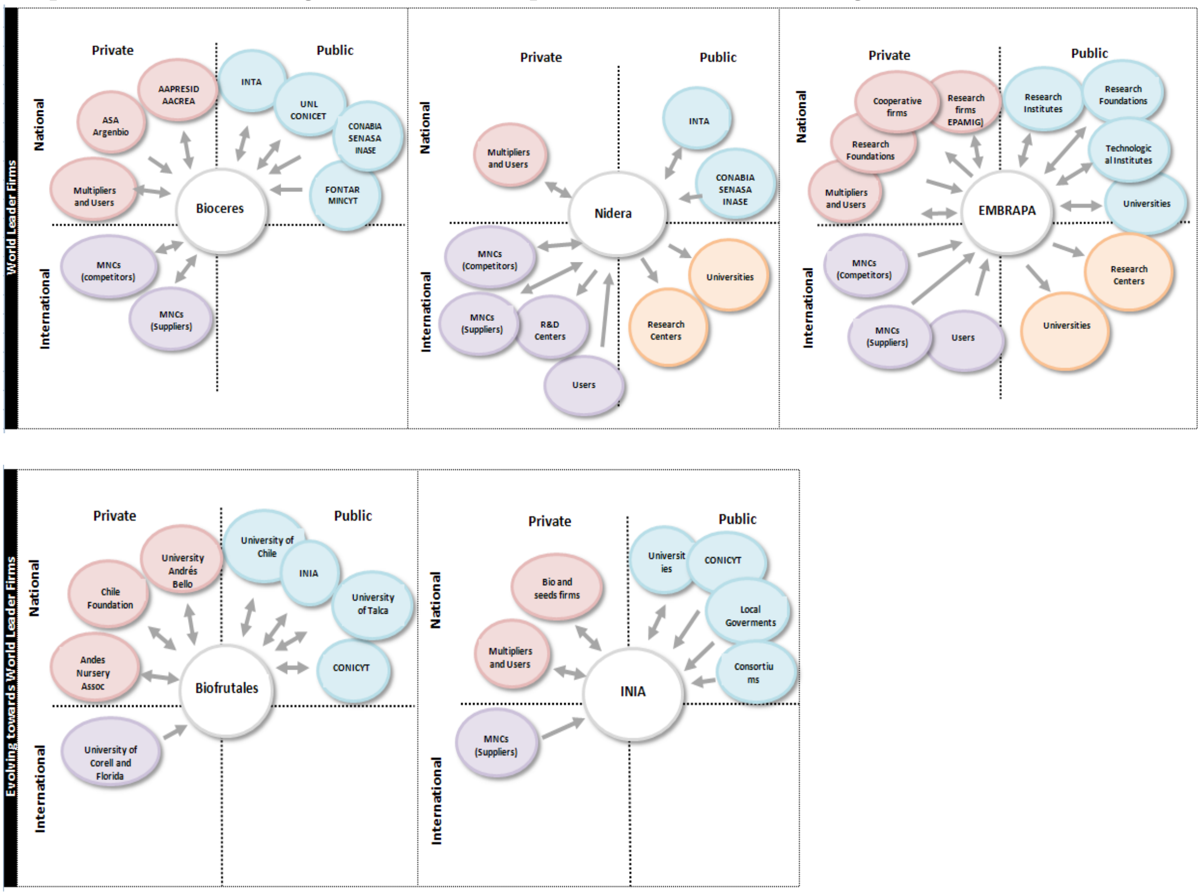
Finally, Embrapa and INIA are agricultural research institutions which count with well-developed extension systems that connect them with farmers and users. Their condition of public research institutions also assures that they are well connected to the public research infrastructure of Brazil and Chile through formal and informal agreements (see Table 16). In the case of Embrapa they have even open a research unit abroad to be able to access scientific knowledge coming from central countries. They have multiple agreements with foreign and domestic firms to develop seeds, such as the agreement between Embrapa and Monsanto to develop Soybean with Bt RR2 gen, or the agreement between INIA and Nordsaat (Germany) to develop new varieties of wheat (see Table 16 in Annex IV).

3) **In the type**: World leaders and firms pointing to world leaders use more advanced forms of co-operation, such as joint R&D programmes, which involve bi-directional flows of knowledge. They are also often engaged, via these interactions, in the creation of new knowledge as well as in the use of existing knowledge.

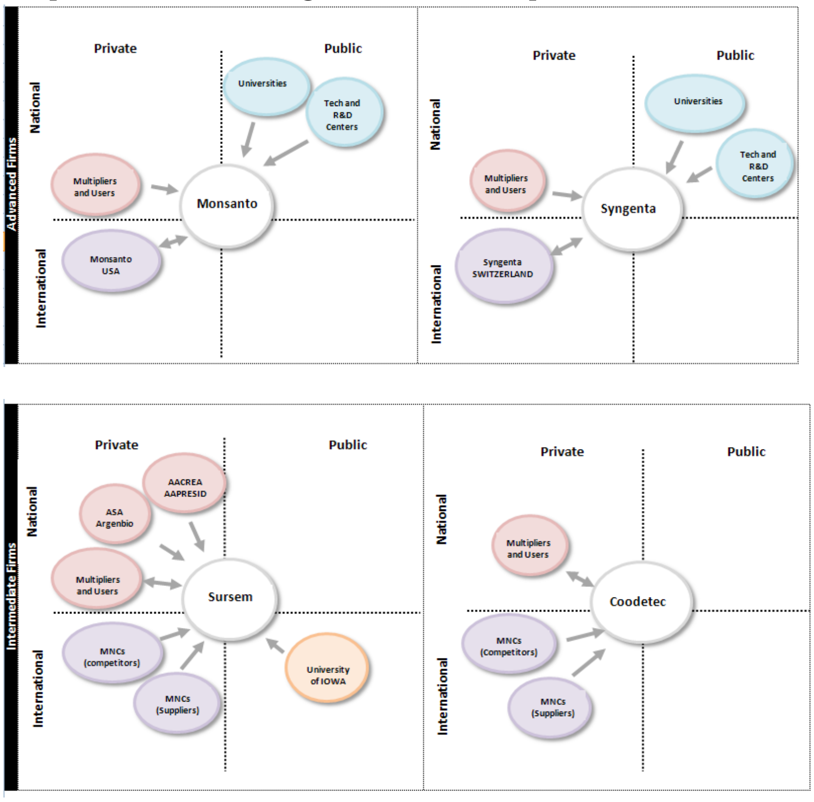
Less advanced firms, on the contrary, mostly interact with competitors and users, using less advanced forms of co-operation, such as licensing, and they do not engage in interactions to create new knowledge. They are interested in taping into existing knowledge.

In the case of MNCs subsidiaries they build partnerships with domestic firms to adapt their products to local environmental conditions. In the case of domestic firms, they mostly work in partnership with MNC subsidiaries to incorporate the genes of their corporations.

Graph 4: External learning and distributed capabilities in WL and evolving towards WL firms



Graph 5: External learning and distributed capabilities in advanced and intermediate firms



Source: own elaboration

4. FINAL REMARKS

We explore technological capabilities in the seed industry in Argentina, Brazil and Chile. These countries are world leading producers of agricultural products, and have pioneered the use of modern technologies in agriculture. An obvious question from a development point of view is: Are developing in parallel the industries that supply this sector which are knowledge intensive, such as seeds. Our analysis in this paper allows us to respond yes. We found that the agricultural sector in Argentina, Brazil and Chile is not only opening opportunities for innovation in the seed sector. The sector is also engaging itself in innovation in the seed industry through several initiatives of farmers. In fact, among the most innovative ventures analysed by our study across countries, are two ventures of farmers, which developed strong links with the local research infrastructure to produce knowledge useful to be used in the development of high tech, highly competitive seeds adapted to the local contexts.

Second, contradicting most expectations we found that domestic firms in the region are moving into world leading positions (they are doing R&D in genomics, in second wave GM, and opening new directions for innovation in the sector). On the contrary, the MNCs subsidiaries interviewed are in less advanced positions, since they draw most of their technological assets from their corporations and are doing very little innovation in the region. Third, movements into world leading positions are not all related to the use of transgenesis for the improvement of seeds. The more advanced firms, in effect, in responding to the new opportunities are directing their innovative efforts in more than one direction, including advanced ways of conventional breeding and non transgenic genetic modification. These face less regulatory restrictions, and are more adequate for certain types of seeds such as fruits and vegetables. Fourth, all firms in the seed industry, independently of the level of capability, perform all forms of internal learning mechanisms, including training, operational experimentation, R&D experimentation, knowledge sharing or socialization, and knowledge codification. They are therefore the minimum threshold to remain in this industry. However, only the more advanced firms deploy certain patterns of external learning mechanisms. All their main innovations include at the same time users (farmers), the knowledge base (researchers in universities) and other seed industries. Also, they do not tap into existing knowledge they create new knowledge, often registered in publications and patents, via complex interactive joint R&D projects with users, universities and other firms, in the same country or even abroad.

There are significant differences across countries regarding capability and structure. Regarding structure, in Argentina, the industry is much more dominated by private companies, both domestic and MNCs, than Brazil and Chile. Private companies carry out most investments in R&D and register most varieties. In Brazil this leading role is played by EMBRAPA (the public research institution linked to the agricultural sector), who seems to be taking advantage of its position as a regulator, to locate itself as an intermediary between the MNCs and the domestic market. In Chile the situation differs according to the market that is served, MNCs dominate the market for exports, that can use GM, while the INIA (the public research institution linked to the agricultural sector) has a leading role in the development of seeds for domestic consume, most for fruits and vegetables.

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ANNEXES

ANNEX I: Patent description by country: class 800

Table 13. Argentina - Patent Class 800

#	Class	Description	Year	Asignee	Co-authored international
1	7968773	Tomato planta having higher levels of resistance to botrytis	2011	Monsanto Netherlands	6 - Netherlands Argentina
2	7875777	Plants and seeds of corn variaty CV078625	2011	Monsanto USA	2 - USA
3	7807882	Herbicide-resistant sunflower plants, polynucleotides encoding herbicide-resistant acetohydroxyacid synthase large subunit proteins, and methods of use	2010	Basf Netherlands and Advanta Netherlands	Only Argentinean
4	7804001	Plants and seeds of corn variety CV476579	2010	Monsanto (USA)	Only Argentinean
5	7674955	Transcription factor gene induced by water deficit conditions and abscisic acid from Helianthus annuus, promoter and transgenic plants	2010	Bioceres, S.A. (Rosario, Santa Fe, AR)	Only Argentinean
6	7674954	DNA constructs that contain Helianthus annuus Hahb-10 gene coding sequence, method for generating plants with a shortened life cycle and a high tolerance to herbicidal compounds and transgenic plants with that sequence	2010	Universidad Nacional del Litoral (Santa Fe, AR), Conicet and Bioceres	Only Argentinean
7	7632984	Modulation of flowering time by the pft1 locus	2009	The Salk Institute for Biological Studies (La Jolla, CA)	1- USA
8	7605313	Plants and seeds of corn variety CV590239	2009	Monsanto	Only Argentinean
9	7598368	COX5c-1 gene intron for increasing expression level in cassettes, plant cells and transgenic plants	2009	Universidad Nacional del Litoral (Santa Fe, AR), Conicet and Bioceres	Only Argentinean
10	7566822	Plants and seeds of corn variety CV256816	2009	Monsanto	Only Argentinean
11	7547826	Plants and seeds of corn variety CV619952	2009	Monsanto	1- USA
12	7518044	Plants and seeds of corn variety CV164272	2009	Monsanto	Only Argentinean
13	7514612	Plants and seeds of corn variety CV593904	2009	Monsanto	Only Argentinean
14	7488873	Plants and seeds of corn variety I291336	2009	Monsanto	1- USA
15	7473829	Plants and seeds of corn variety I539440	2009	Monsanto	1- USA
16	7427489	Screening assay to identify modulators of the sleep/wake cycle	2008	The Scripps Research Institute (La Jolla, CA) and IRM (Hamilton)	4 - USA
17	7368642	Inbred corn line G06-NP2743	2008	Syngenta	Only Argentinean
18	7335822	Plants and seeds of corn variety I211986	2008	Monsanto	2 USA
19	7326834	Inbred corn line G06-NP2744	2008	Syngenta	Only Argentinean

20	7321085	Plants and seeds of corn variety I211988	2008	Monsanto	1 - USA
21	7307200	Soybean	2007	Dairyland Seed Co., Inc. (West Bend, WI)	1- USA
22	7301081	Plants and seeds of corn variety I059952	2007		2 - USA
23	7301074	Soybean	2007	Dairyland Seed Co., Inc. (West Bend, WI)	1- USA
24	7297842	Soybean	2007	Dairyland Seed Co., Inc. (West Bend, WI)	1- USA
25	7205458	Soybean cultivar 4N2V74028	2007	Nidera	Only Argentinean
26	7199288	Soybean cultivar 4N0S63222	2007	Nidera	Only Argentinean
27	7183468	Soybean cultivar 4N2V55022	2007	Nidera	Only Argentinean
28	6982365	Soybean cultivar S56-D7	2006	Syngenta	3 - Brazil
29	6949697	Soybean cultivar S52-U3	2005	Syngenta	3-Brazil
30	6781034	Stress tolerant plants	2004	Plant Bioscience Limited (Norwich, GB)	Only Argentinean
31	6166305	Inbred sunflower line PHA207	2000	Pioneer	Only Argentinean

Table 14. Brazil - Patent Class 800

#	Class	Description	Year	Asignee	Co-authored international
1	7956174	Constitutive promoters from poplar and uses thereof	2011	Allellyx SA	Only Brazilian
2	7943339	Isolated nucleic acid molecules from the genome of citrus leprosis virus and uses thereof	2011	Allellyx SA	Only Brazilian
3	7910810	Soybean variety XB81H09	2011	Pioneer	Only Brazilian
4	7902425	Plants having changed development and a method for making the same	2011	Cropdesign N.V. (Zwijnaarade, BE), Universidade Federal Do Rio De Janeiro	Only Brazilian
5	7847165	Tobacco cultivar AOB 175	2010	Alliance One International, Inc. (Morrisville, CA)	Only Brazilian
6	7847164	Tobacco cultivar AOB 171	2010	Alliance One International, Inc. (Morrisville, CA)	Only Brazilian
7	7847163	Tobacco cultivar AOB 176	2010	Alliance One International, Inc. (Morrisville, CA)	Only Brazilian
8	7790967	Inbred corn line BS112	2010	Agrigenetics, Inc. (Indianapolis, IN)	Only Brazilian
9	7750212	Cotton variety 04P011	2010	Monsanto	Only Brazilian

10	7732664	Genes associated to sucrose content	2010	Universidade de Sao Paulo, Universidade Estadual de Campinas - Fundacao de Amparo a Pesquisa do Estado de Sao Paulo - Fapesp., Centro de Tecnologia Canavieira, Central de Alcool Lucelia Ltda	Only Brazilian
11	7709707	Inbred corn line BS315	2010	Dow AgroSciences	Only Brazilian
12	7709706	Cotton variety 04P024	2010	Monsanto	Only Brazilian
13	7667106	Tobacco cultivar `AOB 175`	2010	Alliance One International, Inc. (Morrisville, CA)	Only Brazilian
14	7667105	Tobacco cultivar `AOB 176`	2010	Alliance One International, Inc. (Morrisville, CA)	Only Brazilian
15	7667104	Tobacco cultivar `AOB 171`	2010	Alliance One International, Inc. (Morrisville, CA)	Only Brazilian
16	7665472	Tobacco cultivar AOB 175 and products therefrom	2010	Alliance One International, Inc. (Morrisville, CA)	Only Brazilian
17	7665471	Tobacco cultivar AOB 171 and products therefrom	2010	Alliance One International, Inc. (Morrisville, CA)	Only Brazilian
18	7665470	Tobacco cultivar AOB 176 and products therefrom	2010	Alliance One International, Inc. (Morrisville, CA)	Only Brazilian
19	7622635	Method of increasing yield in plants	2010	CropDesign N.V. (Gent, BE)	3- Beligica
20	7582809	Sorghum aluminum tolerance gene, SbMATE	2009	The United States of America as represented by the Secretary of Agriculture (Washington, DC), Embrapa	6- USA
21	7566819	Soybean variety 98Y11	2009	Pioneer	Only Brazilian
22	7553668	Papaya ringspot virus genes	2009	Cornell Research Foundation, Inc. (Ithaca, NY)	11- USA, India, Taiwan
23	7381865	Soybean Variety 98R31	2008	Pioneer	Only Brazilian
24	7238858	Coffee plant with reduced .alpha.-D-galactosidase activity	2007	Nestec SA	3-France
25	7186889	Method for genetic transformation of woody trees	2007	Suzano Bahia Sul Papel e Celulose S.A. (Bahia, BR)	Only Brazilian
26	7173173	Inbred maize line PH0R8	2007	Pioneer	Only Brazilian

27	7164066	Inbred maize line PH26N	2007	Pioneer	Only Brazilian
28	7078586	Papaya ringspot virus genes	2006	Cornell Research Foundation, Inc. (Ithaca, NY)	11- USA, India, Taiwan
29	6982365	Soybean cultivar S56-D7	2006	Syngenta	3 - Argentina
30	6949697	Soybean cultivar S52-U3	2005	Syngenta	3 - Argentina
31	6822139	Modulation of storage organs	2004	Advanta	3 - Netherlands and France
32	6765132	Inbred maize line PH26N	2004	Pioneer	Only Brazilian
33	6753458	Process for obtaining transgenic leguminous plants (leguminosae) containing exogenous DNA	2004	Embrapa	Only Brazilian
34	6717036	Inbred maize line Ph0R8	2004	Pioneer	Only Brazilian
35	6664447	Tomato gene.Sw-5 conferring resistance to Tospoviruses	2003	Cornell Research Foundation, Inc. (Ithaca, NY)	1 - USA
36	6239332	Constructs and methods for enhancing protein levels in photosynthetic organisms	2001	Queen's University at Kingston (Kingston, CA)	2- USA and Spain
37	6063991	Soybean cultivar S80-J2	2000	Novartis	Only Brazilian
38	6054634	Methods for within family selection in woody perennials using genetic markers	2000	North Caroline Stata University	3 - USA
39	6040501	Soybean cultivar B630518RR	2000	Novartis	Only Brazilian
40	6011198	Constructs and methods for enhancing protein levels in photosynthetic organisms	2000	Queen's University at Kingston (Kingston, CA)	2- USA and Spain
41	5908978	Methods for within family selection of disease resistance in woody perennials using genetic markers	2000	North Caroline Stata University	6 - USA
42	5877402	DNA constructs and methods for stably transforming plastids of multicellular plants and expressing recombinant proteins therein	1999	Rutgers, The State University of New Jersey (New Brunswick, NJ)	6 - USA
43	5767374	Plants with modified flowers seeds or embryos	1998	Plant Genetic Systems, N.V. (Ghent, BE)	5- Belgium
44	5633441	Plants with genetic female sterility	1997	Plant Genetic Systems, N.V. (Ghent, BE)	5- Belgium
45	5589615	Process for the production of transgenic plants with increased nutritional value via the expression of modified 2S storage albumins	1996	Plant Genetic Systems, N.V. (Ghent, BE)	5- Belgium
46	5196636	High yield sweet corn hybrid	1993	DNA Plant Technology Corporation (Cinnaminson, NJ)	3- USA

Table 15. Chile - Patent Class 800

#	Class	Description	Year	Asignee	Co-authored international
1	7994397	Method to produce sterile male flowers and partenocarpic fruits by genetic silencing, associated sequences and vectors containing said sequences	2011	Pontificia Universidad Catolica de Chile (Santiago, CL)	Only Chile
2	7273931	Plant Promoter	2007	Temuco, IX Region Chile, CL	Only Chile

ANNEX II: Brief history of companies

II.1) Brief history of the companies evolving world leading

Biofrutales

Biofrutales was created in 2006 as a result of the Associated Research Programme conducted by The National Scientific and Technological Research Council (CONICYT). The objective of the Programme was to promote the association among different agents involved in the creation, development and commercialization of new technologies.

Currently the firm is a Consortium integrated by three main groups of agents. The first group consists on entities that provide the scientific capabilities, such as: Foundation of Chile, University of Chile, University Andrés Bello, University of Talca, University Federico Santa Maria, Institute of Agricultural Research (INIA). The second group is formed by private companies that provide the scaling up and positioning capabilities of new technologies. These companies have export orientation, so all the new products developed by Biofrutales aims at international market. The member companies are: Andes Nurserey Association, Viveros El Tambo, Univiveros, Viveros fife Agricultural Brown, Vivero Los Olmos. Finally, the third group is formed by the Fruit Producers Federation of Chile (FEDEFRUTA) which acts as an intermediary between private and public sectors, along with promotional work for the company.

The model business is based on intellectual property agreements among the partners. Biofrutales licenses the new products developed by the technological agents of the Consortium. In turn, the company sub-license to the distributors who end up placing the product into the market and paying royalties to Biofrutales.

The main lines developed by the firm are oriented towards: 1) generation of new varieties using breeding techniques in grapes, peaches and nectarines, and cherries; 2) generation of new varieties through genetic transformation in grapes, plums, peaches and cherries; and 3) generation of biotechnological tools (genomics). They are also working on new developments such as two novelties in grapes and the first peach genetically modified.
Currently, among the new developments of products, which are in pre-commercial stage, are two new varieties of grapes and the first genetically modified peaches.

INIA

The Institute of Agricultural Research (INIA) was born in 1964 within the Ministry of Agriculture. The institute was created by an association of a group of entities specialized in research, development and innovation, such as: 1) The Development Institute (INDAP), 2) The Development Corporation (CORFO), 3) The University of Chile (UCh), 4) The Pontifical Catholic University of Chile (PUC), and 5) The University of Concepción (UdeC).

The main aim of INIA is to transfer technology through products and services that can be used as inputs in the agricultural field. The transference can be implemented through a set of different policies, ranging from training to carrying out analysis to diagnose and recommend solutions for a wide range of subjects (fertilization of fruit trees and crops or detection of diseases, animal nutrition and quality standards of industrial products). For doing so, the institution focused its efforts in applied research and development of basic knowledge. These activities are conducted not only endogenously but also through linkages with other partners from Chile and abroad. INIA currently is present in the whole country through its regional centers, allowing the development of cutting-edge research focused on the economic needs of sectors in the region.

II.2) Brief history of the companies in advanced level

Monsanto Chile

Monsanto started its operations in Chile in 1993 focused on seed production for export. Its operations include the sale of agricultural inputs and the multiplication of seeds that are purchased by business units in other countries (e.g. USA and Argentina). The local production of Monsanto corresponds to 70% of maize, 28% of soybeans and 2% of rapeseed. It is currently the second largest exporter of seeds with 14% of total seed exported.

Similarly to what happened in other countries, from the 2000s the operation of Monsanto has involved the incorporation of several national and international companies working in the agricultural sector in Chile. The first partnership signed by Monsanto in Chile was with Arysta LifeScience, a Chilean company founded in 1978. In 1994 Arysta established a joint venture with Monsanto, in a equity participation of 50% for each company, creating the brand Moviagro. Then, in 2001 Monsanto acquired the remaining shares, creating Arysta Moviagro. Among the main services, the company provides disinfection of seeds and pest monitoring. One of the acquisitions made in the world by Monsanto, that had an impact on the Chilean agricultural market was the company Seminis, which was an American company specializing in the development and production of seeds of fruits and vegetables with operations in the U.S., Europe and Latin America. Its operation began in Chile in 1975 in partnership with Peto Seed Co. Chile for the production of vegetable seeds for both the local market as to the export (USA). In 2005 the company becomes a subsidiary of Mosanto in Chile.

In 2007, Monsanto and the Ministry of Agriculture of Chile announced that Monsanto was chosen to plant up 20,000 hectares of transgenic soybean for seed production. Monsanto is establishing in Chile a new technological platform for developing maize traits and germoplasm. Its experimental facilities are located in metropolitan regions, Arica and Parinacota, O'Higgins and Maule.

Syngenta Brazil

Syngenta is a company founded in Switzerland in 2000 from the merger of Novartis Agribusiness and Zeneca Astra, specialize in products and services to agribusiness in 90 worldwide countries. In Brazil, Syngenta is dedicated to the production of soybeans, maize, vegetables and flowers as well as agricultural inputs such as fungicides, herbicides, insecticides and seed treatment.

The main R&D center of Syngenta in Brazil is in Uberlândia, in the state of Minas Gerais, carrying genetic analysis of plants through molecular markers and developing corn hybrids and soybean varieties adapted to the needs of Brazilian farmers. Along with the research center located in Itatiba, in the state of Sao Paulo, they conduct research focused on control of pests, weeds and invasive plants, and generation of more drought-tolerant seeds with greater nutrient absorption. The division of seeds (Syngenta Seeds) was the first company in Brazil to receive the certificate of quality issued by Biosecurity National Technical Commission on Biosecurity (CTN-Bio). This certificate allowed Syngenta to develop research on major crops (corn, soybeans, cotton and other) genetically modified.

The company has three seed processing units located in Formosa, in the state of Goias, Ituiutaba in Minas Gerais and Matão in Sao Paulo. These units have quality control laboratories to ensure the physiological pattern and vigor of seeds, and make packaging processes which preserve the seeds properly until planting time.

Syngenta is a major producer of agrochemicals in Brazil, through its Division of Crop Protection. In addition to inputs for agricultural production, the firm develops special services such as Syntinela - monitoring program of soybean rust. The division of Crop Protection has a factory in Paulinia, in the state of Sao Paulo, containing an analytical laboratory for chemical residues, and experimental units located in Uberlândia (Minas Gerais) and another in Holambra (Sao Paulo).

II.3) Brief history of the companies in intermediate level.

Sursem

Sursem is a joint venture between two Argentine SME domestic firms created during the ´90s. The joint venture took place in 2008 when a Foreign Investment Fund (Pampa Management which has a representation in Argentina through Pampa Capital) invested in and re-structured the firm. From 2008 and 2011 the Fund invested around 35 million dollars in the company.

The investment of Pampa Fund was aimed at strengthening and increasing of the genetic research programs (based on conventional plant breeding), expanding its sales network, increasing the number of employees and exports. Until 2007, before the arrival of the new owners, the firm had an annual turnover between 7 and 8 million dollars. By contrast, in 2010 they rose to $ 25 million dollars.

The firm is located in the cities of Pergamino and Maciel (in the Province of Santa Fe in Argentina) where it has areas dedicated to research, breeding, laboratories, commercialization and administration. There is also a processing plant in the city of Gahan in the same province. Sursem employs 110 people.

The market share by product is around 2,5% in soybean, 9,5% in wheat, 4% in maize and 6% in sunflower. There are projections according to which the efforts of the firm are oriented to reach 15% in varieties and 10% in maize. Sursem exports soybean and sunflower to Paraguay and soybean to Uruguay. The commercial strategy is mostly based on networks of multipliers (multiplicadores) and distribution.

This company depends heavily on the supplier of biotechnological events. For instance, Sursem buy the genes to be applied to its breeding activities, mostly to Monsanto and Syngenta. In this regard, one of the interviewee explained: “Nowadays, the firm produces only 25% of its own germplasm and has to be provided by all the biotech events and the rest of germplasm that is needed. The short term objective is to achieve the development of all our own germplasm. Development of biotech events is a long term objective, due to it needs a huge investment in equipment, human resources and basic science, among others”.

Regarding comptetition, it is classified according to grain markets and segments. The main competitors in wheat are Nidera, Buck and Don Mario; in soybean are Nidera and Don Mario; in maize Monsanto, Nidera, Syngenta. As it was state by one of the interviewees, “Sursem distinguished itself from the competitors because it is a horizontal enterprise and decisions can be taken fastest with high flexibility”.

Coodetec

The company was established in 1974 when the Organization of Cooperatives of Parana State created its Research Department for conducting research on hybrids and new varieties. In 1995, the cooperatives decided to extend the project and created the Central Cooperative of Agricultural Research (Coodetec). The firm is focused on the genetic advancement of the three main crops in Brazil: maize, soybean and wheat.

In 2008 Coodetec and Dow AgroSciences LLC established a partnership in which Coodetec transferred its new unit at Paracatu (MG). The transaction included an agreement of technological collaboration. Coodetec also received technology and germplasm developed by Dow AgroSciences to extend its portfolio of hybrids.

ANNEX III: Illustrative examples of learning mechanisms

III.1) Illustrative examples of internal learning mechanisms (ILM) implemented by firms

ILM in World Leaders firms

As it was previously explained, this group of firms have implemented more intensively four types of ILM: knowledge codification, knowledge sharing / socialization, learning from formal R&D experimentation and internal training. Following, we present illustrative evidence by company that was obtained in the fieldwork.

Bioceres has implemented internal mechanisms since it was created in 2001. The outstanding ones are the establishment of its own R&D Center, INDEAR and formal R&D experimentation which is conducted in the different technological platforms of the firm such as Gene Discovery and Molecular Farming, among others. Other mechanisms are: internal training; knowledge codification; knowledge sharing and socialization (there are regular meetings between Board of INDEAR and Board of BIOCERES, formal and informal meetings between tech platform chiefs and commercial agronomics engineers, internal seminars in INDEAR).

Nidera has continuously implemented internal learning mechanisms such us internal training, knowledge codification and socialization, learning from formal R&D experimentation. The interviewee explained that "the organizational structure of the firm is horizontal and flexible. Interactions vary from formally arranged meeting to absolutely informal ones". He illustrates saying that "from the exchanges among a couple of researchers, the soybean breeder and two "mates" can come up outstanding technological projects. If the idea is good, we have the freedom to move in that direction with the support of the CEOs". He also explained that "there is continuous feedback among the commercial area, researchers and breeders. This relationship is essential since it allows the inspiration of the new objectives of the projects. We take into account a double source of information, the one that comes from the agriculture farmers´ needs, and the other is based on the evolution of the agronomic environment for the development of new products".

In the case of **Embrapa**, a couple of interviewees stated that "the development and adaptation of genes and the generation of our own germplasm is only feasible by continuous and intensive training programmes, R&D experimentation and exchange of knowledge among different strategic areas of the firm and finally, it is crucial the codification through statistics , protocols, algorithms and similar procedures that constitutes the memory of the projects carried out by interdisciplinary research and technological teams".

ILM in evolving to World Leaders firms

Firms that belong to this group have also implemented several types of internal learning mechanisms. However, the use of some of them has been less intensive than in the case of world leaders firms. In the case of **INIA**, the interviewee illustrated technology transfer activities (which are the main objective pursued by the firm) based on formal R&D experimentation as well as knowledge sharing and codification, and explained that engineering and design experimentation is the less frequent used mechanisms.

Despite being younger than INIA, **Biofrutales** follows similar patterns. Regarding this topic of the interview, the CEO highlighted that the origin of the firm as private – public partnership was successful because of the several practices based on knowledge sharing / socialization as well as knowledge codification and R&D experimentation. Apart from that, as example of the more recent practice, Biofrutales fostered internal training activities through several scholarship programmes.

ILM in advanced firms

This group of firms also implemented almost all the internal learning mechanisms, mainly internal training and R&D experimentation,. However, as they are subsidiaries of MNCs the exchange of knowledge is mostly dependent of the research programmes established by their respective Headquarters located abroad. That is, both firms, **Monsanto** (in Chile) as well as **Syngenta** (in Brazil) did not generate technological externalities that benefit the local agents in terms of knowledge sharing and socialization and knowledge codification.

ILM in intermediate firms

In the case of **Sursem**, we observed that this firm is distinguished by the implementation of internal training programmes, knowledge codification and several practices that involved formal and informal exchanges of knowledge. For instance, internal training programmes are focused on technical, organizational, operational, and managerial activities which are taken by different areas of the firm such as Research Programmes, Development, Marketing, Commercialization and Production. Besides, training programmes are jointly implemented with R&D and operational experimentation and testing in local agricultural sites which depend heavily on the specific characteristics of the different Research Programmes (there is one programme per cultivars: soybean, wheat, maize, sunflower). In that line, each Research Programme undertakes efforts to document activities, procedures, instructions, routines, and standards used in diverse operational processes, as well as experimentation results and complex knowledge developed within and across areas. According to these practices, the firm is involved in knowledge socialization and codification. Beside, there are communicational mechanisms through formal and informal meetings, workshops, seminars, conversations and social interactions (they have schemes for formal product meetings, there are confidential meetings between Research Programmes, CEO and Managers) and interactions in multi-disciplinary and cross-functional teams to exchange knowledge, solve technical problems, identify opportunities needs for innovation.

In the case of **Coodetec**, this private cooperative of farmers has also implemented several internal learning mechanisms and R&D experimentation was the prevailing one.

III.2) External learning mechanisms implemented by firms and institutions

Bioceres

The main technological assests of Bioceres Group are the gen discovery platform and the portfolio of seeds developed under its own germplasm. For the achievement of these assets, the firm was involved in long term R&D projects based on interactions and distributed capabilities with universities and research institutes as well as through continuous agronomic knowledge exchanges with famers and multipliers. These interactions evolved gradually over time by the implementation of several external learning mechanisms such us: exchanges of knowledge with experts that belong to different technological and science fields, searching into specialized sources, active participation in scientific and technical conferences, workshops and specialized meetings, technical assistance, consulting services and license agreements, hiring high skilled human resources (mostly from universities and research institutes but also poaching them from competitors), participation in education and training programmes held in the country and abroad.

In 2001, the main purpose of the firm was to build alliances between the private and public sector, specifically by funding research programmes in agro-biotecnology that were conducted by public research centres and universities. At that moment, the founders of the firms were experts in the production and commercialization of seeds and became aware of their lack of technological capabilities that were needed to introduce science based products into the market. For instance, the starting point of the firm was a technological agreement with INTA (named BIOINTA Programme) according to which the public institution developed wheat seeds and Bioceres sold them into domestic market.

In 2004, Bioceres undertook the first steps in the field of biotechnology developments. The firm held a joint venture agreement with two key partners: Biosidus (a domestic private firm which offered specialised technical assistance and consulting services as the first Argentinean venture in the field of pharmaceutical biotechnology) and CONICET (the National Research Council that promote the formation of high qualified human resources by PhD, Postdoctorate and Master Scholarship Programmes). This public private alliance and the financial support from the National Research Agengy (ANPCyT belonged to the Argentine Ministry of Science and Technology, which conceded low-interest-rates credits to acquire the state-of-the-art infrastructure: building, laboratories, greenhouse and equipments) allowed the creation of INDEAR in 2008 (the R&D Center of Bioceres Group). The Center is focused on genetic engineering, agro-biotechnology science and molecular and breeding technologies. As it was stated by the R&D Manager of the firm "the creation of INDEAR has pursued the development of our own science and technological platform. Moreover, it is our strategy to reduce –and even eliminate- the necessity of buying biotech events from MNCs".

The USPTO has recently granted three invention patents to Bioceres, CONICET and University of Litoral. These developments have been the result of R&D agreements held in 2003 among the firm (which provided the funding resources and agronomic market knowledge), the National Research Council and the University (both institutions with long term expertise in biotechnology based science, in particular genetic engineering and recombinant DNA techniques). The three partners have got the property rights (and will obtained the future royalties from licences) over discoveries that allow increasing the productivity of a wide range of cultivars such us soybean, wheat, maize, sunflower, cotton, among others cultivars and vegetables. The first patent is an enhancer of genes named Hahb4 from which it is possible to obtain transgenic plants resistant to hydride stress and salinity. The second one is COX5c, which is a gene promoter or enhancer and allow increasing the expression level of genes in plant cells. The third is the gen Hahb-10 for the production of transgenic plants (which are characterized by short life cycles and tolerant to oxidative stress).

The introduction of the genes into the market can be done in different ways, such as through the extension or improvement of the germplasm of the firm as well as in the form of exportation of technology. In the first case, the new germplasm allows the development of new seed varieties to be sold in the market. In this line, the Agronomic Engineer from Bioceres explained that the production of new seeds takes a long time (among 5 to 10 years) and commercialization demands strong R&D-based interaction with farmers and multipliers as well as feedback and assistance from agriculture producers. In other words, the successful introduction in the market of these developments is strongly dependant of the interaction among Bioceres and the multipliers and users in order to get feedback knowledge from local conditions and adaptations to soil and climate factors that prevail in different regions or markets where the products are going to be commercialized. Regarding technology exports abroad, Bioceres has already signed a license agreement with Advanta India Ltd according to which the Indian firm will be able to insert the new Hahb4 gen in sorghum, rise, canola and cotton in order to increase the productivity of these cultivars.

Project R&D Leaders from Bioceres and University of Litoral have recently announced that Hahb4 gene was inserted in soybean, maize and sunflower and it is expected an increment of 20% in productivity as well as an increament of 5% in the arable land in the country.

Nidera

Nidera stands out for a wide variety of highly competitive products developed under continuous incorporation of technology. Since the creation of its Seed Unit in the 90s, Nidera has taken advantage of several ways of relationships with different type of agents, particularly from alliances with technological suppliers and strategic interactions with other multinational competitors. Following we describe three examples.

The first occurred in the middle of the 90s when Nidera acquired the Argentine Branch of the competitor Asgrow Seeds (located in USA). With this strategic acquisition, Nidera incorporated two key assets: one of the most advanced development in agro-biotechnology at that moment (the Round Up Resistant –RR- gene designed for seeds to be resistant the herbicide) and a team of large experienced scientists and technicians in the field. Then, Nidera inserted the RR gen into its own germplasm and introduced the OGM soybean that was highly accepted by the majority of agricultural producers in the country.

The second example is regarding the development of the CLEARFIELD (CL) Production System for sunflowers. The starting point of this technology was the R&D and licence agreement held in 2003, between Nidera and BASF (a multinational supplier in the field of agrochemicals). Weed control is often one of the most limiting factors for global sunflower production. The Production System is an innovative agronomic solution that matches carefully selected hybrid seed with custom-designed BASF imidazolinone herbicides. CLHA-Plus makes it easier for seed companies to breed tolerance to BASF imidazolinone herbicides in high-yielding sunflower hybrids. This, combined with the fact that the new gene, CLHA-Plus, was developed in high-performing sunflower germplasm, allowing superior productivity in sunflower hybrids. The R&D jointly investment of Nidera and BASF moved forward with the improved version of CL, named CLEARFIELD PLUS. This technology combines the hybrid Paraiso 1000 CL Plus belonged to Nidera with the resistance to the herbicide Clearsol Plus from BASF. It is a new gene with tolerance to this herbicide. In fact, Nidera modify the gene Ahasl 1 and obtained the mutant Ahas1 1-3. The main difference between the first CL technology and the second one is that the first was applied to wild sunflowers en the USA and the latest one was applied to cultivated sunflowers. Since the introduction in 2003, the CL technology has contributed to move forward with zero tillage techniques in the country (15 to 50%), facilitated the management of parcels of land and improved the cultivar performance (15% in five years).

In third place, Nidera is currently conducting an R&D project with Bayer and Bioagro (both technology suppliers). The objective is to develop a new technology to be applied in founder seed of Nidera during the Campaign 2012. Bayer provides know how in polymers and precise equipments and Bioagro offers the expertise in inoculants. The R&D Manager explained that "the technology offers the possibility of treating each seed with the right amount of product, combining more than four or five active ingredients, fungicides, insecticides and live products such as inoculants or growth promoters".

Apart from the active interactions of Nidera with suppliers and competitors, the firm has invested in education and training programmes and technology transfer projects based on technical assistance and consulting services. For instance, Nidera periodically arrange visits to agronomic production plants located in different regions and foreign countries (such as in Montpellier in France, Gante in Belgium, Gissen in Germany) and send its research teams to take training courses in R&D international organizations, such as The Research Center in Peru (to learn about asexual potatoes), CINIT in Mexico (dedicated to wheat and maize), University of IOWA (dedicated to maize) and University of New York. Since more than a decade, Nidera has maintained genetic engineering exchanges with these organizations. These exchanges allowed the firm being in contact with specialized knowledge sources that contribute to develop or improved continuously the germplasm of the firm. As an example, in 1999 and as a result of R&D agreement with a French seed company, Nidera registered a new variety of wheat, named Baguette 10. It was the first Argentine wheat produced under French germplasm roots. The introduction of Baguette into domestic market revealed an outstanding productivity of the cultivar at that time. Since then Nidera have launched several improvements of Baguette. The most updated one is the new wheat variety Baguette 601 which is a result of continuous R&D efforts applied on the cultivar of interest. According to the Breeder Manager “the productivity of this wheat increased from 2,7 tons per hectare to 9 tons per hectare in the best parcels”.

Nidera also has important knowledge feedbacks with Public Universities in Argentina and Public Research Institutions that belong to CONICET and INTA. In this case, the interchange of knowledge occurs in two main directions, by offering and providing high level of scientific and technology education in the field of agro-biotechnology. On one hand, Nidera trains its researchers in graduate and postgraduate programmes available in Education System in the country; on the other hand, Nidera frequently accepts graduate and postgraduate students that apply to undertake their thesis when the object of study is a cultivar or germaplasm that are under the interest of the company. According to this background, Nidera participates actively in scientific and technical conferences, workshops and meetings through the presentation of lectures and academic papers.

ANNEX IV: External Learning mechanisms

Table 16 below illustrates the main novelties developed by each firm under study. These novelties are the result of strong interactions between the firms and different types of partners. Therefore, we following present: the innovation (in terms of product – process or organizational one), the external agent/s with which the firm has interacted with to conduct the development of the innovation, the external learning mechanism of the interaction, its objective and distributed capabilities.

Table 16: Novelties based interaction (we present one table per firm)

Bioceres	**Novelty Product / Process / Organization**	**External Learning Mechanisms**	**Partner/s Events**
	Three biotechnology events (genes) patented	Research agreements with Universities and Research Institutes	CONICET and the University of Litoral
	Development and commercialization of crops tolerant to drought.	License agreement (export of genes)	Advanta India
	Production of chymosin in safflower plants for the generation of industrial inputs	License agreement (import of technology)	SemBioSys (Canadian firm)
	New seeds varieties	License agreement (acquisition of biotech events) + technical assistance and feedback	MNCs (competitors – suppliers)
	New seeds varieties	Development interactions (technical and commercialization assistance and feedback)	Multipliers and farmers
	Research Programmes by cultivar	Join education and training programmes + active participation in scientific and technical conferences + Searching into specialize knowledge sources	PhDs and masters – Seminars and Congress in the country (Universities, INTA, ASAGIR, MAIZAR, AAPRESID) and abroad For example: Bio 2010 - USA

	Managerial and Researcher Equipment	Hiring expertise + Poach managers from other firms	MNCs (competitors) Universities, CONICET, INTA
	Infrastructure, state of the art equipment, IPR assets	Establishment of R+D facilities	CONICET, Ministry of Science and Technology of Argentina, Roche, Regulatory Bodies.
Nidera	**Novelty Product / Process / Organization**	**External Learning Mechanisms**	**Partner/s** **Events**
	Clearfield Plus Soybean	R&D agreement with competitor	Basf
	New Soybean variety recently launched to the market to be used in the campaign 2012	R&D agreement with competitor	Bayer and Bioagro
	Genetics on sunflower, maize and soybeans	License agreements (export of genetic)	Central Europe, Eastern Europe and Russia (sunflower) and USA and Africa (maize and soybeans).
	New seeds varieties	License agreement (acquisition of biotech events) + technical assistance and feedback	MNCs (competitors – suppliers)
	New seeds varieties	Development interactions (technical and commercialization assistance and feedback)	Multipliers and farmers
	Research Programmes by type of cultivar	Join education and training programmes + active participation in scientific and technical conferences + Searching into specialize knowledge sources	PhDs and masters – Seminars and Congress in the country (Universities, INTA, ASAGIR, MAIZAR, AAPRESID) and abroad (Research Centre of Potatoes in Peru, the CINIT in Mexico dedicate to wheat and maize, IOWA in USA dedicated to maize, University of New York; learning from supplier and technical assistance (such as from Montpellier in France, Gante in Belgium, Gissen in Germany)
	Managerial and Researcher Equipment	Hiring expertise + Poach managers from other firms	MNCs (competitors) For example: hiring a group of researcher from Continental Seed Company Universities and INTA
	Market Trading Technology Strategy	Technical and commercial knowledge	Clients and suppliers
	IPR assets	Technical knowledge	Regulatory bodies
Embrapa	**Novelty Product / Process / Organization**	**External Learning Mechanisms**	**Partner/s** **Events**
	Soybean with Bt RR2 gen	R&D agreement with competitor	Monsanto
	Soybean resistant to herbicides of imidazolinonas	R&D agreement with competitor	Basf
	New seeds varieties Soybeans, beans, corn and other species adapted to the savannah ("Cerrados") and low latitude regions Maize and Sorghum	R+D agreements with University	CGIAR (Centers and national research systems: 75 universities and foundations, 200 public institutions for agricultural research and rural extension, among others)

	developed corn hybrids can promote better adaptation in the field, industrial-quality baking and better disease tolerance		
	Nanostructured materials to develop sensors and biosensors	R+D agreement	National Collaborative Research Network in Nanotechnology Applied to Agribusiness (AGRONANO)
	Virtual Laboratories in Foreign Countries (LABEX)	Monitoring the frontier innovation and scientific knowledge abroad	Research institutions and groups of high and internationally acknowledged excellence
	Work Group in Agro Ecology: inoculation of biological nitrogen fixers for soybean seeds before planting.	Development interactions (technical and commercialization assistance and feedback)	Farmers
Biofrutales	**Novelty Product / Process / Organization**	**External Learning Mechanisms**	**Partner/s Events**
	Development of biotech tools: models, algoritms, bioinformatic and biological tools to apply in genomic and proteomic research. For example: development of “porta-injertos” and commercial varieties of grapes resistant to viruses (GFLV) and funguses (Oidio y Botritis cinérea	R+D agreements with Universities and Research Institutes R+D agreements with suppliers Hiring expertise Active participation in scientific and technical conferences + Searching into specialize knowledge sources	Domestic Universities part of the consortium
INIA	**Novelty Product / Process / Organization**	**External Learning Mechanisms**	**Partner/s Events**
	New variety of wheat Kumpa-INIA (Triticum aestivum L.)	R&D agreement	Nordsaat de Alemania
	New seeds varieties	R+D agreements with Universities and Research Institutes	Universities, CONICYT University of Alberta (CAN); University of Manitoba (CAN); Université de Caen (France); Donald Danforth Plant Science Center (USA).
	New seeds varieties	License agreement (acquisition of biotech events) + technical assistance and feedback	MNCs For example: with Baer Semillas
	New seeds varieties	R&D interactions (technical and commercialization assistance and feedback)	Multipliers and farmers
	Consortiums	Research & Funding Programmes	FONDEF, FONDECYT, FIC, Local Governments
Syngenta	**Novelty Product / Process / Organization**	**External Learning Mechanisms**	**Partner/s Events**

	Germplasm Bank + agreements with local institutions and firms to adapt its seeds to local conditions. Colaborative research with sharing of technical knowledge and infrastructure applied to soy, maize, cotton and sugar cane cultures	Development based interaction with users to adapt technology (seeds and biotech events) to local conditions	Clients: Public institutions, Domestics seed firms, multipliers and farmers
		Development based interactions with universities and research institutes	Instituto Agronômico de Campinas (IAC), Federal University of Viçosa (MG), Federal Universities of Santa Maria (Goiás), Uberlândia and Lavras (MG), Superior School of Agriculture Luiz de Queiroz (ESALQ) .
Monsanto	**Novelty Product / Process / Organization**	**External Learning Mechanisms**	**Partner/s Events**
	Germplasm Bank + Agreements with local institutions and firms to adapt its seeds to local conditions. Colaborative research with sharing of technical knowledge and infrastructure applied to soy, maize, cotton and sugar cane cultures	Development based interaction with users to adapt technology (seeds and biotech events) to local conditions	Clients: Public institutions, Domestics seed firms, multipliers and farmers
		Development based interactions with universities and research institutes	
Sursem	**Novelty Product / Process / Organization**	**External Learning Mechanisms**	**Partner/s Events**
	BtRR2 Soybean	License agreement (acquisition of biotech events) + technical assistance and feedback	Monsanto
	New seeds varieties	License agreement (acquisition of biotech events) + technical assistance and feedback	MNCs (competitors – suppliers) For example: Pioneer, Monsanto, Syngenta
	New seeds varieties	Development interactions (technical and commercialization assistance and feedback)	Multipliers and farmers
	Research Programmes by type of cultivar	Education and training programmes + active participation in scientific and technical conferences + Searching into specialize knowledge sources	PhDs and masters – Seminars and Congress in the country (Universities, INTA, ASAGIR, MAIZAR, AAPRESID) and abroad (University of IOWA and Universities in France, Australia and China).
	Managerial and Researcher Equipment	Hiring expertise + Poach managers from other firms	MNCs (competitors) For example: ex CEO of Monsanto, the new Development and Marketing Director is from Nidera, the Leader of Soybean Research Programme is also from Nidera, there is one professional from Syngenta. Universities
Cood etec	**Novelty Product / Process / Organization**	**External Learning Mechanisms**	**Partner/s Events**

	Acquisition of germplasm to improve the portfolio of hybrids	Licensing agreement with competitor	Dow AgroSciences
	New soybean tolerant to herbicide	Licensing agreement with competitor	Basf

ANNEX V: Patent law by country

Box 2: Patent law
<u>Argentina</u> **Living material:** Argentina's patent law does not consider "any kind of live material or substances already existing in nature" to be patentable (article 6, Law 24.481). **Biological processes:** Argentina's patent law does not consider "biological and genetic material existing in nature or derived therefrom in biological processes associated with animal, plant and human reproduction, including genetic processes applied to the said material that are capable of bringing about the normal, free duplication thereof in the same way as in nature," to be patentable (article 7, Law 24.481).
<u>Brazil</u> **Life forms:** According to Brazilian law, "all or part of living beings, except transgenic microorganisms that satisfy the three requirements of patentability" are not patentable (article 18 of *Brazilian Industrial Property Law*). "For the purposes of this Law, transgenic microorganisms are organisms, except for all or part of plants or animals, that express, by means of direct human intervention in their genetic composition, a characteristic normally not attainable by the species under natural conditions." (article 18 of *Brazilian Industrial Property Law*). **Biological processes:** According to Brazilian law, "all or part of natural living beings and biological materials found in nature, even if isolated therefrom, including the genome or germoplasm of any natural living being, and the natural biological processes" are not patentable (article 10 of *Brazilian Industrial Property Law*).
<u>Chile</u> **Living material - Biological processes – Life forms:** According to article 37 of *Law N^{o} 19.039*, "plants and animals and essentially biological processes for the production of plants and animal […] [,] parts of living beings as found in nature, natural biological processes and biological material found in nature even though isolated therefrom, including genome or germoplasm" are not patentable (South American Report, *supra* note 72 p. 22 – 23).