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KIBS ASSOCIATED TO NATURAL RESOURCE BASED INDUSTRIES:

SEEDS INNOVATION AND REGIONAL PROVIDERS OF THE TECHNOLOGY SERVICES EMBODIED IN SEEDS IN ARGENTINA AND BRAZIL 2000–2014

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Abstract

Argentina and Brazil are world leaders in agriculture; they have expanded production massively recently and have pioneered the adoption of agricultural technology intensive inputs. An important development question is thus: are these countries taking advantage of their position as agricultural leaders, to develop linkages with knowledge intensive providers. This paper explores this question based on the case of seeds innovation in Argentina and Brazil. We focus mainly on the domestic firms that have been successful. We are interested in understanding the R&D strategy of these firms, how do they differ of those implemented by the large MNCs in the sector, the type of innovations they develop, with which kind of capabilities do they develop these innovations, and which are the main challenges they face. The research suggests that there are important opportunities for the development of local innovation and capabilities and the creation of different trajectories of innovation, but also suggests that as firms become more advanced, the policy and business challenges become more significant.

JEL Codes: O13, O33, O38

Keywords: innovation, natural resources, economic development

1. INTRODUCTION

Argentina and Brazil are world leaders in agriculture; they have expanded production massively recently and have pioneered the adoption of agricultural technology intensive inputs. As natural resources (NRs) are becoming more knowledge intensive (Marin et al., 2015) an important development question is if these countries are taking advantage of their position as agricultural leaders, to develop linkages with knowledge intensive providers to this sector. The opportunity to develop knowledge intensive providers linked to NRs is attracting increasing attention of both researchers and policy makers due to the importance of this sector for the diversification of economies with a structure highly concentrated on NRs.

We focus on seeds. Seeds are a key strategic input for agricultural production. It is estimated that up to 50% of increases in agricultural production derives from improved seeds (FA, www.fao.org). Seeds used to be a quasi-natural, quasi-public good, which incorporated limited innovation. However, with the recent changes in science and technology, they are becoming a knowledge-intensive product, embodying several knowledge intensive services. In this paper we are interested in understanding the extent to which the expansion of the agricultural sector in Argentina and Brazil, has created opportunities for advanced forms of domestic innovation in seeds.

Previous studies suggest that domestic enterprises and institutions in the region are playing a central role in the development of seeds innovations in the region (Marin et al., 2015; Marin and Stubrin, 2015). The overall objective of this paper is to analyse the characteristics of domestic firm´s innovation in these two countries. More specifically, we are interested in understanding the share of domestic firms, their R&D strategy, how do they differ of those implemented by the large MNCs in the sector, the type of innovations they develop, with which kind of capabilities do they develop them, and which are the main factor that explain these innovations.

Research on innovation capabilities of firms from developing countries suggests that firms that successfully completed a process of capability building in these type of countries, typically followed a path that starts with the copy and replication of existing technologies developed by firms in advanced countries and, finishes with creative imitation and innovation, when firms from emerging economies start to be able to create completely new things (e.g. Katz 1987; Bell and Pavitt, 1996; Amsden, 2003; Hobday et al., 2004; Kim, 1980; 1991). We explore to what extent this framework is useful to think technological capability building and innovation in NRs and activities linked to NRs.

To perform the analysis we complement quantitative and qualitative evidence. First, to provide a general overview of the evolution of the rate of innovation and the role of domestic firms in innovation, we analyse innovation data based on new plant varieties of soybean, maize, wheat, sunflower, cotton and rice registered in the National Registry of Cultivars (RNC) in Argentina and Brazil. Then, we use evidence of case studies and interviews to key actors to interpret the main trends observed and better understand successful firms´ strategies. We selected the three most successful regional firms (Don Mario/Brasmax, Nidera and Tropical Melhoramento e Genetica (TMG)).

The analysis reveals some interesting patterns and results. First, innovation grew significantly in both countries. Second, it seems that there have been more opportunities for domestic firms´ to develop in Argentina than in Brazil, and in some crops than in others. Third, domestic successful firms have followed a trajectory of capability accumulation clearly different to the one followed by the foreign MNCs. In particular, a common feature of the domestic firms analysed is that they have been successful in serving a particular need of this market, the need for diversity. They have been able to do so, based on a strategy of providing fast response to the changing and diverse demands of farmers of the region. This has allowed them to outcompete MNCs in several markets, which are mostly oriented to deliver patented standardised solutions. We reflect on the implications of these results for theory and policy.

The chapter is structured as follows. In section 2, after this introduction, we present the background of our research in two sub-sections. In the first one, we briefly provide, and discuss, some insights from the innovation literature regarding the understanding of the innovation process in firms from developing countries, and, in the second one, we analyse how innovation takes place specifically in the seeds industry and how this has changed recently creating new opportunities for innovation for firms in developing countries. In Section 3 we describe the data and methodology. In Section 4 we discuss the empirical evidence. This section includes two subsections. In the first one, based on the quantitative data we identify some general patterns about innovation in seeds in Argentina and Brazil. In the second we analyse the cases. We first describe the main features and characteristics of the firms studied and then discuss key aspects of their strategy, research efforts and innovation that explain their success.

2. BACKGROUND OF THE RESEARCH

2.1. Innovation opportunities for developing country firms

A vast body of research has focused on trying to understand how firms from developing countries develop technological capabilities (e.g. Katz 1987, Bell and Pavitt 1996, Amsden 2003, Hobday et al 2004, Kim 1980, 1991). This research suggests that for successfully completing a process of technological upgrading these firms typically followed a path that involved the following stages:

- First, the copy and replication of existing technologies developed by firms in advanced countries, generally facilitated by FDI and technology imports. At this stage activities almost exclusively consist of assembling foreign inputs to produce fairly standardized products.
- Second, incremental improvements to the original technology ("creative imitation").
- Third, innovation when firms start creating new products and processes.

Based on these ideas a great deal of research has been conducted about different mechanisms of technological learning and capability accumulations such as FDI, spillovers, imports, technology transfer, etc. (Lall, 1987,2000; Amsden and Tschang, 2003; Hobday, et al 2004; Lee, 2013; Kim, 1980; Kim, 1991; Marin and Bell, 2006).

This model of upgrading, however, has been developed mostly based on the experience of technological learning in manufacturing industries. It is not clear, therefore, whether it is helpful to understand the processes of learning and innovation that takes place in NRs or in industries strongly linked to NRs. NRs are different to manufacturing in many respects. They are by definition embedded in a territory with specific natural conditions (e.g. soil and climate, temperature, water conditions). This implies that knowledge produced in a specific location might not always work or be useful in another location. Offshore oil technology developed for the Mexican gulf, for example, was not applicable in the northern sea where Norway´s oil was located (Andersen 2012). In addition, NRs activities deal with living matter which has its own specific characteristics. For example, Norway, despite being the most productive country in salmon fish farming, was not able to make cold fish farming work.

This closes down the possibilities for full replication at early stages of development of an industry, such as it happened in manufacturing, but opens up opportunities for innovation in different types of contexts and even for new directions of innovation. In Chile, specific local conditions encouraged the development of a whole set of local capacities, scientific, technological and institutional, after a sanitary crisis threatened the sustainability of the whole activity (Katz et al, 2011). In the South African coal industry the presence of poor quality coal deposits with many impurities led to the development of advanced technological capabilities in the washing of coal.

New research needs to be carried out, however, to better understand the trajectories of technological learning and upgrading followed by firms from less advanced countries linked to NRs activities.

This paper contributes to a better understanding of this issue by analysing the technological trajectory of capability accumulation of firms in the seed industry in Argentina and Brazil.

2.2. Innovation specificities and possibilities in the seed industry

Historically, most seeds improvements were performed by the farmers themselves and public institutions. The process of improvement was mostly done by trial-and-error, i.e. plants with desirable traits were crossed and selection was based on human observation. Currently, however, a significant share of seed improvement is performed by firms and scientific institutions and the process of improvement has become more complex, involving the combination of genetic, biological and agronomical knowledge.

Three main phenomena explain these changes: a) the irruption of hybrids for some crops[1] (e.g. maiz), which meant that firms could more easily recuperate their investments[2], b) the expansion of knowledge about genetics which enhanced the opportunities for seed improvement, and, lately, c) the increasing legal possibilities of private appropriation of plants via IPR.

A major consequence of these transformations has been the concentration of the seeds market.[3] Few multinational companies (MNCs) play a prominent role in the market mostly through their involvement in the development and commercialization of transgenic traits that are incorporated to some crops (generating the so-called transgenic plants).

We suggest, however, that some recent changes in demand, knowledge and institutions are creating new opportunities for a diversity of trajectories in the seed industry, and for the increasing participation of domestic firms from less advanced countries (Marin and Stubrin 2015). We summarized these changes below:

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[1] Hybrids are the result of the intentional cross-pollinitazation of two varieties of a plant. The offspring is an hybrid that contains the best traits of each of the parents.

[2] Most plants are open-pollinating. That means that they keep their genetic attributes generation after generation. Thus, farmers can replant seeds from previous harvests without discernible losses in productivity. Hybrids, on the contrary, have the characteristic that they lose their genetic attributes in future generations. Therefore, farmers need to buy new seeds every season to maintain the improved traits of the original seed. The development of hybrid seeds help companies to recuperate the research and development costs more rapidly as appropriation of the benefits of innovation is guaranteed by hybrids´ seeds reproduction process.

[3] In the 1970s, for instance, 50 US seed companies were acquired by MNCs (Fernando-Cornejo et al. 2002).

a. Changes in demand are creating new and diverse niches

- There has been an increase in the demand for agricultural products, which is expected to keep an upward trend in the next decades, due to a growing population[4] and an increasing demand for energy (FAO 2009). There are a lot of pressures, thus, for agricultural production, most of which takes place in developing countries, to expand. Different types of innovations in seeds are crucial to improve agricultural yields[5,6] and to expand agricultural production to new territories.
- Farmers are becoming more specific in their demands for inputs (Kanungwe 2009). For some important crops (such as soybean or maize) they do not only demand higher-yield seeds but also seeds that pay specific services that facilitate the management of agricultural production and allow them to reduce costs [7]. Again, this creates new opportunities for different types of innovations.
- Consumers are demanding more environmentally friendly and healthier products. Genetic engineering (also called transgenesis when it involves the transfer of genes between different species) is well accepted in general to produce crops for animal food or biofuels, nevertheless consumers are not keen to consume food produced using that technology at least in large parts of the world (see Box 1 for a description of the genetic engineering technology and the other technological options to improve seeds). Transgenic technologies, indeed, are the most rejected technology in the world after nuclear technologies. This type of consumer attitudes generates a demand for niche organic or non-transgenic markets.

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[4] World population is expected to grow by over a third, or 2.3 billion people, between 2009 and 2050. Nearly all of this growth is forecasted to take place in the developing countries (FAO 2009).

[5] According to studies between 50 and 90 per cent of yields increases are due to better seeds (Santos et al 2001; Santos et al 2004; Schnepf et al, 2001; Spetch and Williams, 1984; Brunis M., 2009).

[6] See, "Producing quality seeds means quality yields" (FAO), retrieved from http://www.fao.org/in-action/producing-quality-seeds-means-quality-yields/en/.

[7] Some examples are: soybeans or maiz resistant to particular herbicides, Brussels sprout hybrids with uniform ripening and size that make them more suitable for machine harvesting and monogerm sugar beet varieties that reduce the need for laborious thinning and enable fully mechanized cultivation (Burnis 2009).

Box 1: Existing technologies to improve seeds

Currently three technologies are used to develop innovations in seeds. Crossbreeding, which consists in choosing from the existing and known genetic variation, individual plants containing desirable traits; cross them, and then select the desired characteristics; mutagenesis which involves forcing genetic variation within a species in the search for desired traits and; genetic engineering, that is used to identify sequences of genes (encoding for certain desirable traits) and transfer these to the varieties of plants. When genes are of other species, this technology is called transgenesis. Transgenic plants are also known as GM plants.

b. Changes in S& T are creating more possibilities for different types of innovations

During the last decades a series of phenomenal advances that occurred in areas of knowledge related to breeding activity –mostly on molecular biology – opened up new opportunities to make new kinds of seeds innovations.

The most acknowledged of these new opportunities is that of genetic manipulation. Genetic manipulation can be used to identify, isolate and transfer gene sequences with the purpose of providing seed varieties with a code for characteristics that are unknown within the same species. When genetic engineering involves the transfer of gene sequences from one species to another (e.g. using genes from bacteria to modify soy varieties), the plant varieties are known as transgenic plants.

The new opportunities opened by genetic manipulation has been mostly taken by large MNCs, the kind of companies that have the resources needed to both develop transgenic plants and patent and accomplish the biosafety regulations that are required for transgenic events.

Nevertheless the advances in molecular biology are also allowing to complement traditional phenotype selection (based on plants observable characteristics) with genetic information (genotype selection) making the breeding process – including the processes performed using classical breeding and mutagenesis (see Box 1) - more precise and efficient in general. Genotype information (obtained by biotechnological tools) allows breeders to anticipate and explain plants' phenotype and, in turn, to significantly reduce the length of the breeding process[8] (the process can be shorten

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[8] A similarly effect has had the use of bioinformatics. Seed companies can use computer-assisted prediction of test results on genetic modification to replace growing every modified

several years). In addition, the combination of phenotype and genotype selection (mostly assisted by a biotechnological tool called Molecular Marker) has been very successful in producing a variety of innovations that delivered productivity increases – which cannot be developed by genetic engineering – and heat, drought, flood and disease tolerant traits in key crops such as beans, maize, rice, soy or wheat.[9]

The development of these non-transgenic innovations are being taken by different kinds of firms and institutions. These innovations are central for this market due to several reasons: a) not all industrial crops can incorporate transgenic events, since some markets such as wheat or sunflower, do not accept transgenesis; b) not all demanded innovations can be performed with transgenic technology (productivity increases for instance, since they are explained by a multiplicity of genes interacting that cannot be tackled with the identification, isolation and transferring of single foreign genes) and, c) transgenic events (genetic engineered traits) perform well only when they are introduced into genetic backgrounds that are well adapted to local agro-ecological conditions, and these backgrounds are typically developed by other technologies that domestic firms do master (e.g. cross-breeding).

c. Changes in IPR regulations

IPR regulations surrounding plants are very complex and controversial, because they involve the appropriation of parts of nature. Hybrids offer companies a way of assuring technical appropriation for some crops, however, most crops are self-pollinated and require some kind of legal protection for appropiation. A few countries have allowed patenting plants and genes, namely, North America, Japan, Korea and Australia. The rest of the countries, do not have patents but other form of protection: the Plant Variety Protection (PVP). This is a sui generis IPR regime modelled on a

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plant in the field or green house. The implementation of bioinformatics certainly shortens the breeding process substantially and helps to improve the innovation process.

[9] Just to provide some examples, recently researchers from the National Forestry, Agriculture and Livestock Research Institute (INIFAP) in Mexico have developed a new variety of wheat that is more resistant to leaf rust (a disease), which will allow producers to reduce the use of fungicides. Another example comes from the Philippines-based International Rice Research Institute (IRRI) where scientists have developed a non-GM rice variety (through marker assisted selection) with high submergence-tolerance underwater and adapted them to different flood-prone areas of Laos, Bangladesh and India.

protocol developed by the International Union for the Protection of New Varieties of Plants (UPOV), which provides weaker rights to the inventor in comparison to patents. This gives seed breeders exclusive rights to market their own registered varieties, but allows competing plant breeders to freely use those registered varieties as an initial source of germplasm for the purpose of creating new plant varieties. Conventional plant varieties are in effect open source innovations. By contrast, the patent regime does not allow patented gene sequences to be used as a basis for further improvement to seeds without a license from their owner. This means that seed companies that have developed transgenic seed varieties have the right to a financial claim on all future seed varieties that use the transgenic gene sequence (at least until their patent expires).

Until 1990s, having PVP legislation was an almost exclusive feature of developed countries.[10] However, this situation dramatically changed in 1994, when countries signatories of the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) were forced to agree on Trade Related Aspects of Intellectual Property Rights (TRIPs). In particular in the article 27(3) b of the TRIPs' agreement contain the obligation to provide some form of protection for plant varieties, either by patents or by an effective sui generis system or by any combination thereof.[11]

This put developing countries under pressure to establish some kind of IPR system to protect seeds innovations. However, they still preserve some freedom to establish the system that better serve their interests. The patent system is often advertised as an incentive to stimulate innovation in seeds, since it provides a strongest way of appropiability. We should point out, however, that the evidence is not conclusive respect to the effects of PVP systems on innovation activity. Some studies that took place in developing countries show that PVP legislation provided little incentive for firms to

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[10] The US leaded by introducing in 1930 the Plant Patents Act whereas other OCED countries – mostly the Western European countries – adopted PVP legislation in 1961 under the auspices of the International Convention for the Protection of New Varieties of Plants (UPOV).

[11] The sui generis system most diffused across countries to protect plants is the UPOV Convention. This is a sui generis protection as it provides weaker rights to the inventor in comparison to patents. Two systems are now in force: UPOV 1978 and UPOV 1991. The latter is more similar to the patent system. Developing countries predominate among those that chose the UPOV 1978 system, while developed ones prevail among those that adopted the UPOV 1991.

modify their research plans (Tripp et al, 1997, Gutierrez y Pena 2004). Our research support these findings.

The above mentioned changes in demand, S&T and IPR regulations, provide domestic seed firms in developing countries with new opportunities to innovate and compete in the seeds market. In the following sections, we analyse the extent to which these opportunities are being taken in Brazil and Argentina by domestic firms.

3. DATA AND METHODOLOGY

We use two types of evidence for the analysis: seeds´ innovation data of six crops (maize, soya, wheat, sunflower, cotton and rice) in two countries (Argentina and Brazil) and evidence from three case studies. We describe the data and the methodology used below.

Data on innovation was based on new plant varieties registered in the National Registry of Cultivars (RNC) in Argentina and Brazil. In these countries, new seeds that are traded have to be certified as reaching minimum standards of genetic purity, identity and quality. The RNC contains information, for each plant variety, on the name owner of the plant variety, the year of registration in the RNC, the year of registration in the National Registry of Property of Plant Varieties (RNCP)[12] (if applicable), the country of origin of the variety, and, only for some crops, other technological characteristics of the cultivars (for example, whether the cultivar has transgenic traits). The RNC in Argentina covers the period 1977-2013. In Brazil data collection on new varieties registration started in 1998, so we have the period 1998-1013.

This data allowed us to identify main trends in seed innovation in Argentina and Brazil in the last decades. In particular, we use this data to unravel the rate of innovation in the six crops studied, the participation of different types of actors in seed innovation in each country, and to identify the introduction of transgenic innovations for some crops.

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[12] Plant breeders that wish to protect their varieties under the intellectual property rights system for seeds must apply for registration at the RNPC.

Our three case studies are Don Mario and Nidera, both from Argentina but that operate in both countries, and the company TMG from Brazil (see Table 1). We describe the main characteristics of each case briefly below:

- Don Mario is an Argentinean company, which defines itself as a “genetic provider”. The firm has its own breeding programmes and makes use of advanced biotechnology tools to develop well-adapted seeds. Its main market is the soybean seeds market. In 2013, the firm had 43 per cent of the Argentinean soybean seed market and 35 per cent of the Latin American soybean seed market. In the last years it has opened subsidiaries in Brazil, Bolivia, Uruguay, Paraguay and more recently in the US. In Brazil, the subsidiary named Brasmax is the leading soybean seeds´ company in that country.
- Nidera is a large multinational company created in Argentina in 1929. This is a trading and agribusiness company with strong roots in Argentina and the Netherlands (tough very recently has sold a part to Chinese capitals). The company has foreign affiliates in 15 countries, including Brazil, France, the United Kingdom, Germany, Russia, Italy, and Australia. Nidera concentrates its main innovative efforts in the area of agronomic seeds in Argentina. The seeds unit of the company was created in 1990. Its creation was based on the interest of the firm in developing its 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). In 2000, Nidera created the division of agricultural chemicals and fertilizers under the objective of increasing the seed business inputs needed by agriculture producers (seed, fertilizers, agrochemicals). 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 for the Brazilian territory. In Argentina it has 39% of the soybean market, 20% of the corn market, 28% of the wheat market and 21% of the sunflower market.
- TMG, founded in 2001, is controlled by an association between Unisoja, entity that congregates seeds producers from Mato Grosso, and TGX,

a research organization focused on genetics. Unisoja controls 70 per cent of the company. TMG employs 300 people, 200 of which are full time researchers. The company not only sells its own seeds of soybean and cotton but also provides genetics to other seed companies. In the Brazilian soybean market, TMG is the only local company having a share of around 17per cent (being the third most important company after Monsanto and the Argentinean company Brasmax). TMG started to sell cotton seeds in 2013. Currently it accounts for 16 per cent of the cotton seed market. In the near future, the company plans to also offer their own maize varieties in the local market.

Table 1. The cases

	Don Mario/Brasmax	Nidera	Tropical Melhoramento E Genética (TMG)
Firms´ characteristics (foundation year, capital origin, subsidiaries, employees)	Founded in Argentina in 1982 100% Argentinean capital Subsidiaries in six countries (Brazil, Uruguay, Paraguay, Bolivia, South Africa and the USA) 700 employees	Founded in 1920, Argentinean-Dutch MNC-recently sold 51% to Chinese Capitals Subsidiaries in 18 countries. 1400 Employees	Founded in 2001. Controlled by Unisoja, entity that congregates seed producers from Mato Grosso (70%) and TGX formed by researchers in the genetic field (30%). Brazilian capitals No subsidiaries 300 employees
Activities in the seed industry	Plant breeding	Plant breeding, seed production, conditioning, marketing and distribution	Plant breeding and seed production
Crops	Soya	Soya, Wheat, Corn and Sunflower	Soya and cotton
New varieties registered in RNC (in shares)	ARG:19.07% BRA: 7.36%	Soya (ARG):18.2% Soya (BRA):6.5% Maize (ARG): 16.25% Maize (BRA):2.67% Sunflower (ARG): 4.75% Wheat (ARG): 0.8%	Soya (BRA) 6.34% Cotton (BRA): 9,4 %

Market share (in shares)	ARG (2013):48% Soya BRA (2013):25% URU (2013):50% Latin America (2013):35%	Soya (ARG,2014):39% (Bra, 2014): 22% Maize (ARG, 2014): 20% Maize (BRA, 2014): 3% Sunflower (ARG,2011):21% Wheat(ARG,2012):28.63%	Soya (BRA, 2014): 17% Cotton (BRA, 2014): 16%

Source: Own elaboration.

We carry out at least one interview with a key informant of each of the study cases. Interviews were key to gather data about: firms` characteristics (history, main activities, type of products they offer, type of crops they improve, the technologies they master, the size of the firm, market share, exports, and internationalization), innovation activity (amount and type of R&D efforts, type of innovations achieved and the organization of the innovation activity), and appropiability issues (how the current IPR regime affect the firm`s innovation activity, which is the firm strategy to cope with the current IPR regulation).Data collected was used in the empirical analysis to better understand the strategies of successful firms to compete in the seed market, the type of technological capabilities they have, the sort of innovations they achieve and how they organize their innovation activity.

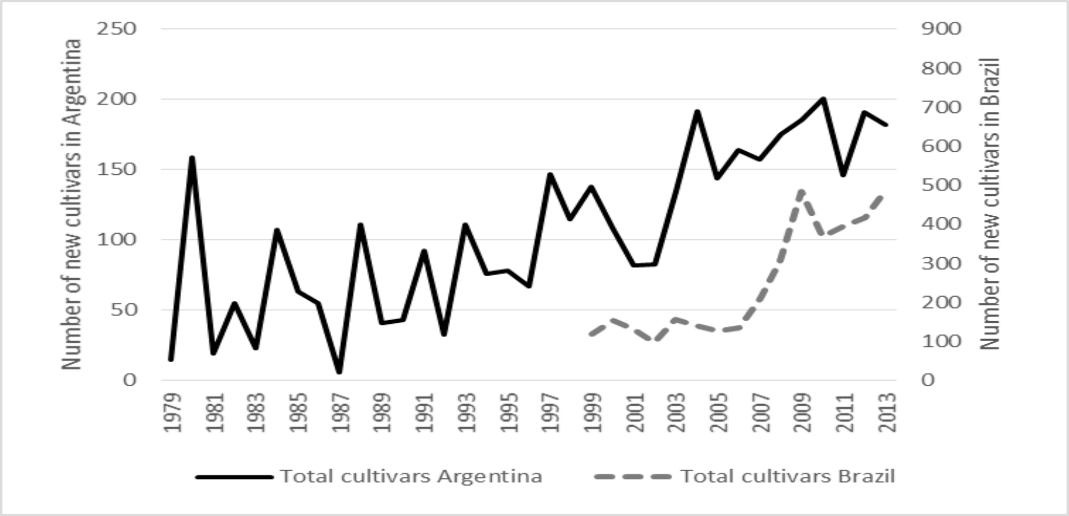
4. EMPRICIAL ANALYSIS

This section is organized in two parts. First, based on new plant varieties registered in the RNC we identify the main general trends in seed innovation in Argentina and Brazil. Second, we analyse the firms behind the data and their strategies.

4.1 Stylized facts: main innovation trends

During the last decades there has been a significant increase in the rate of seed innovation both in Argentina and Brazil. Figure 1 shows the number of new seed varieties of six major crops (soybean, wheat, maize, sunflower, rice and cotton) registered in the RNC. In the case of Argentina the rate of innovation went from around 15 new varieties per year in 1979 to around 180 varieties in 2013; in the case of Brazil from around 120 new varieties in 1999 to 490 in 2013.[13] If we consider the last two decades, the average annual rate of growth of new seed varieties was 14 per cent in Brazil and 5,96 per cent in Argentina.

Figure 1. New registered cultivars of major industrial crops in Argentina and Brazil[1]



Source: Own elaboration based on data from RNC in Argentina and Brazil.

Note: [1] For the sake of the presentation of the data we did not show the number of new cultivars registered in Brazil in 1998, which were 815.

As a general trend, thus, it can be said that despite the differences in magnitudes, in both countries there has been a similar upward trend in innovation activity.

Figure 2 (left hand figure) depicts the share of new plant varieties per type of crop in Argentina and Brazil for the period 1999-2013. New seed varieties of maize and soybean account for the largest share of innovations in both countries. Maize seed varieties explain 54 per cent of seed innovations in Brazil and 45 per cent in Argentina, whereas soy represents around a quarter of seed innovations in each country (27 per cent of new cultivars in Brazil and 22 per cent in Argentina).

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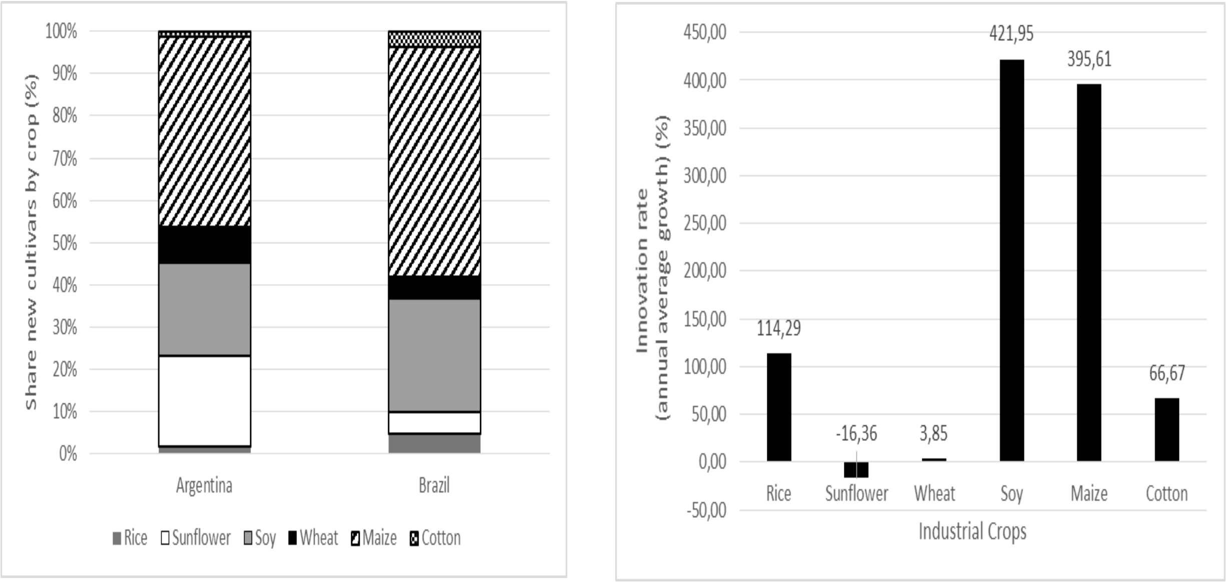
[13] The difference in the time period observed from Argentina and Brazil is related to the differences in the year in which plant varieties started to be registered in the RPC of each country (See Data and Methodology Section).

Figure 2. New plant varieties by type of crop (1999-2013): Shares and Rate of growth

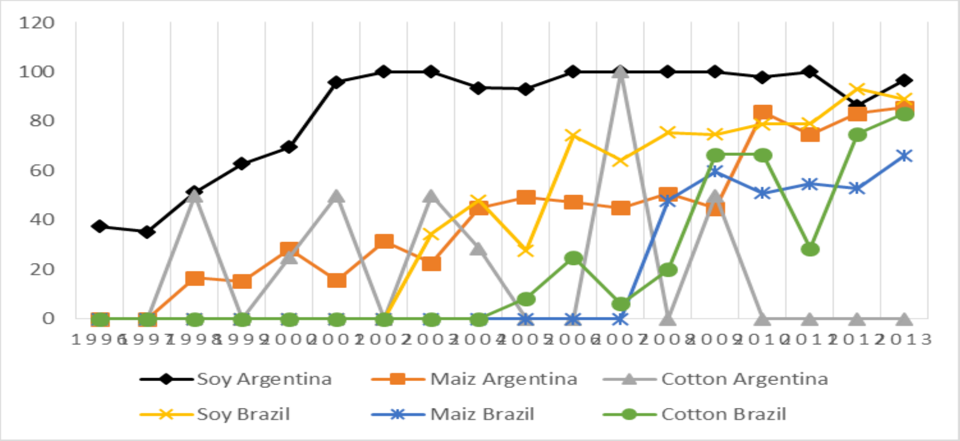


Source: Own elaboration based on data from RNC in Argentina and Brazil.

A similar picture emerges when we consider the dynamics of innovation activity per crop during the period (see Figure 2- right hand figure). The most dynamic crops are soybean and maize. However, recently, soya shows a more positive evolution than corn.

Figure 3 shows the share of new seed varieties that contain transgenic events for soybean, maize and cotton. From the figure we can observe that in both countries the highest shares of transgenic seeds are in soybean seed varieties (85% in Argentina, and 67% Brazil), but transgenic events diffused also for corn (55% in Brazil and 46 % in Argentina and in cotton (42% Brazil and 22% Argentina). For crops destined directly for human consumption (such as wheat, sunflower and rice), transgenesis modification are not well accepted so producers do not use them.

Figure 3. Share of OGM cultivars registered by type of crop in Argentina and Brazil

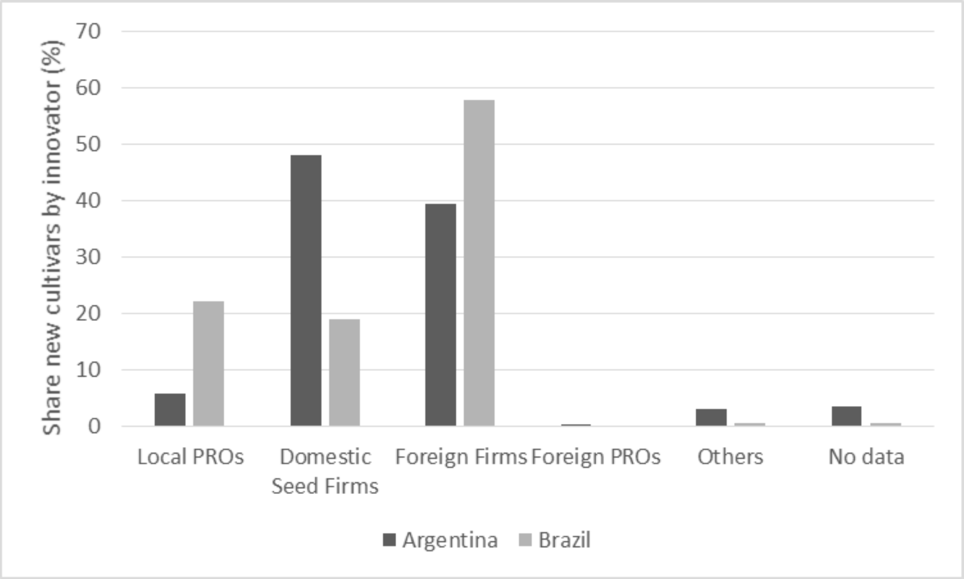


Source: Own elaboration based on data from RNC in Argentina and Brazil.

Three type of agents explain the majority of innovations: domestic firms, foreign firms and Public Research Organizations (PROs). However, the participation of each of the actors varies between the two countries and crops (see Figure 4):

- Domestic seed firms account for almost a half of all new seed varieties introduced in Argentina (47,95%) whereas in Brazil their participation is much more reduced (18,86%).
- Foreign firms explain the bulk of innovations in Brazil (57,69%) whereas they account for more than one third of innovations in Argentina (39,38%).
- Local PROs are more relevant to explain innovation activity in Brazil than in Argentina. They account for 22,19% of all innovations in Brazil and 5,72 per cent in Argentina.

Figure 4. Introduction of new cultivars by type of innovator in Argentina (1979-2013) and Brazil (1998-2013)



Source: Own elaboration based on data from RNC in Argentina and Brazil.

On the whole this evidence tells us that domestic firms are more relevant to explain innovation activity in Argentina, and that in Brazil multinationals and PROs (mostly Brazilian Agricultural Research Corporation (EMBRAPA)[14]) are more significant to explain innovation rates. However if we compare by crop (see Figure 5) we observe some interesting differences.

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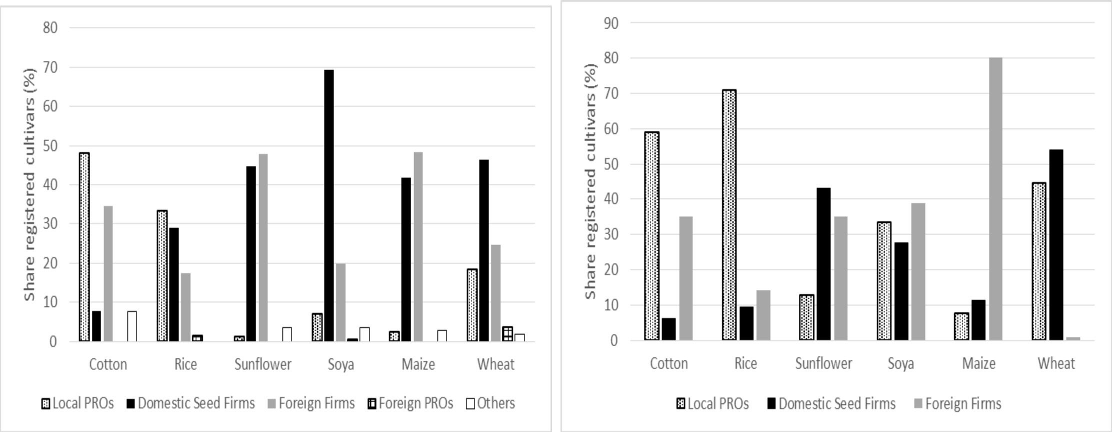
[14] EMBRAPA is a Brazilian state company founded in 1973. The focus of EMBRAPA is to generate knowledge and technology to Brazilian agriculture. The company is linked to the Ministry of Agriculture, Livestock and Food Supply.

Figure 5. Share of new seed varieties by type of innovator, by crop in Argentina and Brazil (1979-2013)



Argentina Brazil

Source: Own elaboration based on data from RNC in Brazil.

Table 2 summarises, the crops for which each actor (domestic firms, local PROs and foreign firms) contributes to at least 30 per cent of all innovations. The evidence there shows that:

- domestic seed firms in Argentina contribute to develop new seeds in a wider array of crops in comparison to Brazil. In Argentina domestic firms develop at least a third of innovations in rice, soya, maize, sunflower and wheat; whereas in Brazil domestic firms only do that on wheat and sunflower.
- local PROs in both countries perform a more central innovative role in rice and cotton. However, local PROs in Brazil also contribute significantly to innovation in soya and wheat.
- in both countries foreign firms concentrate their innovative efforts on crops that either provide high levels of appropiability (such as hybrids of maize and sunflower)and/or where it is possible to develop transgenic plants (cotton, maize and soya). However, this phenomenon is much more significant in the case of Brazil. In this country foreign firms have a stronger role in developing new seed varieties of soya than in Argentina. Something similar takes place in the case of maize and sunflower.

- it is important to notice, however, that in Brazil some of the foreign firms have Argentinean capitals (we will see more about this in the following subsection).

Table 2. Innovation by type of actor in Argentina and Brazil

	Domestic seed firms	Local PROs	Foreign Firms
Argentina	Maize Sunflower Rice Soy Wheat	Rice Cotton	Cotton Maize Sunflower
Brazil	Sunflower Wheat	Cotton Rice Soya Wheat	Cotton Maize Soya Sunflower

Source: own elaboration.

In the next sub-section the analysis is focused on understanding the strategies that domestic seed firms pursue in Argentina and Brazil, and the type of innovations they are delivering.

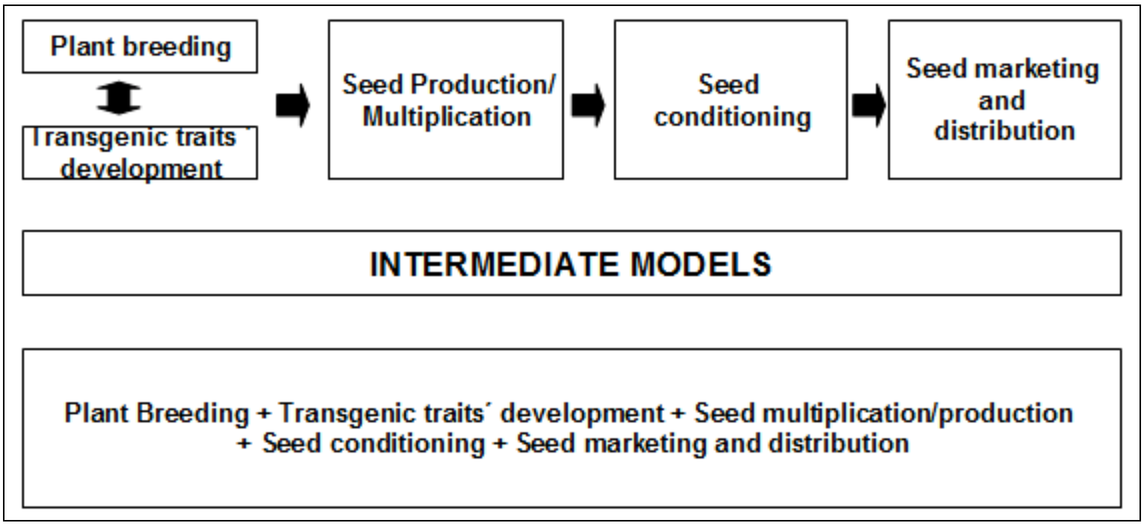
4.2. The firms behind the data

This subsection is structured in three main parts. First, we provide an overview of firms´ main characteristics and strategies. Second we describe in detail firms´ innovation efforts. In the last part, we show which are the main innovations developed by these firms.

4.2.1 Overview of the main characteristics and strategy of the successful domestic firms

Actors in the seed industry can be distinguished according to the type of activities they perform. These activities include: plant breeding (developing seeds embodying improvements such as high yields, resistance to disease and pests, or traits specific to regional agroclimatic conditions), transgenic traits´ development (includes identification and isolation of genes from other species), seed production or multiplication, seed conditioning (consisting of drying, cleaning, sorting seeds, treating them with fungicides and packaging them for distribution and sale), and seed marketing and distribution. Actors vary between those that are fully integrated (performing from "plant breeding" to "seed marketing and distribution") and those that perform just one of the possible activities. Between this two extreme cases, there is a huge diversity of combinations: firms that perform plant breeding and develop transgenic traits, firms that perform plant breeding and multiply, firms that produce and condition seeds, and many others (see Figure 6).

Figure 6. Seed industry organization



Source: own elaboration.

In Brazil, there are over a thousand seed developer and multipliers listed in the national register of seeds and seedlings (RENASEM). However, only 137 firms invest in breeding programs in the country. Even for "platform crops" - cotton, maize and soy - less than a hundred different firms are responsible for all genetic material listed at RNC.[15] Data from the Argentine Seed Association (ASA) indicates that in the 2012 season there were registered over three thousand companies involved in the multiplication, production, processing

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[15] This number of firms appears to be very low when compared to the ones registered at countries with such as India, China and USA.

and packaging of seeds for agricultural use in the country, and from this around 40, are dedicated to develop new seeds.

The selected cases in this study stand out among the firms dedicated to develop new genetic materials.

Don Mario develops new soy seed varieties. The company accounts for 19.07% and 7.36% of all soybean varieties registered in the RNC in Argentina and Brazil respectively (187 varieties in Argentina and 94 varieties in Brazil). In 2013, starting with a negligibly share of the market in the 1990´s, the company had 48 per cent of the Argentinean market, 25 per cent of total Brazilian market (around 70% in the South of Brazil), and 40% of the regional market, including Paraguay, Bolivia and Uruguay. This means that more than 20% of soybean worldwide varieties produced belong to Don Mario genetics.

Considering the last 15-20 years, Don Mario has grown exponentially. In 1993 the company operated only in Argentina, had 20 employees and a turnover of 1.4 million USD, but in 2014 Don Mario has subsidiaries in six other countries (Brazil, Uruguay, Paraguay, Bolivia, South Africa and the USA), 700 employees and an annual turnover of 220 million USD. Interestingly, Don Mario´s growth has taken place in a period in which domestic seed firms in developing countries have been massively acquired by large MNCs. In the soybean seed market in Argentina, most other competitive domestic seed firms have been acquired by foreign capitals (e.g. Relmó, Seminium, La Tijereta). Don Mario, thus, is an interesting case to explore as it has followed a successful strategy that allowed it to survive and gain market (locally and internationally) in a very concentrated and MNCs dominated market.

Nidera, the second firm studied deeply, differently to Don Mario, develops seeds for different crops (such as sunflower, wheat, soya and corn), and also produces, conditions and sells its own seeds. However, similar to Don Mario, it does not develop transgenic traits. Nidera carries out cross-licensing agreements with MNCs in order to incorporate their transgenic traits in its own varieties of soybean and maize, and licenses to other MNCs (and other domestic firms) their varieties and traits developed with mutagenesis.

Currently Nidera positions itself among the leading firms in soybean in Argentina and Brazil (having 39 per cent of the Argentinean market and 22%

of the Brazilian market), has the second market share in the maize market in Argentina (20 per cent) which is a market typically dominated by large MNCs and leads the sunflower and wheat market in Argentina (with a market share of 21 and 28 per cent, respectively).

The third case, TMG, develops soybean and cotton seeds (and has recently started research to develop corn seeds). The company has grown by 10/15% per year since it was created in 2001. Currently it has 17 per cent of the Brazilian market, which places it in the third position in the national market, after the Argentinean Brasmax (Don Mario Sementes) and Monsanto. In Mato Grosso, TMG is the largest soybean producer with 45 per cent of the market. TMG also started to sell cotton seeds in 2013, and gained the 16% of the national cottonseed market one year after. TMG has activities in Uruguay, Bolivia and Paraguay, it is starting its activities in Argentina, Colombia and South Africa, and plans to expand to the U.S. market in the near future. Among the current company's portfolio of 30 products the most important are soybean cultivars resistant to the cyst nematode and soybeans with resistance to Asian rust. In October 2014, the USPTO granted TMG a patent for the development of the gene Rpp5 which is responsible for conferring soybeans resistance to the Asian rust.[16] [17]

The performance of these three companies shows clearly that despite the importance of a small number of MNCs in providing key technologies embodied in seeds for the global seed market, some domestic enterprises in the region are playing a central role in the domestic markets by acquiring a large share of it.

A key question is thus: how have they done so? What do they provide?

These companies do not develop transgenic events or multiply or perform seed´s conditioning or marketing. They dedicate entirely to develop genetic improvements using cross breeding assisted by modern biotechnology. Our analysis suggests that in doing so the companies analysed serve very well a particular and crucial need of the seed market, the need for diversity.

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[16] Asian rust is a serious disease caused by the fungus Phakopsora pachyrhizi and Phakopsora meibomiae.

[17] The commercial name of the soybean ressistant to Asian rust is “Inox” and was launched in 2009.

NRs activities are context specific. Each place has its own agro ecological characteristic (e.g. certain temperature, type of soil, wind, type of insects, etc.). Seeds developed for one particular context, thus, do not work well in all the other contexts. In addition, contexts are not static over time but they evolve. A region can become drier from one planting season to another, other region can be suddenly attacked by a plague, other can get affected by heavy rains, etc. Seeds that respond as quickly as possible to these changes perform better. The market of seeds, therefore, appreciates diversity and rapid adaptation to changing conditions.

Domestic firms´ strategy is to develop innovations that respond to this need for diversity. That is, to develop seeds that adapt to multiple contexts responding timely to a diversity of farmers´ demands. These firms remain flexible to change their seed varieties over time responding to changes in the environment.

As pointed out by a key informant interviewed from Don Mario: "A key element of Don Mario strategy is positioning itself as a first mover (…). Don Mario´s strategy consists of possessing a wide spectrum of seed varieties that are suitable for different climate and soil conditions as well as resistant to pests. Thus, Don Mario attempts to be the first that cater to the market with the type of variety that is more suitable for the problems or agro-ecological conditions of each year and region". A TMG key informant also asserts that: "Time-to-the market and diversification are the main strategies to compete in the seed market".

How do they provide diversity and adaptation? Domestic firms´ technological strategy.

As discussed above the domestic firms analysed do not develop transgenic events (see Box 1 for a description of the technologies available to develop seed innovations). This is due to several reasons: (i) they are very expensive to develop, not only for the traditional R&D costs, but also and mostly indeed, because of the regulatory and biosafety costs, (ii) this technology is not effective to deliver the number and type of innovations demanded by this market (see Box 2 for a more detailed explanation of the technical possibilities offered by this technology vs the others available); (iii) several markets do not receive well seeds that have been genetically modified using transgenic events.

Research on transgenesis concentrates mostly on looking for characteristics in other species that are unknown within a species (see Box 1). This is time consuming, risky and very expensive, and as said it is not well accepted in many markets. A proof of this is that only a few characteristics developed using transgenesis are in the market (resistance to herbicides and to insects). For large MNCs is profitable to concentrate efforts on this particular technology because they have the resources and the capabilities to patent and defend the events within biosafety institutions and the public opinion. Once they have done so, the existing IPR system allows them to recover the benefits of their innovations in multiple locations for long periods of time. Transgenesis, however, is not effective to deliver the multiple innovations that the seed market requires to function well in different agro-ecological conditions.

Domestic firms purposely develop seeds using the other two technologies available: cross-breeding and mutagenesis (see Box 1). They concentrate their innovation efforts thus on identifying the variability that exists within species – but that is unknown - to develop new varieties. This implies investing in efforts to identify and understand much better the genome and possibilities of specific species to adapt to different types of agro-ecological conditions and changes in the environmental conditions over time. And to do so they use advanced levels of biotechnology capabilities. For example, all the successful domestic firms studied use molecular markers[18] in the breeding process (we explain more of their R&D capabilities in the next subsection). This type of biotechnological tools help firms to gain precision and shorten the breeding process.

The following quote from one of our interviewers at Nidera reflects the strategy of the company regarding their technological approach to innovate in seeds: “In sunflower, oil consumers are willing to pay a surcharge for quality, and also they are not in favour of acquiring seeds that have been modified by transgenesis. In this context, other technologies, such as

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[18] Molecular markers are a modern biotechnology tool that allows for revealing certain characteristics of the plants based on their DNA information.

mutagenesis, appear as a very helpful tool to improve sunflower, because they do not generates resistances or fears, and can generate traits. For example, Nidera generated 5 families herbicide resistance using mutagenesis" (see the next sub section for more examples of the kind of innovations that domestic firms deliver)".

When the "market" demands it, however, these firms acquire transgenic events through licenses with MNCs, and then paste them into their own developed plant varieties. This is the case in the market of soy, corn and cotton.

Box 2. Genetic engineering: an appraisal of results

Genetic engineering, and in particular the use of transgenesis - is often advertised as the most sophisticated and advanced of the technologies to improve existing seeds. These justifications are of two types. One is that genetic engineering can improve the process of seed innovation. The claim is that it is a more precise and efficient technique for improving seeds. The second is that the technology can improve the outcome of seed innovation. Both justifications deserve careful scrutiny. The first of these - that genetic engineering techniques will improve the process of seed innovation - is based, in large part, on the fact that genetic engineering is able to exploit advanced scientific knowledge in molecular biology. Yet, as many individual scientists and professional scientific associations are careful to acknowledge, the same bodies of advanced knowledge can be and are being used in cross breeding and mutagenesis, enhancing the speed and precision of innovation using those techniques too (Biochemical Society 2011). For example, the use of genomic techniques such as molecular marker assisted breeding significantly increases the precision and predictability of cross-breeding, and reduces the time involved in creating a new cultivar (Beddington 2010; Morrell et al. 2011; McCouch et al. 2013). The claimed advantages of genetic engineering, in terms of improved processes, are not necessarily apparent in practice (Gepts 2002).

As for the argument that genetic engineering can improve the outcome of seed innovation, it is striking how little evidence there is in support of that claim. Instead it is based largely on expectations about what the technology may be able to achieve in the future (e.g. Smith 2000). For the time being, at least, the innovative outputs from genetic engineering can often be achieved with other approaches. Thus key traits achieved by genetic engineering - for herbicide tolerance, coleopteran pest resistance, b-carotene enrichment and delayed ripening - have all been introduced in major food crop varieties by advanced cross breeding and mutagenesis techniques (Arundel 2001; Zamir 2008; Brumlop and Finckh 2011). Furthermore, genetic engineering techniques have not yet been able to modify complex 'quantitative' traits, such as for yield and stress resistance (that are determined by numerous interacting genes), but such traits can be modified using cross breeding techniques, especially when using advanced genomic knowledge (Fernie et al. 2006).

The evidence is conclusive in this respect. Transgenesis has been used to

Box 2. Genetic engineering: an appraisal of results

develop a few standardised innovations i.e. transgenic events that deliver a standard service (such as resistance to a particular herbicide) to all producers wherever they are located. These transgenic seeds are then inserted into seeds that are adapted different conditions.

Source: Marin et al, 2015

4.2.2. R&D organization

One common characteristic of domestic firms analysed is that they have generated a rich and diversified germplasm bank[19] and that have developed the capabilities to take advantage of it (through advanced capabilities in storing, classifying and reading genetic information) so to respond to market needs timely. We elaborate more about this below.

The size and diversity of the germplasm bank is the key asset of a seed firm. Don Mario has nowadays the fourth more important soy germplasm bank in the world, after the foreign MNCs Monsanto, Pioneer, and Stire. And, TMG, has the most important germplasm bank in Brazil, similar to the one owned by EMBRAPA – a key actor in the seed market in Brazil (see section 4.1.).

Firms develop their germplasm banks through: a) the acquisition of germplasm from other companies or countries, and/or b) the development of their own germplasm.

Imported germplasm introduces variability to the local germplasm bank, and can be highly beneficial in the innovation process. For instance, Nidera, was a first mover in importing French wheat germplasm to Argentina (Baguet) and adapt it to local requirements of quality. French wheat provided higher yields in comparison to the Argentinean wheat, but it had much lower quality for the local standards. Nidera, using cross breeding assisted by biotech tools, managed to upgrade the quality of French wheat and gained an important share of the domestic market. Another example is that of Don Mario, which started importing USA germplasm and adapting it to local conditions. Then the company started to develop its own germplasm, but it is still importing soybean germplasm from elsewhere (currently signed an agreement with the Chinese Science Academy to explore Chinese soybean germplasm). A key

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[19] A germoplasm bank can be defined as a collection of live plant matter in the form of seeds.

element in the strategy of these companies is the use of foreign direct investment and joint ventures, as a way not only to gain market, but also to broaden up its germplasm and to get to know the agro-ecological problems and solutions from other regions. TMG, for instance, has signed a partnership with the Dutch Mutagene, to obtain access to a higher number of genes.

To develop their own germplasm (and also to assess and incorporate foreign germplasm) these firms invest heavily in R&D. TMG, for example, invested in 2012 approximately R$ 50 million in their R&D program, which was close to 90% of TMG´s revenue in that year. Don Mario, invests around 10% of its revenues in R&D in general (in 2014 20 millions dollars).

Firms´ R&D activity is typically organized in the following way: there is one breeding programme for each crop (e.g. a breeding programme for soy, other for maize, etc.) and there is at least one biotech lab that assists breeding programmes in the process of selection of the best plant varieties.

Breeding programmes are composed mostly by agronomists who are trained in breeding practises and perform all the experimental work on the field. The Biotech lab has a key role in assisting breeders in the process of selecting the best materials. Through modern biotechnological tools, the biotech lab helps to identify whether plants have certain traits or not. Firms use a biotechnological tool named “molecular markers” to unravel whether a certain traits is present or not in a plant. Molecular markers are acquired through different sources: (a) public knowledge, (b) MNCs and (c) own development.

Don Mario has two labs, one in Argentina in Chacabuco, and the other in Londrinas, Brazil. Nidera has also two labs, one in Venado Tuerto, Argentina and the other one, in Uberlandia, Brazil. These labs assist the breeding programmes, in the case of Don Mario almost a 100% and in the case of Nidera a 60%, since the company develops also traits for sunflower using mutagenesis. In Nidera, 30% of the lab, thus, is dedicated to develop new traits. TMG has also a biotech lab dedicated to the development of molecular markers. In 2013 the company invested US$ 5 million to acquire the first robot that performs genotyping in South America.

To perform basic research (and to find and train human resources), these companies tend to have agreements with universities (i.e. to perform research on genetic mapping of their varieties). Don Mario has agreements with the University of Buenos Aires, the University of Rosario and the University of Londrina. TMG hires biotechnology laboratory services from Londrina and Maringa State Universities. In addition, it has an agreement for human resources training with Illinois and Iowa Universities in the US.

They also invest heavily in the development of capabilities (human resources and equipment) to read, and storage information out of their germplasm. They have several agreements with universities and laboratories that help them to read this information.

However, the success of these firms is not only explained by the development and organization of genetic information, but on the exploitation of the synergies among: genetic information, the testing of genetic material and the use of greenhouses.

The experimental testing on the field is key to assess whether materials developed in the lab or in greenhouses perform well or not in different locations. Field testing demands high investments in specialized machinery and trained human resources (mostly agronomists) that are able to identify the best plants. Field testing takes several years.

The size and magnitude of the experimental testing, as well as the number of greenhouses that each firm has developed are key to explain the success of firms to develop timely better performing seeds. Tables 3 and 4 show the magnitude of the network of testing for maize and soybean of the companies analysed here, relative to the size of the network of two less successful companies ACA and Santa Rosa from Argentina for which data is available.[20]

Table 3 focuses on maize, Table 4 on soy. The size of the experimental network (in number of plots) in Argentina of Nidera (20% of market) is 1500 times higher than that of ACA (5% market share). In addition, Nidera performs experimental work in other countries which is key to contribute to increase the variability and richness of its germplasm bank.

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[20] Due to the availability of data, here we focus only on the differences between the successful domestic seed firms studied, and others less successful ones regarding the scale of their field testing programes, However, firms also differ regarding other important dimensions such as their investment in R&D, sizes of their germoplasm banks, type of R&D equipment, among others.

Table 3 – Experimental maize network of domestic seed firms in Argentina

	Nidera	ACA
Number of experimental plots in Argentina	120.000	8.000
Locations of experimental plot in Argentina	75	13
Other countries	USA: 10.000 experimental plots in 17 locations. Europe: 10.000 experimental plots in 20 locations	No

Source: Own elaboration.

If we look at the case of soya, TMG has 200 experimental stations in Brazil; Nidera and Don Mario have experimental plots in 50 and 60 locations in Argentina; whiles Santa Rosa only has experimental plots in 14 locations. An interesting difference takes place also when we consider the magnitude of the testing network outside the firms´ home country. Santa Rosa has a small network of testing both in Argentina and abroad. Nidera and Don Mario, instead, which are leading firms in Argentina and other countries (such as Brazil), do have a broad network of testing outside Argentina both in terms of number of countries and, the number of locations in each foreign country. TMG is different from Nidera and Don Mario in this respect. TMG is a leading firm in Brazil, but it is more inward oriented. Hence, its network of testing is locally broad, but not that big in other countries.

Table 4 – Experimental soybean network of domestic seed firms

	Nidera	Don Mario	TMG	Santa Rosa
Number of experimental plots in Argentina	270.000 (between Argentina and Brazil)	750.000	0	No data
Number of experimental plots in Brazil		500.000	500.000	No data
Crosses in their home country per year	650	4500	5000	No data
Locations of experimental plots in Argentina	50	60	1	14
Locations of experimental plot in Brazil	60	70	200	20
Other countries where the company performs experimental testing	USA: 10.000 experimental plots in 17 locations. Europe: 10.000 experimental plots in 20 locations	USA: 95.000 experimental plots in 30 locations. Europe: 2000 plots in 5 locations. Bolivia 450 experimental plots in 8 locations. Three other countries (Uruguay, Paraguay and South Africa) – 14 locations and 4500 plots	Uruguay (2 LOCATIONS), Paraguay (2 LOCATIONS), Bolivia (2 LOCATIONS) and Colombia	Paraguay 4 locations, Uruguay 4 locations and South Africa 4 locations.

Source: Own elaboration.

In sum, the R&D strategy of the domestic seed companies that have succeed in this market is based on: a broad base of genetic diversity, heavy commitment to R&D activities, highly qualified personnel, world-class equipment and technologies, quality in selection and assessment (based on mechanisation, computerisation, etc.), a large and diverse scale of testing and agreements with other institutions to perform basic research.

4.2.3. Innovations

In this subsection we present some examples of innovations developed by the domestic firms analysed in Argentina and Brazil. These are divided into four types: i) changes in plants´ cycles, ii), resistance to diseases, iii) yields´ improvements, and iv) development of new non- GM traits. We provide some examples of each of them below.

(i) Changes in plants´ life cycles

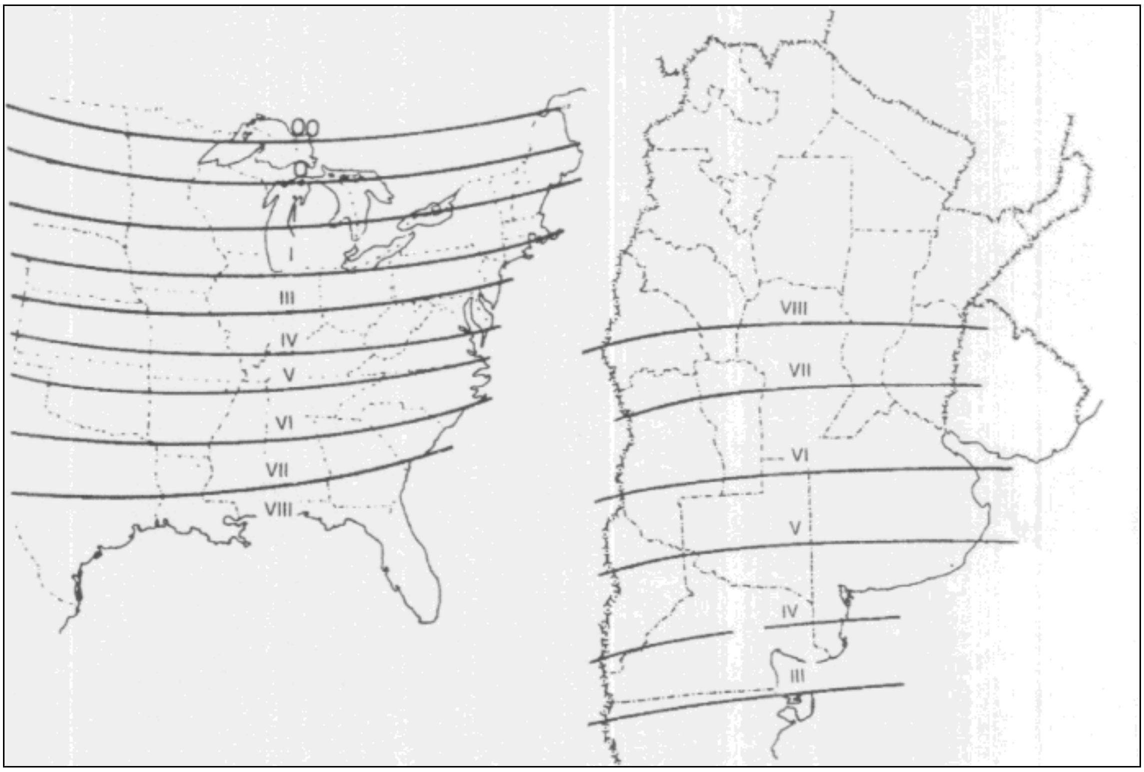
Two major innovations have been made by the companies Nidera and Don Mario based on the introduction of genes that have allowed to change the cultivars life cycles.

- Changes in the growth habit of soybean varieties of long maturity groups.

One of the most important soybean innovations in LAC in the recent years, which allowed to increase productivity significantly and improve field management, has been the change of the growth habit of soybean varieties of maturity groups (MGs) V to VII, which work well in the Pampeana North Region and the North Region, in Argentina and in southern region of Brazil, two regions that experienced a significant increase in the cultivated area during the last decade.

Soybeans varieties belong to different maturity groups (MGs), each of which are best suited to particular latitudes. In Argentina, during the 1990´s, for example, MGs II-IV are best adapted to the Pampeana Southern Region; III to VI to the Pampeana North Region and, IV to IX to the North Region. In Brazil long maturity varieties (MG VI, VII, VIII) work well in the southern region (see Figure 7).

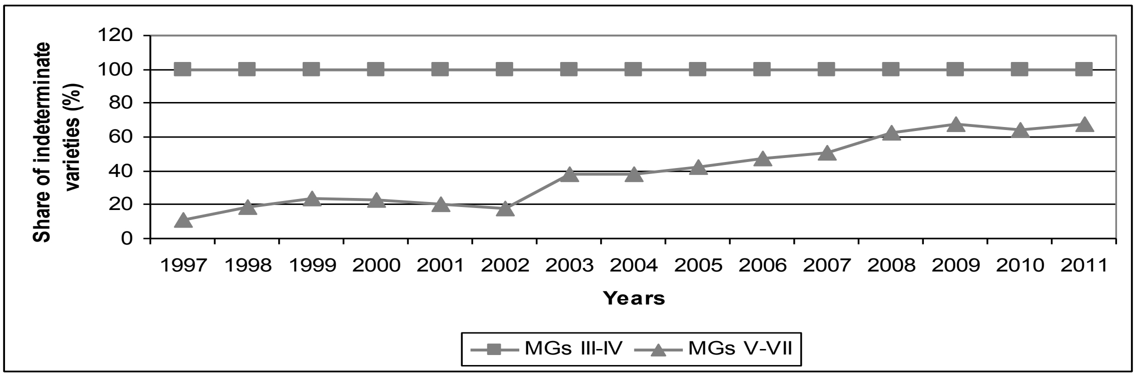
Figure 7. Maturity groups of soy in Brazil and Argentina (1990´s)



At the same time soybeans can be either determinate or indeterminate. Determinate varieties flower at a certain time of the year, when days begin to shorten, at which point vegetative growth stops and only reproductive growth (i.e. flowering and the production of fruit pods) continues. Indeterminate varieties, by contrast, continue with vegetative growth after the plant flowers and sets pods, until the weather dictates that it is time to curtail plant growth. An advantage of indeterminate soybean varieties is that they can recuperate after periods of dry weather, and so they yield better under those conditions. In addition, indeterminate varieties mature early (approximately two weeks earlier than determinate varieties) and this provides more time to plant a second crop together with soybean.

Soybean varieties of MGs IV and below have traditionally been indeterminate whereas soybean varieties of MGs V and above have been determinate. Nidera developed indeterminate soybean cultivars for MGs V to VII. Figure 8 shows the rate of diffusion of indeterminate varieties within different MGs in the period 1997 to 2012 in Argentina. Whilst all commercialized soybean cultivars of MGs III-IV were and are indeterminate, the share of indeterminate varieties in MGs V-VII increased significantly across the whole period, from 10% in 1997 to 70% in 2011, with the period of most rapid diffusion occurring between 2002 and 2011.

Figure 8. Share of indeterminate soybean varieties by type of MG in Argentina



Source: Own elaboration based on Red Nacional de Evaluación de Cultivares de Soja (RECSO).

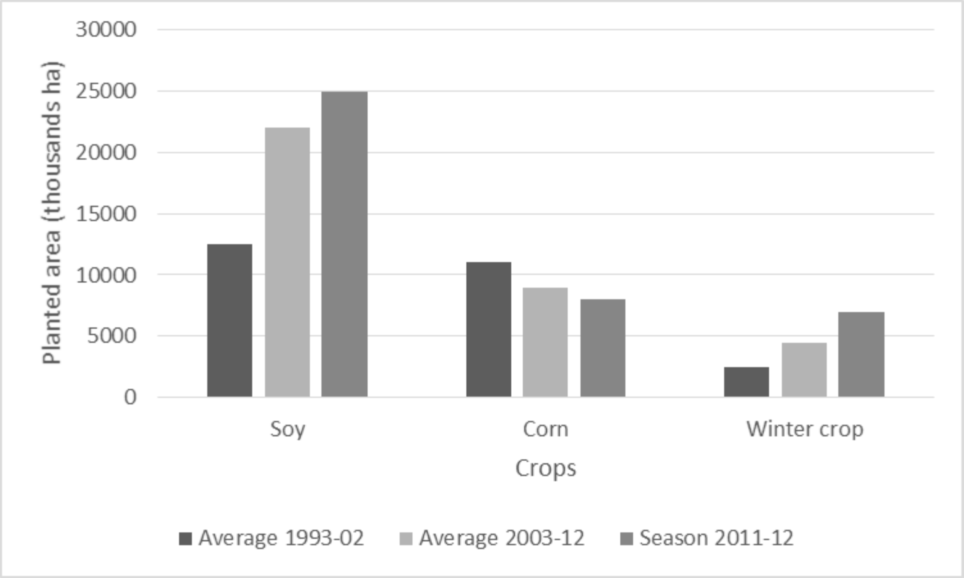
- Adaptation of varieties of short maturity groups to work well in regions where before only worked well varieties of long maturity groups

As showed in Figure 9 in the Northern areas of Argentina and Southern areas of Brazil, in the early 1990´s, only worked well seed varieties of long maturity groups. A major innovation of Don Mario was to develop varieties of short maturity cycles for these regions. Now in the North of Argentina and the South of Brazil producers can use varieties of short maturity cycles. Some of the advantages of these varieties for the farmers are that they can avoid diseases such as Sclerotinia sclerotiorum (White Mould), they have best cultivation structure (less Bedding-) and have anticipation of the reproductive period at higher temperatures that do not favor the spread of the fungus.

But more important than anything else, by advancing the period of maturation, these varieties allowed double cropping of soy and corn, which in

Brazil has explained the boom in production of both crops during the last recent years (see Figure 9).

Figure 9. Expansion of double cropping in Brazil



(ii) Resistance to diseases

It is estimated that 10 - 15% of production losses can be attributed to diseases. Genetic engineering approaches have not made any contribution to confer plants resistance to diseases. Domestic firms thus have been key in the development of varieties that address these diseases.

For example, following the expansion of land cultivated with soya after 2005, a pest called Frog Eye disease (caused by the agent Cercospora sojina) began to have an adverse impact on soy yields and seed quality in Argentina. This disease was originally prevalent in the North Region, where cultivars of higher MGs were used which are resistant to Frog Eye disease. However, between 2008 and 2010, the disease spread to other regions (specially the North Pampeana Region) where soybean cultivars (of lower MGs) were not resistant to this disease. As a consequence, yields became severely affected. Since then, an intense breeding effort took place to develop resistant cultivars for lower MGs (Arias 2011, Sillón 2009, Formento et al 2009). The Argentinean company Don Mario was the leading firm in the development of varieties resistant to this disease and currently 70 per cent of its seed portfolio is resistant to Frog Eye.[21]

Other important diseases that were addressed by the breeding efforts of domestic firms in recent years have been Phytophthora root and stem rot (PRR), SDS, SCN, and bacterial blight. Currently, resistance to other type of diseases are in adjustment phase just as Northern Steam Canker, White Mold or Traget Spot.

In Brazil, TMG developed the first RR soybean resistant to the disease called root nematode. Another important development of this company was the discovery of the genes Rpp5 (which was granted a patent of the US Patent Office in 2014) that confers soybeans resistance to Asian rust (an aggressive disease that appeared for the fist time in Brazil in 2002). TMG was the first company to launch a commercial soybean variety that is resistant to Asian soybean rust disease in the world. The discovery was the result of the screening of soybean varieties looking for rust-ressistant genes. The company finally discovered a cluster of genes, which have their origins in Asia, which provide resistant to that fungus. The first rust-resistant variety, named Inox, was developed in record time (seven years, when the normally it takes 15 years).

(iii) Yields´ improvements

Domestic successful firms have become experts in yields increases. The varieties of Don Mario for instance, have showed in field during the last 14 years an average genetic gain of 1,63 per year. In that period, the genetic gains obtained by Don Mario has allowed the company´s varieties to increase productivity by 22,8% in total. In the case of Nidera the gains have been between 1,5 (in lower Maturity Groups) and 1 (higher Maturity Groups) per cent. Both firms have attained higher yields compared to the average of the industry for the same period (1 per cent).

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[21] Something similar happened with the disease Southern Steam Canker (caused by Diaphorte phaseolorum f.sp. meridionalis) (SSC), a very destructive disease that caused severe damage in the years 1996-1998 (Wrather et al 2001, Ploppler 2004). Since then an intense breeding effort took place to obtain soybean varieties resistant to that disease. In 1997, the Argentinean company Nidera responded to this need of the market by launching five soybean varieties that were resistant to SSC.

(iv) Development of new non GM traits.

In 2010, Nidera patented a hybrid sunflower seed obtained by mutagenesis which is resistant to imidazolinones herbicides. It was the first biotechnological event of the firm. 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. 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).

5. FINAL REMARKS

In the context of the growing knowledge intensification of the agricultural sector, this paper investigated the extent to which the significant expansion that the sector experienced in Argentina and Brazil during the last 20 years, encouraged the development of local advanced innovation in seeds. Seeds are a key input for agriculture and have transformed very rapidly recently, incorporating increasingly a number every time larger of knowledge intensive services. We work with secondary data on innovation and conducted three case studies of successful firms, two in Argentina and one in Brazil.

The quantitative analysis shows that seed innovation increased significantly in Argentina and Brazil following the massive expansion that the agricultural sector experienced in both countries. Innovation rates in both countries within the major industrial crops (soy, maize, sunflower and wheat), measured by registered seeds, went from around 100 new varieties per year in the 1990´s, to around 500 in the 2000´s.

The research confirm what it was suggested by previous studies that, despite the importance of a small number of MNCs in providing some standardized technological solutions contained in seeds (based on two transgenic events: resistance to herbicide and to insects), some domestic enterprises and public scientific institutions in the region are playing a central role in the development of these innovations. An indication of the importance of domestic firms in domestic seeds innovation is the participation of these firms in the ownership of the new IPR registered varieties coming to the market (or market share). In the case of Argentina, for example, for the four most important industrial crops (soybean, maize, sunflower and wheat), within the first five companies, the first three are local; for Brazil within the first ten, 3 are from Argentina or Brazil.

This is surprising with a world seed market increasingly concentrated in a few large MNCs that own almost all patented genes.

The case study evidence shows that the successful domestic firms analysed have followed a trajectory of capability accumulation clearly different to the one followed by MNCs. In particular, a common feature of the domestic firms analysed is that they point to serve a particular need of this market, the need for diversity. They sell diversity and speed of adaptation, not to one particular context, but to enter multiple contexts, which in agriculture is crucial because biology and needs change very rapidly. They have been able to do so, based on a strategy of providing fast response to the changing and diverse demands of farmers of the region. Some of the new characteristics or features embodied in the seeds that they have developed include shorter growing habits, resistance to specific diseases and climate conditions, higher yields, etc.

These firms do not use transgenesis not because they do not have the capabilities to do so, but mostly due to the high regulatory costs associated to this technology. Instead, they privilege flexibility, have invested in horizontal technologies, which can serve different types of innovations and, therefore, have less sunk costs and commitments to one particular innovation relative to the large MNCs (which put most of their efforts in selling and updating the few standardised innovations that have managed). This has allowed them to outcompete MNCs in several markets, even without patented innovations.

Interestingly, the strategy followed by these firms show clearly that firms in NRs from less advanced countries do not follow a similar trajectory to the one followed by firms in manufacturing sector, based on copy, replication and improvement, at least for product innovation. They develop entirely new products every season to satisfy domestic specific demands. With this aim they use some standardised processes, but change them and create new ones. For example, domestic firms create their own molecular markers and their own ways to carry out field testing.

A key development question is, would these companies be able to survive in the next years and further expand? We identified three main restrictions these firms are facing: one is related to expectations, the other is related to regulations and the third is related to capabilities.

Regarding expectations, the huge expectations created around transgenesis, which is one of the existing technological possibilities to modify seeds, is inducing governments in developing countries to perform huge investments in the development of capabilities related to this technology. This does not necessarily constitute a problem for companies that are based in germplasm improvements, such as the ones analysed here. Nevertheless, financial resources are limited, R&D and other forms of support for the development of capabilities in seed genetic engineering means less resources available for alternative options (unless the capabilities can be applied generically across innovation approaches). Beyond that, it is not clear the extent to which these investments might capitalise in benefits. For developing country governments, the promise of highly profitable domestic seed firms specialising in transgenic seed innovation might be tantalising, but it is an option that in practice is unlikely to be available for all but the largest MNCs firms since the barriers to market entry (regarding IPR and biosafety regulations) are very high.

As far as regulations are concerned, IPR systems tend to disfavour companies focused on germplasm improvement in comparison to those focused on transgenic modification. This creates an unbalanced situation between the owner of a plant variety (such as firms analysed here) and the owner of a gene (MNCs), where the former cannot have access to the gene protected by a patent without a license; the later may legally access the plant variety without the breeders' authorization and without compensation. Currently, in the soy market in Argentina, IPR asymmetries generate that MNC owner of the genes pasted in varieties developed in local germplasm, capture a great deal of the value of seeds, whereas domestic firms (Don Mario, for instance) capture a minority of the total value of seeds. There is no evidence, however, that shows that the way the rent is distributed among the different actors is related to their relative contribution to the total value of seeds.

In addition, the high barriers to entry into the "gene business", in which MNCs play a dominant position, generates that countries like Argentina, with a domestic seed market highly developed and domestic seed firms with advanced capabilities in breeding run the risk of both losing these local capabilities and transferring the ownership of local biological diversity (contained in germplasm banks owned by domestic firms) to large MNC (Nidera for instance was during the time of this project sold 51% to Chinese capitals). This is an important challenge for agricultural countries´ policy.

Finally, regarding capabilities, it seems clear from the analysis that further expansion of the domestic companies analysed requires that they develop not only scientific and conventionally understood technological capabilities. This is because they need to adapt to the changing and demanding regulations and institutions that characterise these industries. Accomplishing IPR and biosafety regulations, for example, can be important obstacles for these types of firms to compete and survive in this market.

Governments seeking to support local natural resource-based companies need to set up the right institutions and regulations (such as those related to IPR or market concentration) and need to support the creation of knowledge and skilled workers and supportive infrastructure that is more adequate to the domestic capabilities. But to do so they need to have a broad understanding of the industry and an informed view about its future prospects.

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