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Innovation in natural resources: New opportunities and new challenges

The case of the Argentinian seed industry

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Innovation in Natural Resources: New Opportunities and New Challenges.

The case of the Argentinian seed industry

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Abstract

In this paper, using the case of seeds, we explore the existence of both new opportunities and new challenges for innovation in Natural Resource Based Industries (NRBIs) in developing countries. Conventional views construe NRBIs as low tech, with low technological dynamism, little innovation, and little capacity to create linkages towards other sectors. However, these views are being increasingly questioned. Some authors argue that although NRs have always provided opportunities for innovation and growth; substantial changes in international institutions, markets and technologies during the last two decades or so have created new and a more diverse set of opportunities for a larger number of developing countries to take advantage of their NRs. We contribute to this literature by providing new empirical evidence that helps to better understand these new opportunities. In addition, we suggest that as new opportunities are being created, new challenges also emerge, and countries which do not comprehend fully both of these might lose the opportunity opened by this historical moment of change to become world leader innovators in NRs and related industries. Empirically we study the case of seeds innovation in Argentina – a world agricultural leader with a strong and advanced domestic seed industry. Based on firms' interviews and secondary data we show how the new opportunities created for innovation in seeds have been taken by some companies in the developing world and how some new challenges are questioning the capacity to pursue further some of the new opportunities.

Keywords: Innovation, Natural Resources, Economic Development, Argentina

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1 Introduction

Conventional views construe Natural Resource Based Industries (NRBIs) as low tech, with low technological dynamism, little innovation, and little capacity to create linkages towards other sectors, and even with the capacity to destroy other more dynamic sectors. NRBIs are seen in all these dimensions as inferior to manufacturing activities. This is reflected, for instance, in taxonomies of industries, all of which classify NRBIs as having low technological dynamism (examples of these taxonomies include OECD (1997), Lall (2000) and Katz and Stumpo (2001)).

These views are now, however, being increasingly questioned. Two types of arguments are used to confront them. First, using the examples of some countries, which have managed to grow and develop based on Natural Resources (NRs) (e.g. USA, Canada, Norway), several studies have argued that NRs have always provided opportunities for innovation, linkages and growth. Some countries have taken them, encouraging the right institutions, and have developed based on NRs, but others have not being able to do so. The question thus is: which are the institutions which facilitate the use of NRs to encourage innovation, linkages and development, and which are the ones that limit this possibility? Historical studies are commonly used to analyse this question (Acemoglu et al., 2002; Stevens, 2005).

Second, others argue that although NRs have always provided opportunities for innovation and growth; international institutions, markets and technologies have changed substantially during the last two decades or so, and these changes have created new and a more diverse set of opportunities for a larger number of developing countries to take advantage of their NRs. This literature encourages research to try to understand what are these new opportunities (Perez, 2010; Marin et al; forthcoming). The argument is that although it is important and interesting to understand the path followed by countries which have managed to succeed in the use of NR abundance to develop, it seems crucial also to understand what are the new opportunities that countries rich in NRs are facing.

In this paper, using the example of seeds, we will explore the existence of both new opportunities and new challenges for innovation in NRBI in developing countries. We will suggest that as new opportunities are being created, new challenges also emerge, and countries which do not comprehend fully both of these might lose the opportunity opened by this historical moment of change to become world leader innovators in NRs and related industries.

Seeds are an excellent case to explore both the new opportunities and challenges for innovation in NRs in developing countries because of several reasons. First, they are a key strategic input for agricultural production, an activity central to most developing countries. Second, and maybe more important, the ways in which seeds are developed and sold in the market, have experienced massive changes recently. Changes in world demand, which has become larger and more varied,

and the expansion in the knowledge base, have created new opportunities for agricultural less developed countries to become world innovators in seeds. However, important changes associated to Intellectual Property Rights (IPR), other international regulations (e.g. biosafety regulations) and changes in the world seed market structure, which is getting more and more concentrated, have also opened important challenges for new entrants, which need to be fully understood for the new opportunities to be taken.

The paper has four main parts. In the second part, after the introduction, we discuss the main forces opening new opportunities for innovation in general in NRs. In the following section we use the case of seeds to analyse how these forces are operating in practice and are opening opportunities for some developing countries. In the last section we will discuss, using the case of Argentina – a world agricultural leader with a strong and advanced domestic seed industry-, how the new opportunities created for innovation in seeds have been taken by some companies in the developing world and how some new challenges are questioning the capacity to pursue further some of the new opportunities. Finally, we conclude with some final remarks.

2 New opportunities for innovation in Natural resources and the seed industry

Recent changes in the world economy induced by the Information and Communication Technology (ICT) revolution have been radically transforming some of the conditions under which sectors operate. Many manufacturing industries, for example, which were dynamic and high-tech in the past are now becoming commodities with low technology content and market dynamism (e.g. some electronic goods, the automotive industry, etc.). At the same time many activities within NRBI which were low tech and with low dynamism in the past are now becoming more dynamic (Perez, 2010; Marin et al, forthcoming). Key examples can be found in agriculture, the oil sector and the mining industry.

The literature has identified four set of changes which are creating new opportunities for innovation, dynamism and linkages in NRs in general: changes in the volume of demand, changes in demand requirements, changes in science and technology and changes in the global market context (including institutions, regulations and the strategies of global actors, among others) (Perez, 2010; Marin et al; forthcoming). We briefly outline the main characteristics of these changes below.

a) *Changes in the volume of demand:* The rise of Asia and the incorporation of the so-called second world to the market system have accelerated the rhythm of growth in the demand for energy, food and raw materials to the point of straining the limits of resources (Alexandratos and Bruinsma 2012). This increase in the volume of demand has provided opportunities to increase production via innovation, since the expansion in the production of NRs can come only from a

more efficient and productive use of existing resources (land, mines, fishing areas); the incorporation of new land or the exploration of new mines generally demand higher costs due to large distances and lower productivity or; from the discovery of new uses of natural resources (Andersen 2012) all of which require different types of innovation³. Expectation of rising prices and profitability have throughout the 2000s encouraged investments in such innovations.

b) *Changes in demand requirements*: worldwide demand for less standardised products, more variety and higher quality goods is expanding. This phenomenon not only applies to manufacturing but increasingly also to NRs (i.e. organic wines, more aromatic lavender, tomatoes of different colours, high-quality and sustainable produced lumber, etc.). The large varieties of natural resource products (outputs from NRs) that are offered today for culinary based on unique ingredients, cosmetics based on natural assets (e.g. Amazonia essences), health and decoration purposes was unthinkable two or three decades ago when standardisation predominated and the possibilities of differentiation related to natural resources were not even there. This change seriously challenges the “commodity” notion of natural resource products. The threat of global warming and other environmental and social concerns have also opened opportunities for new demands of a wide array of products and services based on more sustainable patterns of natural resource exploitation, which were virtually non-existent before. These changes in demand have opened new possibilities for innovation creating new niche and premium price markets. Within these niches, innovation is not strictly related to good production but also to conservation methods, certification (e.g. organic certification), packaging, distribution, branding, etc. In addition, it is key to remark that these new opportunities also impact on user industries which have to innovate in order to deal with a larger diversity of flavours, textures, sizes, shapes, compositions etc.

c) *Changes in Science and Technology*: a fundamental change of recent decades has been the phenomenal progress in ICT. Advances in this area by fostering communication and the articulation of producers, suppliers and users located in different parts of the world enabled that local innovations can reach global markets, that the needs and demands of users concerned with very specific issues can be attended from all the planet, that the most remote places can get inserted into global value chains, that knowledge advances occurred in a particular area can quickly reach global spread, among others. Another major change in recent decades has been the emergence of new technologies such as biotechnology and nanotechnology, which are multiplying the possibilities of differentiation and innovation in activities related to NRs. Some important innovations based on biotechnological advances have been, for example, the use of marker-assisted

³ This is a major difference with manufacturing which growing volumes usually imply less costs and lower prices or greater unit profits (due to economies of scale, increasing in productivity, or adding new plants with better technology).

selection in plant breeding, the use of bacteria in mining and the development of new vaccines for livestock and fish. Natural resource producers are massively incorporating these new technologies in the extraction and transformation of natural resources and this is questioning the “low-tech” notion of NRs, as well as forming and deepening linkages towards other industries creating new opportunities for diversification.

d) *Changes in the global market context.* MNC’s behaviour provide one key example of these changes. In the last decades, MNCs have changed their usual behaviour of acting as an enclave (typically in extractive industries) (Singer 1950, 1975) towards adopting a more decentralised way of operating taking advantage of local specialised capabilities in host economies (Marin 2007, Marin and Arza 2009, Cantwell 1995, 2001, Kogut 2002, Dunning 1994, Cantwell and Sanna-Randaccio 1993). Natural resource intensive economies can profit from the MNCs’ new behaviour and even encourage it. But they can also be threatened by them. Another example is the increasing demand for environmentally friendly products from informed and environmentally concerned consumers and the worldwide strengthening and harmonisation of regulations related to environment preservation which is generating a demand for new products and the re-design of existing ones, changes in process towards less contaminant methods, the reduction of industrial waste, the cut in energy consumption, among others.

Several studies have analysed how these changes are affecting the potential for innovation and dynamism in NRs (see Perez, 2010; Marin et al, forthcoming; Kaplinsky, 2009). In the next sections we use the example of the seeds industry to examine how they have affected a particular NRBI.

Seeds are an excellent example to analyse these changes for several reasons. First, they are changing status from a quasi-natural and quasi-public good to a private good with high knowledge and technology content. Second, we cannot continue to consider seeds, as pure natural resources. They have – the commercial seed varieties at least- an increasing component of knowledge intensive services. Third, their market is clearly in times of change, meaning that a single best technology to develop and innovate with seeds has not been selected, not even in advanced country contexts. This is mainly because of the combination of two factors. First, because of the numerous scientific developments in the several knowledge bases connected with seeds, such as genomics and molecular biology, which are permanently opening up different possibilities for new directions of innovation. Second, because of the changing and diverse consumer attitudes and regulations towards the new technologies for seeds development (e.g. genetic engineered crops), which are making it difficult to predict which technologies will be accepted by the market and allowed by regulators (Marin et al 2014).

3 The case of seeds

In historical perspective, seed improvement has evolved from a trial-and-error process, on which plants with desirable traits were crossed and selected based on human observation, to a science-based process, in which genetic, biological and agronomical knowledge is combined to select and create better seed varieties. Historically, seed improvements were performed by the farmers themselves and, later on, by public institutions. Since mid-1950s, however, a significant share of improvements, at least most of those used for commercial agriculture, have been performed by firms. The increasing participation of enterprises in seed improvement and the consolidation of a seed market have been triggered mostly by a) the irruption of hybrids for some crops⁴ (e.g. maize), which meant that firms could more easily recuperate their investments⁵, 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. In the last decades the seed market has become increasingly internationalised and very concentrated around the world.⁶ Few MNCs play a prominent role in the world market mostly through their involvement in the development and commercialisation of transgenic seeds for some important crops (soybean, maize and cotton).

However, changes in demand, technologies and international institutions have also created new opportunities for firms in developing countries to innovate and compete in the seed market. We analyse these changes in detail in this section.

3.1. Changes in demand volume for seeds

According to estimates, demand for agricultural products is expected to grow steadily in the next decades. This upward trend is both explained by a growing population and an increasing demand for energy (FAO 2009). In particular,

⁴ Hybrids are the result of the intentional cross-pollination of two varieties of a plant. The offspring is a hybrid that contains the best traits of each of the parents.

⁵ 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.

⁶ In the 1970s, for instance, 50 US seed companies were acquired by MNCs (Fernando-Cornejo et al. 2002).

demand for cereals (only considering both food and animal feed uses) is projected to rise by 1 billion tonnes (being today nearly 2 billion tonnes) – however, changes in the biofuels market can raise these estimates even more.

There are thus significant transformation pressures for agricultural production to expand. Seeds are a key and strategic input for agricultural production. Improving the quality of seeds is one of the most economical and efficient inputs to improve crop production and productivity (FAO, 2006). Improving seeds are crucial to explain yield increases. According to studies, a substantial proportion (that varies from 50 to 90 per cent) of crops' yield increases is explained by improved seed varieties (others are the diffusion of better agronomic practices) (Santos et al 2001; Santos et al 2004; Schnepf et al, 2001; Spetch and Williams, 1984; Brunis M. 2009). Moreover, as agricultural production expands it is also necessary to adapt seeds to new agro-ecological conditions. According to estimates, almost all of the land expansion in developing countries would take place in sub-Saharan Africa and Latin America. Much of this land, not yet in use for agriculture, is less productive, suffers adverse agro-ecological conditions and is also vulnerable to local diseases and weeds. Thus, innovation in new improved and locally adapted seeds is going to be key to make crop production economically viable in new territories.

Apart from the need to develop seeds to new territories, the continuous modification of the environment (e.g. evolution of disease resistance, development of varieties that perform well in different agro climatic environments, climate change effects) even in territories that are currently used for agricultural production creates a permanent demand for new and improved seeds to maintain or attain higher levels of agricultural production. For example, increasingly reduced rainfalls in Africa demanded the creation of improved seeds that are drought resistant. Other areas, on the contrary, are expected to experience an increase in the level of rainfall (Brunis 2009). The effect of pathogens and insects also demands continuous breeding efforts as, according to FAO data, the current annual loss worldwide due to pathogens is around 85 billion US dollars and to insects at 46 billion US dollars.

3.2. Changes in demand preferences

An important change that affects the seed market is that farmers are becoming more specific regarding their demand 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 (i.e. herbicide or insect resistance) that facilitate the management of agricultural production and allow them to reduce costs. Three examples of seeds innovation that simplify production are (1) RR

soybeans⁷, which made soy resistant to one particular herbicide and reduced the number of herbicides to be applied to kill weeds – at least in principle- and, (2) Brussels sprout hybrids with uniform ripening and size that make them more suitable for machine harvesting and (3) monogerm sugar beet varieties that reduce the need for laborious thinning and enable fully mechanised cultivation (Burnis 2009).

Another change is the increasing demand for more environmentally friendly and healthier products. These changes in demand have created a premium price market: organic and non-GM (e.g. cotton with improved fibre quality and yields, Organic Cotton Association, 2014). For example, some recent seeds' innovations addressing health issues are transgenic tomatoes with high levels of antioxidants which could prevent certain diseases such as cancer, heart attacks and degenerative diseases (developed at the Oregon State University and other variety at the University of Sao Paulo); a new variety of broccoli known as Beneforté, developed at the Institute of Food Research and the John Innes Centre using conventional breeding techniques, which contains two to three times the level of the phytonutrient glucoraphanin as commercial varieties; and rice varieties with higher levels of beta carotene (named "golden rice") which can benefit those affected by vitamin A deficiency.

3.3. Changes in Science and Technology

Until the 20th century, seed improvements relied almost exclusively on a process of trial and error through which plants with desirable traits were selected based on their observation (phenotype selection). This method, commonly known as *cross-breeding*, largely relied on tacit knowledge (i.e. the external appearance and performance of the plant). During the last decades, however, a series of phenomenal advances occurred in areas of knowledge related to breeding activity (e.g. molecular biology) which opened new opportunities to make new kinds of innovations, which are also of more feasible appropriation via IPR instruments (analysed in the next section).

Recent advances in molecular biology, and biotechnology in general, allowed to:

a) *complement traditional cross-breeding based on phenotype selection with genetic information (genotype selection)*. Hence, the application of modern biotechnology to seed improvement allows breeders to obtain and analyse genotype information of plants. Some of the most important advantages of using genotype information is that breeders can anticipate plants characteristics (such as length of the plant, its resistance to certain pests or diseases, etc.) without the need to wait until the plant is fully developed. This, in turn, allows breeders to significantly reduce the length of the breeding process, making it more precise and

⁷ The RR soybean (Roundup Ready) or soybean 40-3-2 is a transgenic variety resistant to the herbicide glyphosate.

efficient. In recent years, the cross-breeding method combined with advanced biotechnological tools has been very successful in producing a variety of heat, drought, flood and disease tolerant traits in key crops such as beans, maize, rice, soy or wheat that have been developed and disseminated in developing countries.

b) *explore new ways of modifying seeds, using genetic manipulation within the same species or from different species (the latter lead to what we know as “transgenic plants”).* Genetic engineering technology can now be used to identify, isolate and transfer gene sequences to a plant with the purpose of providing seed varieties with a code for characteristics that they did not originally have, such as resistance to a particular herbicide. Where 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 obtained are known as *transgenic plants*. Crops modified by transgenic methods are soy, maize and cotton. Transgenic events⁸ applied to these crops which have been commercialised confer them insect-tolerance, herbicide-tolerance and disease-resistance. It is key to remark that the use of genetic engineering to produce new transgenic plants has generated great expectations about what the technology may be able to achieve in the future creating incentives for massive investments in innovation.

⁸ A transgenic event refers to the unique DNA recombination event that takes place in one plant cell, which is then used to generate entire transgenic plants.

Box 1: Seeds improvements based on molecular biology

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. An excellent example of seeds' innovation based on mutagenesis is that of the rice with high yield and resistant to imidazolinone (a herbicide commercialised by BASF), Puita-INTA-CL, developed by the Argentinian National Institute of Agricultural Technology (INTA). This rice variety, patent protected in several countries (Argentina, Brazil, Colombia, Costa Rica, India, Italy, the Dominican Republic, Thailand, Uruguay, and the USA), allowed for the selective control of weedy red rice, which is one of the main problems faced by rice producers over the world. This mutant variety has been largely adopted in Argentina and other Latin American countries.

3.4. Changes in the global market context.

Several important changes in the world market context and institutions have altered the opportunities for seeds innovation. However, these changes are affecting the opportunities for innovation and entry to this market in a different manner to different actors and countries.

The first and more important is the change in IPR regulation that affects the possibilities of private appropriation of seeds. The second is the associated change in the global market structure, in which large MNCs dominate the transgenic market. The third and last one we are going to analyse is related to changes in consumer attitudes towards the different technologies available to improve seeds.

3.4.1. Institutions: IPR regulations

IPR regulations surrounding plants are very complex and controversial, because they involve appropriation of parts of nature. Hybrids plants offer companies a way of assuring technical appropriation for some crops, however, most crops are self-pollinated and require some kind of legal protection. 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 property rights regime modelled on a 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.⁹ 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). The TRIPs agreement consisted of a new international standard on the protection of intellectual property, which was significantly higher than earlier standards, and also broader as included intellectual property protection for plant varieties. 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.¹⁰

This put developing countries under pressure to establish some kind of IPR system to protect seeds innovations however, they still have still 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 appropriability. 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 modify their research plans (Tripp et al, 1997, Gutierrez y Pena 2004)

⁹ The US led 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).

¹⁰ 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.

3.4.2. Industry structure: World market concentration of transgenic events

As a result of the significant changes in the knowledge base, technology and IPR regulations, the seed industry has become very concentrated. Only a few MNCs own the majority of plant-related patents, have pushed innovations in a particular direction (the transformation of plants by genetic engineering methods to obtain transgenic seeds) and were able then to take advantage of the new opportunities (Fernandez-Cornejo et al 2002, Fernandez-Cornejo 2004, Schenkelaars et al 2011). Nowadays, the market of transgenic events is fully controlled by six companies, called the "Gene Giants" (Monsanto, Syngenta, Novartis, Bayer, BASF and Dupont). They control 66% of the world market and 84% of the patents. Most of these MNCs have their origins in the pharmaceutical, chemical or food industry, and have entered the seed business (mostly acquiring smaller seed firms) attracted by (a) the potential complementarities (between crops and agricultural inputs), (b) the new IPR regulations regarding plant varieties and (c) the expectations generated by scientific advances in biotechnology. They have the size and resources to face the large investments in R&D to identify and isolate genes that can then be used to develop transgenic seeds (e.g. a gene that confers plants resistance to draught or to a certain herbicide), and, what is more important, they can afford the cost of regulations and GM approvals.¹¹

Public institutions and domestic firms in developing countries, however, still play an important role in this market. First, because not all demanded innovations are transgenic or can be performed with transgenesis (productivity increases for instance, since they are explained by a multiplicity of genes interacting that cannot be tackled with the identification, isolation and transfer of a single gene); second, because not all markets accept transgenic crops and; third, because transgenic events, perform well only when they are introduced into existing seeds that are well adapted to local ecological, and these backgrounds are typically obtained by cross-breeding techniques and owned and developed by local breeders (public institutions of agricultural research and private companies).

The presence of local small and medium local firms and institutions, however, as we will discuss in the next section, which is crucial to provide local adaptation, diversity, and market competition, is threatened by several factors: (i) the trend of the seed market to get more concentrated, (ii) the disequilibrium existent between the levels of IPR protection that receive genetic engineered events and germplasm improvements in some countries, and (iii) the tendency of policy makers to support and encourage genetic engineering technology mostly on the basis of the large expectation that this technology generates.

3.4.3. Values/institutions: Consumer attitudes towards GM technologies

Transgenesis is well accepted in general to produce crops for animal food or biofuels. However, consumers are not keen to consume food produced using this

¹¹ Regulatory costs to bring a GM crop to the market can vary from 15-30 million US dollars to 100-180 million US dollars. Similarly, the estimated regulatory compliance costs for GMO approvals vary from 10-30 million US dollars to 80-110 million US dollars (Schenkelaars et al 2011).

technology, at least in large parts of the world. Transgenesis indeed is 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.

4. Taking advantage from the new opportunities but facing new challenges

In this section we will show how the new opportunities created for innovation in seeds have been taken by some companies in the developing world, using the case of Argentina, and how some new challenges are questioning the capacity to pursue further some of the new opportunities.

Box 2: Data and methodology

The empirical analysis of this section draws on data from scientific and policy documents; evidence that we collected from interviews with both: seed companies based in Argentina (Don Mario, Nidera, Bioceres, ACA and Santa Rosa) and researchers from the National Institute of Agricultural Technology (INTA). In addition, data on agricultural production and cultivated area was obtained from the Argentinian Ministry of Agriculture (<http://www.siaa.gov.ar/>).

The main indicator of innovation used, PVP certificates, was obtained from plant registration data compiled by the National Registry of Property of Varieties (RNPC) (www.inase.gov.ar). Plant breeders that wish to protect their varieties under the intellectual property rights system for seeds in Argentina must apply for this registration. The RNPC contains information, for each plant variety, on the name of the breeder, the year in which property rights were requested, the country of origin of the variety, the plant variety maturity group to which it belongs, and whether or not the variety is transgenic. Information on market data is based on certifications on seeds that were placed on the market each year. This data was provided by Asociación Argentina de Protección de las Obtenciones Vegetales (ArPOV) (www.arpov.org.ar)

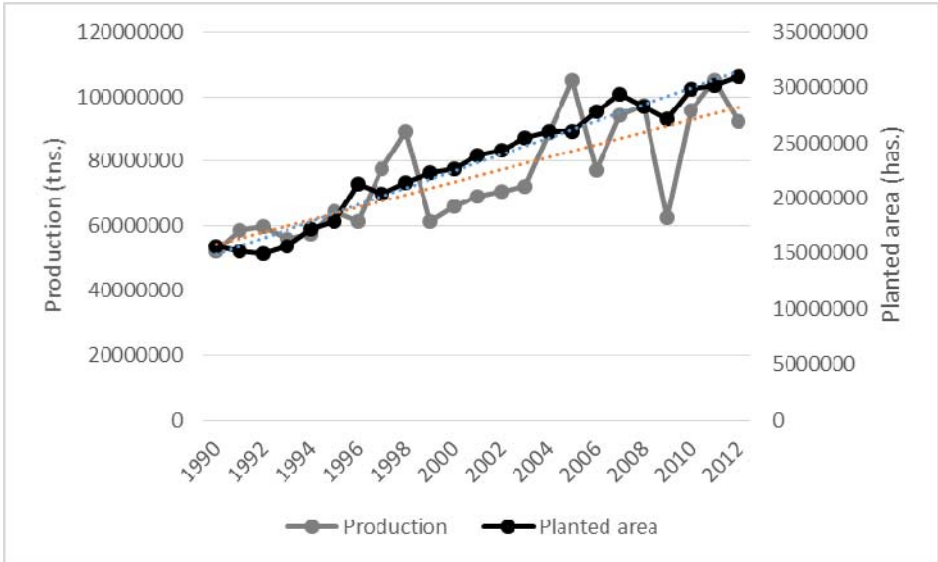
Information on the strategy of local seed firms was based on two case studies: Don Mario and Bioceres.

Don Mario is an Argentinian 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. Currently, the firm has 32 per cent of the Argentinian soybean seed market and 25 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.

Bioceres is a small R&D intensive firm, which is closely linked, through R&D agreements, to public research institutions and universities. The company is mainly advocated to the gene business: discovery and isolation of genes. Its target is to develop traits. It has three patents in the US and export technology to foreign multinationals.

Argentina is a world leader in agricultural production and a pioneer country in the adoption of high-tech inputs in this sector. It has recently expanded agricultural production massively based on the incorporation of new land and the intensification in the use of high technology inputs (see Figure 1).

Figure 1. Argentina: evolution agricultural production and planted area of four main industrial crops (soy, maize, sunflower and wheat) (1990-2012)

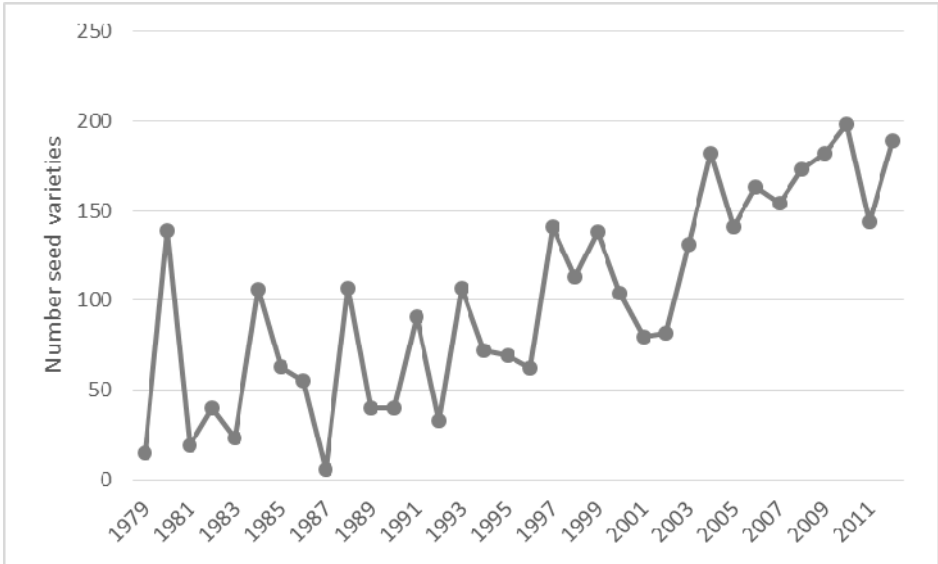


Source: Own elaboration based on data from the Ministry of Agroculture, Argentina. (<http://www.siaa.gov.ar/>)

Together with the massive expansion in agriculture, the rate of seed innovation has expanded significantly in Argentina. Figure 2 shows the increase in the rate of innovation within the four major industrial crops (soy, maize, sunflower and wheat), measured by IPR registered plant varieties, which increased from around 50 new varieties per year in the 1980's, to around 200 in the 2000's.

An important phenomenon that has characterised the seed market in Argentina during this expansion has been the diffusion of transgenic events. Between 1998 and 2013, 29 transgenic events were approved in this country. These provided soy and corn seeds resistance to 3 herbicides (Glyphosate or Imidazolinone or Glofosinate ammonium) and resistance to 2 types of insects (Lepidoptera or Coleoptera) and combination of some of them (the so called "piled events"). These traits have been incorporated (or pasted) into domestic varieties and massively diffused within corn and soy. As a result of this diffusion, Argentina, with a planted area of 24.4 million hectares, is now the 3rd world producer of transgenic crops.

Figure 2: Argentina: seeds' innovation – new varieties IPR registered* for four main industrial crops (soybean, wheat, corn and sunflower) (1979-2012)



Source: Own elaboration based on the data from INASE. www.inase.gov.ar

Since these transgenic events have been developed by a few MNCs (the so called six Genetic Giants), many observers have argued that these companies have been the main seed suppliers and have driven the process of seed innovation (e.g. Bisang, 2003; Trigo, 2011). A careful analysis of the data, however, reveals a different situation. If we explore the number of new plant varieties registered for the major crops, and the market shares of new varieties by company in Argentina, between 1997 and 2013, the two firms that registered most varieties are from Argentina (Nidera and Don Mario). In the top five, three are Argentinian (Nidera, Don Mario and ACA) (See Table 1).

Table 1: New seeds of four main industrial crops (soybean, wheat, sunflower and corn) IPR registered and sold in the Argentinian seed market by firm (1997-2013).

	Companies	PVP Certifications	Share
1	Nidera**	6460596	30,76
2	Don Mario*	3414201	16,26
3	Monsanto****	2139732	10,19
4	Sursem***	1084589	5,16
5	ACA*	997442	4,75
6	Pioneer ****	974964	4,64
7	Klein*	849392,6	4,04
8	Syngenta ****	788132	3,75
9	Bioceres*	607378	2,89
10	Dow Agrosciences ****	581151	2,77
11	Buck*	497981	2,37
12	Seminium ***	359275	1,71
13	Ferías del Norte*	289522	1,38
14	Santa Rosa*	256558	1,22
15	La Tijereta***	250325	1,19
16	Lealsem**	238936	1,14
17	SPS***	231222	1,10
18	Advanta****	148874	0,71
	Others (41)	831552	3,6

Source: Own elaboration based on the data from INASE

Notes: (*) Domestic Companies, (**) Mixed companies (local and foreign capitals), (***) Domestic Companies fully acquired MNCs, and (****) MNCs.

Despite the dominance of some foreign MNCs in the Argentinian seed industry, the participation of domestic firms is possible due to the way in which seeds are developed nowadays. Hence, most of the new seeds registered and sold are, similarly to a telephone or a computer, an assembly of different components: (i) a transgenic event (obtained and owned typically by MNCs); (ii) a number of other new traits obtained by cross-breeding and other technologies such as mutagenesis (such as resistances to new diseases, indetermination, short cycle maturity, etc. all of which enhance the productivity of the new seeds), mostly developed in the case of Argentina by domestic firms; (iii) and all the other characteristics embodied in the seeds that derive from years of improvements in plants by farmers, companies and public institutions (each plant has around 28000 gens).

Domestic firms typically license transgenic events from MNCs, “paste” them to their own varieties and, then using cross breeding techniques (assisted by modern biotech tools) and advanced forms of mutagenesis, develop new varieties that

reach the market every year, embodying multiple innovations. The most innovative firms, which have managed to bring to the market each year improved varieties highly demanded by the domestic farmers, have managed to gain dominant positions in the market (between 1997 and 2012 yields in soy, that can be exclusively attributed to improvements by cross-breeding, increased 32%).

Box 3: The context; local accumulation of capabilities in seed breeding in Argentina

The importance of domestic firms in Argentina in seed breeding is associated with a long breeding tradition in the country. Public sector and commercial seed breeding activities started very early in Argentina. By the 1930's there was already a relatively dynamic seed market of both local private companies, and public experimental stations (Gutierrez, 2006). Three decades later, foreign seed companies entered the local market, the first being Cargill in 1947 (Gutiérrez, 2006). Very shortly after, plant breeding started to be regulated in Argentina by laws that were designed to make the seed market more transparent and to protect farmers' interests (new plant varieties had to be assessed and authorised prior to their diffusion in the market). By 1970s, the seed market was sharply divided between foreign firms that focused on hybrid varieties (mostly corn), and local firms and public institutions that developed new plant varieties in non-hybrid plants (mostly wheat) (Gutiérrez and Penna, 2004). However, this division soon began to be blurred as local companies learned about hybridization.

Today, Argentina is the 9th largest seed market in the world, valued at 600 million dollars, and is the world's 11th largest seed exporter. Plant breeding is mostly performed by the private sector which has an annual turnover of 772 million dollars (ASA, 2012). There are about 40 seed companies which produce seeds for a wide variety of crops. The market is dominated by three different kinds of players: MNCs, domestic companies and the National Institute of Agricultural Technology (INTA) which is the state agricultural research institution. INTA produces knowledge useful for the sector, which is then licensed to other firms, both domestic and foreign, who commercialise the seeds. Despite the importance of INTA for the seed market (e.g. it owns 50% of new seed varieties), this institution does not trade seeds itself.

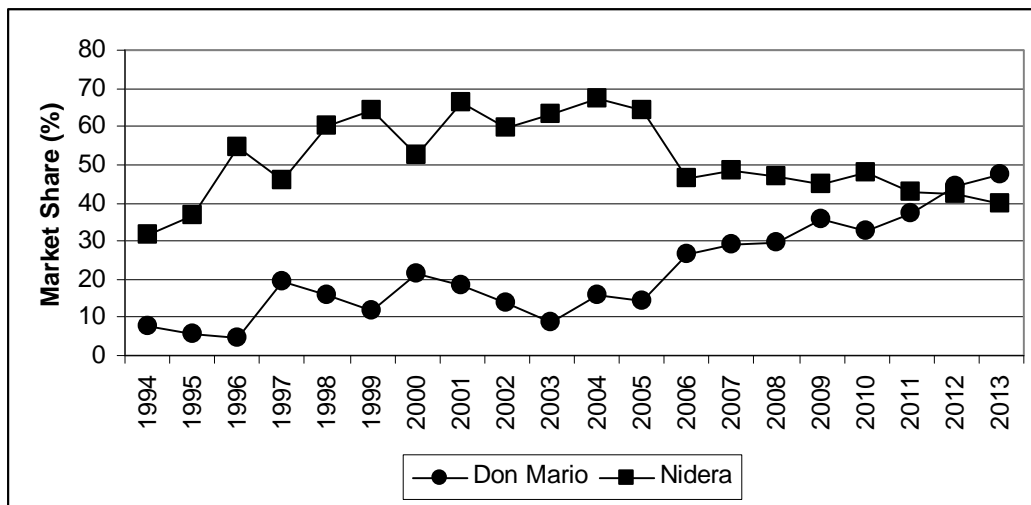
Although MNCs have gained a prominent role in the seed market, especially in the wake of the economic liberalization of the agricultural sector in the 1990s, domestic firms have developed strong capabilities in breeding technologies and have maintained a key role, together with INTA, at least for some crops. Local firms typically buy biotechnological events from, 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 90% of the market).

Argentina adopted IPR legislation for plant varieties in 1973. In the early 1990s, that legislation was modified so to adhere to UPOV 1978's plant variety protection scheme. Patent law in Argentina allows isolated gene sequences with known function, such as the novel genes introduced into transgenic seeds, to be patented. As with most other countries, with the exception of USA and Japan, Argentina does not allow the patenting of life forms (such as seed varieties) and/or genome (or genes), as found in nature.

The case of *Don Mario* is a good example. *Don Mario* is an Argentinian company dedicated to the development of new varieties of soybean. The firm has managed to gain a significant share of the domestic market not only in Argentina but also

abroad. The company, with subsidiaries in Brazil, Bolivia, Uruguay, Paraguay (and more recently in the USA) had in 2013 almost 50% of the Argentine soybean market (other 40% was served by another Argentinian/Dutch company *Nidera*, around 25% of the total Brazilian market and 57% of the South of Brazil, where the company is named *Brasmax*, and an estimated 25 % market of all the LAC soybeans market (See Figure 3 and Figure 4).

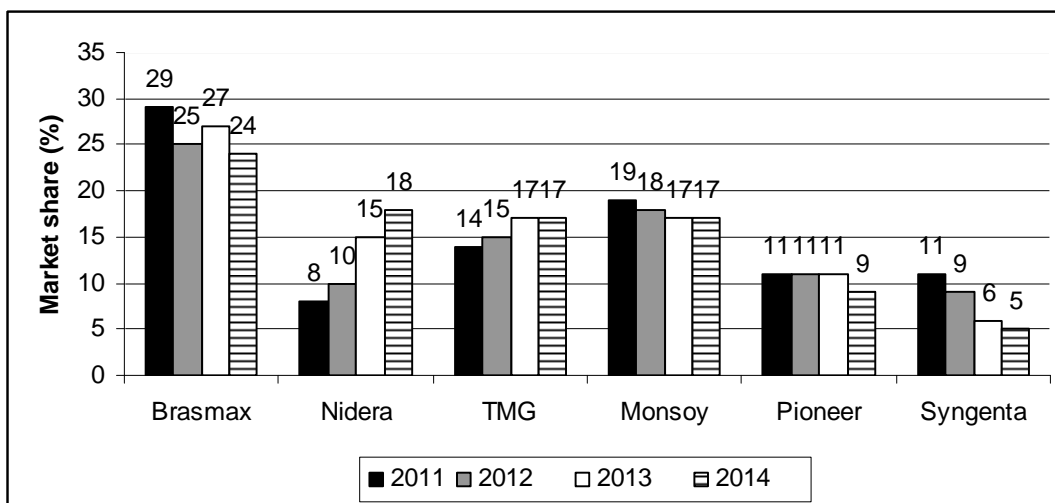
Figure 3 – Market share of leading companies in the Argentinian soy seed market (1994-2013)



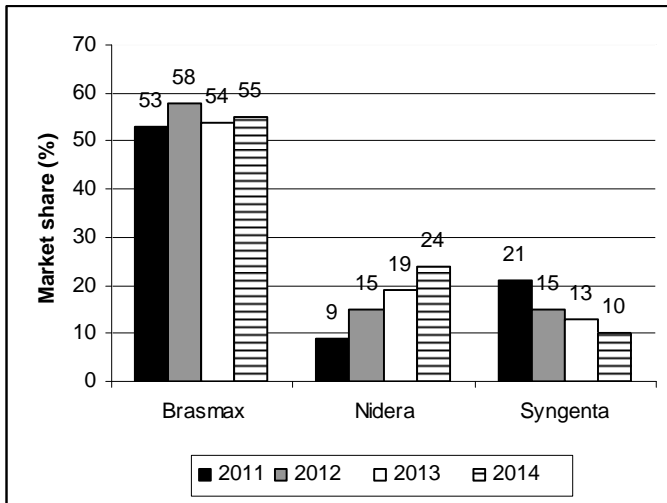
Source: Own elaboration based on certified seed. ARPOV (www.arpov.ar)

Figure 4: Market share soybean seeds Brazil – country total (a) and south region (b)

(a)



(b)



Source: Data provided in the interviews with company managers from Don Mario, from <http://www.kleffmann.com/en/>)

Don Mario is deliberately not involved in the development of "transgenic events". The strategic decision is mostly related to the enormous costs of complying with regulatory biosafety requirements and patenting of transgenic events.. The company, however, performs cross breeding relying on advanced biotech tools (e.g., molecular markers) and on a complex network of experimentation that spread all over the soy regions in Argentina, the south of Brazil, Paraguay, Uruguay, Bolivia, South Africa, the US and some European countries. Table 2 shows the improvements achieved by the company in crucial dimensions key to the process of innovation in seeds well adapted to different agro-ecological conditions. These innovation efforts have resulted in significant genetic gains, e.g. it has been estimated that yields of its soy varieties have increased on average 1.63% per year, and 22.84% in total, during the period 1998-2013.

Table 2 – Evolution of Don Mario innovation efforts (1997-2013)

	1997	2013
Soybean Varieties developed in experimental phase per year	8,500	400,000
Number of experimental Plots	30,000	1,100,000
Number of locations of experimentation	5	70
Breeding time (average)	12/13 years	5/6 years

Source: Own elaboration based on information provided in the interviews.

Don Mario has no patents, since it is not involved in the genetic business. However, is one of the companies with the largest number of soybean varieties registered in the Argentine market (in the period 2000-2013 it accounted for 26% of all registered soybean varieties at the RNCP).

This is a company, thus, it can be argued, that has been able to take advantage of the new opportunities opened by the expansion of a natural resource intensive industry in Argentina and have done so despite the massive diffusion of transgenic events which were controlled by a few MNCs.

Another interesting case is *Bioceres*. The company was created in 2001 by a co-operative of 23 agriculture producers belonging to two important agricultural trade organisations, the *Asociación Argentina de Productores en Siembra Directa* and the *Asociación Argentina de Consorcios Regionales de Experimentación Agrícola*. The aim of the initiative was to improve linkages between biotechnology research, that was being conducted mostly within public institutions (INTA and Universities), and the needs of industrial farmers in Argentina. This company, differently from Don Mario, has opted to focus on the transgenic market. In 2008 the company created its own research lab, INDEAR, which was the result of a public-private alliance with Argentina's National Research Council (CONICET), almost entirely funded with public funds, and fully dedicated to gene discovery. As one of the interviewees explained:

“INDEAR has pursued the development of our own technological platform... it is an alternative to 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”.

A major achievement has been the granting of three patents by the US Patent and Trademark Office. The first, based on collaboration between the firm, CONICET and the National University of Litoral, was for a gene enhancer that confers resistance to hydride stress and salinity, and which was subsequently licensed to the MNC Advanta. The second was for a gene enhancer that increases the expression level of genes in plant cells, and the third is for a gene which confers shorter life cycles and tolerance to oxidative stress.

At present, however, Bioceres has not been able to introduce its transgenic events into their own germplasm because the event has not been approved for commercialisation yet and they had to license them to other large MNC, Advanta. For this reason, they continue to buy transgenic events from MNCs and backcross them into their own seed varieties. One of the main problems they face concerns patenting and complying with biosafety regulations, both of which are very demanding processes that require skills, time and resources which most small and medium companies do not have. They are developing alliances and subcontracting with international companies to help them with these processes, but our interviewees stressed that patenting and regulatory hurdles are still serious restrictions.

4.3. *Considering the challenges*

We discussed two companies, and two completely different models of entering this market. The question is, would these companies be able to survive in the next years and further expand? We mentioned before some restrictions they are facing. In this section we discuss them more in detail. These are of two types: related to expectations and related to regulations

Transgenics generate huge expectations. The evident novelty of genetic engineering techniques, and very significant investment in the technology by some of the world largest R&D intensive firms, no doubt contributes to these expectations. However, they are to a large extent related to promises about the technology that were not fulfilled so far. 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). The second is that genetic engineering can improve the *outcome* of seed innovation. It is striking, however, how little evidence there is in support of that claim. In the early 1990s, advocates of the technology claimed, for example, that increased yields, tolerance of drought, more efficient use of fertilisers, and ability to produce drugs or other useful chemicals were all forthcoming. Such expectations

have declined considerably in recent years because 25 years of investment and global effort have basically delivered only two single trait types, herbicide tolerance and pest resistance. Furthermore, while these traits have helped to reduce uncertainty and costs, and have simplified management, they have had no overall effects on intrinsic yield (Qaim 2009).

As a consequence of this high expectations, however, governments in developing countries, such as China, India, Brazil, Argentina, Egypt and South Africa, are performing huge investments in the development of capabilities related to transgenesis, in an attempt to 'catch up' with what is seen as the leading technological frontier in seed innovation (Ministerio de Economía y Producción 2004; Pray and Naseem 2007; Uctu and Essop 2013). The support provided by the Argentinian government to the company Bioceres, which funds its research activity almost entirely with public funds, is a clear example of these kind of policies. This does not necessarily constitute a problem for companies like *Don Mario* that are based in germplasm improvements.¹² Nevertheless, financial resources are limited, and R&D and other forms of support for the development of capabilities in seed genetic engineering means less 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 are so high. The regulatory costs of commercialising transgenic seeds are formidable. Food safety and environmental bio-safety testing for transgenic seeds (which are not required for seeds created using cross-breeding or intra-genic approaches) can exceed by up to an order of magnitude the R&D costs. Estimates from other developing countries of the direct regulatory costs to firms seeking to gain a licence, i.e. the costs of providing the necessary data, range from 100,000 to 4 million dollars, depending on the jurisdiction and crop-event combination, and on whether there already exists, for example food safety or composition data, as a result of prior applications in other countries. Furthermore, whilst it is typically the case that R&D costs of a new technique decrease over time, sometimes quite substantially, regulatory costs are unlikely to and may well increase. The outlook for the structure of the transgenic seed industry is reminiscent of that for innovative pharmaceutical firms, where high regulatory costs have helped to create an oligarchic industrial structure. The

¹² Indeed different seed innovation strategies may not be incompatible with one another (except where contamination of non-genetically engineered seeds or crops with trans-genes has implications for seed input and/or crop output markets).

strategies and experience of our case study firms back up these points. Thus, Don Mario, despite being a strongly innovative and science intensive firm is not interested in entering into the transgenic seed business because it lacks the scale and the financial resources to afford the regulatory costs involved. Although *Bioceres* is in the transgenic seed business, it faces problems complying with patenting and bio-safety regulations, and needs alliances with much larger international companies to enable it to do so¹³.

In addition, IPR systems in Argentina, like in many other countries, however, clearly disfavour companies like Don Mario which focus on plant variety improvement (germplasm improvement) and not on transgenic modification. Nowadays in Argentina, for instance, IPR that affect plant breeding are regulated by UPOV 1978 which gives a level of protection substantially lower than patents. But, gene sequences with known functions, such as novel genes introduced into transgenic seeds, can be patented. This creates an unbalanced situation between the owner of a plant variety (mostly domestic firms such as Don Mario) 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' authorisation and without compensation.

Currently, in the soy market in Argentina, IPR asymmetries generate that Monsanto, which is the owner of the traits that are being pasted in the local germplasm, captures 66% of the value of soybean seeds whereas the other 33% is shared between the developers of the germplasm (Don Mario, for instance) and the firms that multiply 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. On the one hand, transgenic traits that confer to plants resistance to certain herbicides help the farmers to reduce production costs but, on the other hand, improvements in germplasm has impacted more on soybean yield's increases (Marin et al 2014). Local seed firms claim for the strengthening IPR that apply to improvements in germplasm (for instance by adherence to UPOV 91) which would reduce the asymmetry between them and the owners of the genes. However, others claim that the full privatisation of seeds, that would impede that farmers save seeds for own consumption (the "farmers

¹³ In addition to high market-entry costs there are a number of other reasons why, for developing country seed firms, the transgenic approach may be limited or risky. These include the fact that high regulatory costs mean that large markets are required to justify the development of novel traits. For firms interested in breeding crops grown for relatively smaller markets, transgenic technologies may not be commercially viable. In addition, concerns about potential, but difficult to predict, adverse effects of transgenic crops and food on biodiversity and/or human health have meant that markets for the products of transgenic plants do not currently exist in some jurisdictions, most notably in Europe. Likewise, some crops that are only used in human food stuffs, such as wheat and rice, currently have no potential market in transgenic forms; indeed the entire market for transgenic crop products is vulnerable to the discovery of future adverse negative effects in ways that are not anything like as risky for alternative approaches to seed innovation.

privilege" that it is conferred under UPOV 78), would go against biological diversity and food security. In addition, we do not know beforehand whether adopting stronger IPR would certainly encourage further innovation activity by local breeders.

This could be addressed by moving in the direction of increasing or making the IPR system that regulates improvements in germplasm more similar to the patent system, this change however is widely resisted in the country because is thought to be problematic for small farmers, since their rights to replant will be restricted and because of issues of biodiversity and food sovereignty.

Meanwhile the large MNCs gain increasing market power. In the case of crops with approved transgenic events (like corn, cotton or soybean) MNCs play a dominant position in the market of transgenic traits. This is mostly due to their capacity to fund the cost of all biosafety and patent regulations that these innovations require to reach the market. However, MNCs do not only sell traits, they are also attempting to expand into the germplasm market buying small and medium seed firms in developed and developing countries. 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. This is an important challenge for agricultural countries' policy. Setting up the right institutions and policies become crucial. But, are countries such as Argentina or Brazil able to prevent the advance of monopoly positions in the domestic seed market by MNCs? In the context of the world standardisation of IPR regulations and the lobby of MNCs which threaten to leave the countries where their conditions are not satisfied, would developing agricultural countries be able to enforce regulations that protect their local productive and technological capabilities as well as their local biological diversity? Furthermore, what regulations are more suitable for the further development and protection of the local seed industry in these types of countries?

5. Final Remarks

This article analysed new opportunities for innovation in a NR activity, the activity of developing new seeds which is transforming very rapidly. Seeds used to be a natural public good and are now transforming into a knowledge intensive product, which contain a multiplicity of new technology services. New technological possibilities have appeared to develop and embody these services in seeds and an increasing demand is favouring the application of the new knowledge and new technologies to develop different types of innovations in seeds.

Countries like Argentina which have an important and well developed agricultural sector, a history of breeding and important public institutions of agricultural technology are in a good position to take advantage of the new opportunities. We have showed in the case of Argentina, indeed, that a few domestic firms have gained important positions in the regional market based on a significant investment in innovation.

The two case studies show different strategies to compete in the seed market. One of the firms analysed (Bioceres) focus on the transgenic market. It aims at providing solutions to agricultural problems by making use of transgenic modifications of plants. That is, by developing standardised solutions in the form of new transgenic traits, which can then be pasted to local germplasm (e.g. locally adapted plant varieties) elsewhere. The other firm, Don Mario, follows a very different strategy. It has gained capabilities in genotype selection (by using modern biotechnology techniques) which combines with phenotype selection so to develop improved seeds adapted to different agro-ecological conditions. Thus, Don Mario, which have deliberately not opted for the transgenic option, shows that companies from developing countries can take advantage of the differences in domestic agro-ecological conditions to compete with MNCs (instead of providing standardised solutions). They could serve domestic markets better than MNCs by meeting the specific local demands that emerge in association with the differences in agro ecological conditions that characterise natural resource production.

However, further expansion of domestic companies in developing countries (in the two type of cases analysed here) requires that firms develop different kinds of capabilities, not only scientific ones. Firms need also 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 also 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.

A key question is thus, can developing countries develop the capacities and institutions to address these challenges in a creative manner, in the context of a global economy every time more “regulated” by international agreements?

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