DIFUSSION PROCESS IN NETWORKS: The case of transgenic soybean in Argentina

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1. INTRODUCTION.

The aim of this paper is to analyse the diffusion of new technological package in the Argentinian agricultural sector, most specifically the widespread use of genetically modified (GM) seeds. The sector has in recent years been caught up in a race to adopt and adapt new technology of product and process both, principally in soy, maize and wheat. The process has been particularly rapid in soy production. Attracted by the expansion of external markets and supported by a favourable domestic policy, production with conventional technology increased rapidly up to the mid-1990s, reducing the technology gap with other countries. This was complemented by changes seen elsewhere, namely in a greater use of fertilizers and pesticides and the spread of zero tillage as a predominant technology process. In 1996, Argentinian authorities launched the first GM soy seed. The new seed contained a gene resistant to glyphosate, a herbicide affecting a wide range of weeds except the modified soybean. The new seed, known as RR soybean, was made widely available due to lax Argentinian property right laws, and was quickly adopted along with zero tillage techniques and other minor changes. This new technology package allows a reduction in production costs, permits double cropping (wheat/ soybean) and pushing further the farming land frontier.

The result has been an quick economic and productive performance from the agricultural sector as a whole: soybean crop yield has increased threefold since 1996, reaching almost 30 million tons in recent years. Driven by the external market, this accounted for almost 20% of total exports from Argentina in 2002. The area of cultivated land using the new technological package of zero tillage and RR seed has risen considerably, replacing traditional crops (sunflower, maize) and other activities previously competing for the same land (extensive cattle production and dairy products) both in the corn belt and areas outside of the pampas. In six years RR soybean has replaced conventional varieties, covering more than 90% of total land allocated to soy.

The aim of this paper is to analyse the process of the diffusion of the new technological package -centred on GM seed use- from a network perspective (Freeman, 1991, Camagni, 1991; Chesnais, 1985). To do so, it will consider the common goals of different actors involved in several stages of the soybean network: farmers (landowners or otherwise), seed designers, producers, public R&D-oriented institutes, machinery suppliers, and large multinational businesses involved in the production and

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diffusion of bio seeds, biocides and zero tillage procedure. The changes in structure of agriculture activity and in the way of organization of the production running on support of the diffusion of new technological package too. At last, the diffusion process of the new technological package, took place encompassing the goals of the agents of the networks. It dynamics gives a high speed to the diffusion process and it re shaped the internal hierarchies of the soybean network too.

2. AGRICULTURE IN ARGENTINA: FROM STAGNATION TO FAST DEVELOPMENT

2.1. Productive performance of Argentinian agriculture in the 90s

Argentina's wealth of natural resources and technological capabilities allowed the agricultural sector to reach a sizeable market in several crops during the last decade of the 19th century. Less dynamic was its performance five decades later in the so-called *green revolution*. In fact, Argentina's agriculture lagged behind the rest of the world in the adoption of fertilizers, hybrid seeds and the wider process of mechanization between 1950 and 1980. In the ISI strategy for industrial development, the primary sector performed badly due, according to different perspectives, to the behaviour of local farmers, unattractive relative prices affected by tax on external trade, incentives from other investments and an inhospitable macroeconomic environment. As a result, at the beginning of the 1980s, domestic agricultural production levels were similar (in tons) to those of the 1960s. External market participation in main crops and meat declined, and the number of people working in agriculture dropped.

Currently, domestic agricultural production seems to be re-engineering its capacity. Total production of grain and oil has risen from 35 million tons in 1990 to almost 71 million ten years later.

TABLE 1. TOTAL AGRICULTURE PRODUCTION. ARGENTINA 1980/81 - 2001/02

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Crops	1980/81	1990/91	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02
Sunflower	1.260.000	4.033.800	5.558.000	5.450.000	5.600.000	7.100.000	6.000.000	3.200.000	3.843.579
Maize	12.900.000	7.684.800	10.518.000	15.536.000	19.360.000	13.504.110	16.816.980	15.660.000	14.712.079
Soybean	3.770.000	10.862.000	12.448.000	11.000.000	18.732.000	20.000.000	20.206.600	26.882.912	31.000.000
Sorghum	7.550.000	2.252.400	2.132.000	2.499.000	3.762.335	3.221.750	3.505.163	3.100.000	2.847.225
Wheat	7.780.000	10.991.900	9.445.000	15.914.000	14.830.230	12.443.000	15.302.560	15.918.432	5.291.660
Others	2.407.852	3.159.300	3.716.443	3.557.000	4.332.185	3.770.820	2.984.186	3.361.705	2.895.685
TOTAL	**35.667.852**	**38.984.200**	**43.817.443**	**53.956.000**	**66.616.750**	**60.039.680**	**64.815.489**	**68.123.049**	**70.590.228**

SOURCE: SAGYPA.

This trend is most notable in soy, wheat and maize production. Soybean production is the leading example: launched in the 1970s, by the beginning of the 1980s production reached 4 million tons yearly, exceeding 10 million tons by 1990 and currently reaches 30 million tons. Soybean production accounts for almost 50% of total agriculture in tons, and 20% of all Argentinian exports.

How can this dynamic behaviour be explained?

Firstly, total land allocated to primary production has not changed at the same rate over the same period. In fact, by 1996 the total land used for crops was around 21 million hectares, in addition to 5 million hectares for extensive meat and dairy production. In the last five years, the total land devoted

to agriculture has increased to 25 million hectares (in addition to 3.5 million for other activities). In other words, crops have superseded meat and dairy production and enlarged production boundaries, although this does not entirely account for production increases.

Secondly, the total average yield per crop has increased slightly. Soy, wheat, maize and other crops have generally shown even growth. Nevertheless, average yield is not a good measure of performance. In fact, the advance of new crops on marginal areas trend to reduce the average yield, although some reports show that recent yields are similar to international levels in the corn belt area.

Third, the agriculture trend is close connected with soybean performance. In the early eighties, total production reached 3,7 million ton. sown on 3,6 million has using a conventional technology available (rotation, local varieties of seeds, and a low use of pesticide and fertilisers). Attracted by the expansion of external market and supported by a favourable internal policy framework, the production grew fast up to the middle 90's using a conventional technology and closing the international technological gap. In parallel a smooth change occurred in a complementary technology: major use of fertiliser and pesticide and the diffusion of zero tillage as main technology process.

TABLE 2. SOYBEAN: ZERO TILLAGE, BIOCIDES AND TRANSGENIC SEEDS USED. ARGENTINA, 1980/2002

Year	Total sown - Has	Zero Tillage - Has	Zero tillage total swon - %	Glyphosate comsuption - millon Htl	Transgenic Seeds - Has	Trasngenic Conventional - Seeds -%-	Total Production - Tons
1980/81	1925000	0,0	0,0	s/d	0,0	0,0	3770000
1981/82	2040000	0,0	0,0	s/d	0,0	0,0	4150000
1982/83	2362000	0,0	0,0	s/d	0,0	0,0	4000000
1983/84	2920000	0,0	0,0	s/d	0,0	0,0	7000000
1984/85	3300000	1000	0,0	s/d	0,0	0,0	6500000
1985/86	3340000	1500	0,0	s/d	0,0	0,0	7100000
1986/87	3700000	6000	0,2	s/d	0,0	0,0	6700000
1987/88	4413000	22000	0,5	s/d	0,0	0,0	9900000
1988/89	4670000	50000	1,1	s/d	0,0	0,0	6500000
1989/90	5100000	80000	1,6	s/d	0,0	0,0	10700000
1990/91	4966600	280000	5,6	s/d	0,0	0,0	10862000
1991/92	5040000	445000	8,8	s/d	0,0	0,0	11310000
1992/93	5319660	775000	14,6	100000	0,0	0,0	11045400
1993/94	5817490	1350000	23,2	250000	0,0	0,0	11719900
1994/95	6011240	1670000	27,8	500000	0,0	0,0	12133000
1995/96	6002155	2150000	35,8	762000	0,0	0,0	12448200
1996/97	6669500	2859500	42,9	1263000	36735	0,6	11004890
1997/98	7162250	3250000	45,4	2852000	1756000	24,5	18732172
1998/99	8400000	3782500	45,0	4543000	4800000	57,1	20000000
1999/00	8790500	5016000	57,1	6097000	6640000	75,5	20206600
2000/01	10665000	6658800	62,4	82350000	9290000	87,1	26882912
2001/02*	11307000	8670000	76,6	81499870	10295000	91,0	31000000

NOTE: *ESTIMATE

SOURCE: DATA BASE OF IDEI, U.N.G.S.

In 1996 Argentina's authorities released to the market the first event of GM modified seed in soybean. The new seed contained a gene resistant to the gliphosate (an herbicide of wide range

except the modified soybean). The new seed -known as RR soybean- was made freely available -under a soft local property rights law- and was quickly adopted jointly with the zero tillage techniques and other minor changes.

The result was an impressive technological and productive performance: soybean crop growths almost three times in production since 1996 reaching over 31 million tons in the last years. Land cultivated using the new technological package -zero tillage and RR seed- has been growing very fast replacing other traditional crops (sunflowers, maize, etc.) or competitive (in terms of the land) activities (extensive cattle production and/or milk) both in corn belt and extra pampeana zones. In six years this transgenic seed (RR soybean) replaced conventional varieties covering more than 90% of total land devoted to soybean.

It can then be inferred that production increases must be due to improvements in technology or production organization methods.

2.2. Technological performance of Argentinian agriculture in the 90s

2.2.1. Catching up the international high tech in biotechnology

Agriculture is one of the oldest activities known to man. Initial production was undertaken by trial and error, and observations of different soils and climates. It meant that the farmer's tacit knowledge was a central element in the production process.

From the mid-1950s, the *green revolution* introduced various scientific criteria. On the one hand, it allowed the use of fertilisers (to improve/restore soil quality), mechanization (tractors and other machinery) and the use of selected hybrid, or improved, seeds, borrowing and adapting basic elements from industry. On the other hand, new techniques were implemented. Based on land rotation, this entailed several steps in completing the sowing stage. In this model, farmers gained a new kind of tacit knowledge related to handling machinery, fertilizers and the yield/reaction of different kinds of seeds.

The Argentinian agricultural sector adopted this technological package with the restrictions and opportunities of the local environment. Relative prices of grains, oils, fertilizers and herbicides, instability in macroeconomic figures, distorted tax systems, low efficiency in financial markets and other aspects, were the main causes for delays in the fully adopting international technology. Consequently, production grew very conservatively in the Argentinian agricultural sector between the 1950s and the 1980s. Farmed land -mainly in the pampas or the corn belt- was allocated to semi extensive grain production (80%) and extensive cattle and dairy production.

The international scenario has undergone swift changes in recent decades. Biotechnology engineering is used to design seeds to specific orders. Bringing together knowledge from different disciplines, this technology adds genes from others species a particular seed. This new process is used to obtain new products and methods, including:

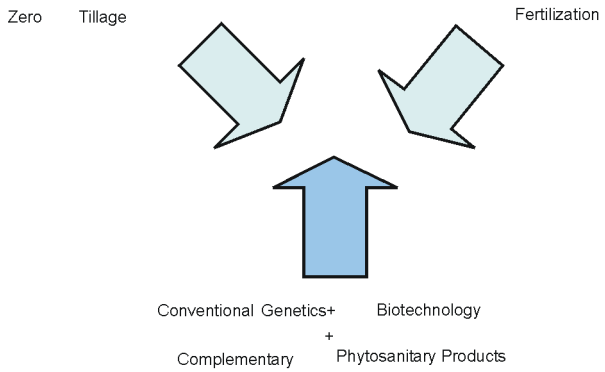
a) Specific behaviour in plants (resistance to herbicides, insects) which affects the ongoing technological process, bringing a wide range of results (lower costs, improved yields, shorter life cycle, cold-resistance); the benefits of which are passed on to the farmer.

b) Changes in nutritional content (low calories, high protein); the benefits of which are passed on to the consumer.

The first stage of development aims to make the plant resistant to specific herbicides. This technological breakthrough has an impact on the prevalent paradigm in different ways: i) it introduces coded instructions into the seeds as to the function of later production; ii) it reshapes the industrial use of primary raw materials; iii) it questions and redefines farmers' previously tacit knowledge; iv) it redefines network hierarchies in favour of newcomers supplying a limited number of critical technologies.

How should Argentinian agricultural society react to these changes, concurrent in a select number of developing countries and multinational enterprises?

The previous technological package -formed during the *green revolution*– was adapted by local farmers who had fallen behind more developed markets. This new package is now being adopted and recreated rapidly. It is to be assumed that such behaviour is closely related to the domestic production structural frameworks or networks. New technology is being applied rapidly and with great coordination in order to build a new package following the sequence shown in the diagram below:



2.2.2. Re-shaping the technological package

Seeds. Domestic seed production has a long history in Argentina. The earliest activities began a century ago in public institutes and a few small private firms. Between the 1950s and 1970s a wide range of varieties and hybrids appeared on the market. Minor changes in products and processes were necessary in order that high quality varieties could adapt to specific local soil and climate conditions.

A well-balanced market (public/private or domestic/foreign) allowed cross-fertilization activities to develop a new varieties and hybrids. The opening of a germ plasm bank in the middle of 1970s, national seed breeder activity, and the presence of strong multinational producers allowed farmers to choose from a wide range of different crops. The quality of these products was recognized by the external market in flux exports.

The supply of hybrid, improved seeds changed radically from the mid-1990s onwards with the appearance of biotechnology. The earliest development in GM crops was in a variety of soybean, highly compatible with local conditions, to which a gene was added, rendering it resistant to the glyphosate herbicide. The seed was first introduced by Nidera at its headquarter based in the United

2 The gene was initially the property of Monsanto in the USA, who licensed it to Asgrow. This company was then taken over by Nidera, who made inroads into Argentina. When Monsanto later patented the product abroad it had already been released for sale in Argentina by a third party (Oaim M. & Traxler G, 2002).

States, with tests starting in Argentina in mid-1991[2]. Given that these techniques were of an experimental nature, their development from formation onwards was regulated by the National Commission of Agricultural Biotechnology (CONABIA, Comisión Nacional de Biotecnología Agropecuaria) and their general sale release authorized five years later[3 4].

In all cases, the original product was developed abroad, while in Argentina adaptation trials were carried out in accordance with Argentinian regulatory frameworks. As we will analyse below, the mass use of these products consolidated the market position of transgenic seeds for a limited number of international companies.

The present panorama therefore rests on three central elements: i) The existence of a highly limited number of **multinational enterprises** with great economic potential, control of the best international techniques in genetic engineering, and control of genes relevant to specific varieties through patents in the country of origin. In contrast, domestic efforts, with fewer resources and researchers and less equipment at their disposal, can only aspire to a more limited range of products; ii) A limited number of private domestic companies, large multinational businesses and public research institutes which control the specific **varieties** adaptable to particular demands from different regions of the country[5]; iii) The need for adaptation and testing of imported products in a wide range of variable local conditions[6].

How is the profile of the foreign suppliers of such key elements for local production?

At international level there have been significant changes in supply, with a notable concentration of firms from high-tech research in pharmaceutics and fine chemistry. On the one hand traditional seed firms, whose main activity was the development of varieties adapted to specific local contexts, merge with or are taken over by enterprises dedicated to herbicide production and fine chemistry. On the other hand these are joined by pharmaceutical companies, whose advances in this field arose from their superiority in genetic techniques (Trigo *et al*., 2002).

New domestic regulatory conditions and technical changes in the international context are thus dominant in the restructuring the profile of domestic seed demand. This restructuring is based on:

- The dominant presence of a limited core of foreign capital businesses in the production of the most dynamic crops.

3 At the same time, another private multinational in Argentina started developing BT maize with genetic modifications rendering it resistant to lepidoptera. This product similarly went on sale commercially in the mid-1990s. A like approach was taken with LL maize, resistant to glyfosinate. These new products contained genes from other species, modifying the plant's behaviour and bringing changes in process technology.

4 Transgenic soybean was put on general sale in the USA in late 1994 (applicable to the following year's harvest), while in Argentina it went on sale in 1996 and was applied on a small scale to the same year's harvest.

5 This gives a minimal balance to the market and any future development insofar as specific domestic demands are concordant only with high performance varieties whose obtentor's right is in the hands of the local (private and/or public) nucleus.

6 In parallel, INTA (National Institute of Agricultural Technology/ Instituto Nacional de Tecnología Agropecuaria) has started to carry out activities on some crops in this area, as have some agronomy faculties, but these have not yet produced maize or soybean for commercial use.

• The transfer to a local context of the technological and commercial strategist that characterizes international supply, based on merging seed supply with biocides and fertilizers.

• A reduced relative influence of local suppliers through the de-nationalization of various domestic capital firms -herbicide, insecticide and seed producers- taken over by newly renovated multinational businesses. This dynamic is based on the production potential of local developments (the varieties of some seed producers), the supply network and the use of long-established brands in the local market, as in the case of biocides.

Thus in the local sphere the balance in market structure is tipped in favour of the predominance of a limited number of businesses. In contrast, the influence of local supply is limited to the work of the state and a handful of private producers operating with conventional hybrid seeds.

Fertilizers. The adoption of early mechanization models and the mass use of improved seeds was not matched in Argentina by a general increase in the widespread use of fertilizers. In the 1970s and 80s, the use of urea and other fertilizers was mainly confined to a small part of wheat production. In a context of a closed economy, unfavourable relative prices and macroeconomic instability, there was minimal demand for such products. Internal supply was limited to a handful of highly concentrated plants and to imports, which were in turn affected by high taxes. Consequently, in the early 1980s the agricultural sector required around 250,000 tons of various fertilizers, 70% of which was imported, while local production was based around two main local capital firms, PASA and YPF.

Changes in the 1990s brought about a more dynamic local market attended by a dozen large firms (each with predominance in a given product) through national distribution networks (Mercado, 1999). Dynamic demand activated the imports of some products, while leading to a greater fostering of local development in other products[7].

The last decade has seen a greater use of fertilizers, most notably between 1991 and 1996 when use grew from 325,000 tons to just over 1,600,000 tons per year. Since 1996, annual consumption has risen slightly to just over 1,800,000 tons.

Although it is the tendency of generalized practices, activities are centred mostly on the most dynamic crops: wheat, soy and maize. In the case of wheat, while in the 1991-2 period 25% of sown surfaces were fertilized, five years later around 2/3 of crops were fertilized. By the 2000-1 period, an estimated 85% of sown surface was fertilized.

The consumption of fertilizers grew through a private network made up essentially of the distribution controls of principal private supply companies of this and other inputs. In this way, the boost from private companies acted as a mechanism for the widespread growth in the use of these products.

7 The seven largest firms in the market- Profertil, Pecon Energía, Cargill, La Plata Cereal, Hydro, AgrEvo, and ASP made considerable investments during the 1990s (M&S, 1997). The most relevant project was Profertil, with an investment of US$600 million in the production of gas-based urea; the start of operations in 2000 created a production volume which widely exceeds domestic needs, generating an exportable surplus of US$ 200 million per year. A production capacity of over one million tons per year dedicated to urea makes it one of the largest ventures of its kind in the world. Its stockholders' composition reveals crossovers in the market: Repsol-YPF holds 33%, another 33% is in the hands of PASA (part of the Pérez Companc Group), with the rest owned by Agrium (an international business with additional interests in biocides and seeds). Other investments by the likes of PASA (around US$25 million), AgrEvo (US$1.5 million), Cargill and ASP have reinforced in other products a growing trend of greater consumption of these products in Argentina.

Biocides. The biocide market takes in a wide group of products whose use depends on both farming techniques in use and the kind of pest in question. Biocides are chemical products with diverse environmental impacts and are generally produced in large volumes by the chemical industry[8]. Global supply of these products is dynamic and innovative, mostly based around a core of large firms which are the result of strategic international mega-mergers and alliances. In Argentina, and in the context of business transformations in the 1990s, the principal international suppliers and a few local producers are the most conspicuous.

The domestic phytosanitary market is worth approximately US$ 700 million per year, of which 71% corresponds to herbicides, 13% to insecticides and less than 10% fungicides, with the remainder shared over a wide variety of uses, most notably seed treatment products.

In the sector's aggregate evolution there is a clear dynamism from the 1980s onwards in the consolidation of soybean crops, and later on with wheat. Within this trend, the particular conditions of the 1990s re-encouraged the use of these products. There has been a noticeable growth in value and volume. Levels reached by 2000 exceeded 1989 levels by 184% in value and 355% in volume. This evolution was uneven among different products. On the contrary, differentiations in supply reflect the particular conditions of demand and of the regulatory framework. In this area it is notable that:

- The larger part of the biocide market is increasingly concentrated in herbicides, which accounted for 50% of volume and 67% of value in 1989 and 80% and 71% respectively in 2000.
- The use of herbicides grew threefold in terms of value and six times in terms of volume during the 1990s.
- In the context of a sustained trend of biocide incorporation, a break occurred from the 1997-8 season, particularly in terms of values, and to a lesser extent, volumes. This was largely caused by internal substitutions in the use of new technologies (the availability of glyphosate-resistant soybean encouraged consumption of this in place of atrazines used in conventional soybean farming).

In sum, throughout the 1990s and in the context of a tendency towards the mass use of biocides, market mechanisms (price reductions and a greater external dependency on supply) reinforced the use of certain products in accordance with the greater weight of transgenic seeds in the most dynamic productive sectors, namely those dedicated to soybean and, by extension, wheat and maize.

Machinery and equipment. The operation of the agricultural machinery market in the 1990s had a particular regulatory support. With a view to causing accelerated technological capitalization, the import of such equipment was permitted without tariffs, reducing their relative prices and encouraging their incorporation via imports[9]. Additionally, credit facilities were established through public banks for agricultural capitalization. Lastly, the production of agricultural machinery was considered in

8 Biocides demand an enormous R&D effort until the commercial stage is reached, they are subject to sanitary checks prior to release and are often patented or protected by other copyright methods. Early stages of development occur in large centralized production while later stages are carried out in decentralized areas, close to consumer markets.

9 In addition to this, and so as not to unbalance the position of local manufacturing businesses, a reimbursement was brought into place for sales that these firms made in the domestic market, of a amount equivalent to the effective lack of protection caused to them by this freeing up of tariffs.

competitiveness plans, that included tax-deductions and relief from social security contributions on salaries.

Taking into account the dynamic behaviour of aggregate production, the evolution of the demand of agricultural machinery had not followed similar lines. Although figures show a rise in the first half of the 1980s and 1990s and a decline in the second halves of these decades, this is not enough to delineate a trend of similar depth and consistency as that observed in the grain production. Some particular elements determining the growth in agricultural machinery are:

- During the 1980s, tractor sales averaged in the region 6,300 units, with a peak of almost 13,000 in 1984 and a minimum of less than 3,400 in 1981. Even considering the increased production of cereals and oils in the 1990s, demand was not so dynamic, averaging 3,912 tractors per year between 1990 and 2001, with an abrupt drop in the last two years.
- Global tractor figures cover up significant qualitative changes. The tractors most in demand from the early 1990s were medium to high power machines (over 120 hp), in contrast to the demand for low to medium power machines in previous decades. That is, although fewer tractors were bought these were mostly high powered and generally double traction machines. The average power of tractors sold in the last five years around 120 hp.
- In the traction machines market, rising production levels can be seen in the first five years of the decade, followed by a substantial decrease in sales over the last two years. 1996 and 1997 were particularly dynamic.
- In this context, there are certain implements with divergent and clearly dynamic demand, namely zero tillage seed drill and fumigation equipment. In the first of these cases, while sales struggled to exceed 100 units in the mid-1980s, by a decade later sales had soared to 2,200, levelling out at 2,500 in recent years.

In sum, during the first half of the 1990s, production followed demand in agriculture-related activities. But in the second half of this decade, the sole productions to grow were those of high power tractors, zero tillage seed drill machineries and a few complementary equipments that accompanied the new technological package[10].

Zero Tillage. Zero Tillage (ZT) technology was initiated in the early 1960s in the United States, by chemical companies seeking to stimulate demand for certain herbicides and by public agencies motivated by conservationist principles. ZT progressed in Latin American economies during the 1980s, particularly in Brazil, Argentina and Paraguay, with particular features in each country. This was the result of a joint effort between private agricultural equipment/machinery supply companies,

10 This brings about two phenomena: the need for a greater fixed capital and the reduction in value of equipment used in the previous capital goods stocks. Both elements reinforce the trend toward concentration and subcontracting of activities.

national agricultural research institutes and a handful of international development agencies[11]. Remarkable role in diffusion was played by AAPRESID (Asociacion Argentina de Productores de Siembra Directa) a private non profit organization. This institution -on behalf of the idea of co evolution between technology and institutions- was launched in the eighties in order to promote (and finance) the use of the conservation soil techniques. Currently is one of the more relevant institutions in the agriculture sector in Argentina.

The new technique consists of planting without the need to till the land and other associated processes (levelling, sowing and necessary subsequent covering). Instead, the technique plants the seed in a single process through the opening and subsequent flattening of a furrow where the seed is deposited and, if necessary, fertilized. This requires as great a reduction as possible of competition from other species which requires the elimination of anything planted beforehand, through fumigation. In this way, the use of herbicides is tied up to the new technique. Further, times can be reduced and developments improved where desired by complementing this technique with the use of diverse types of fertilizers.

This technology affects the process as a whole in the following ways:

- It reduces the operating costs (working capital and labour) of different crops as it eliminates a variable number of activities needed in previous techniques (Peiretti, 1999).
- It reduces farm work, improving labour productivity and raising the question of the global use of this resource (Peiretti R. 1999)[12].
- Restates on new terms the package of tacit knowledge among producers induced to operate with a new technique, to which various external equipment suppliers contribute.
- It improves soil moisture use by allowing a greater accumulation of water from not ploughing the land with every sewing (Penna J & Lema D, 2002)
- It requires new machineries, such as fumigation and zero tillage seed drill. Access to new equipment can be a barrier to progress depending on the producer's size, financial situation, market perspectives and other elements. New capital requirements, with their minimal technical and economic scales, lead to restating on new terms the producers' attitudes as regards levels of vertical integration and, together with other reasons, affect the previous form of productive organization[13].

11 Initial developments in the private field were carried out by ICI in the early 1970s, when the introduction of *paraquat* into the market in order to weed control. In the public sphere, technical developments were made at the University of Kentucky, in Canada, in the mid-1970s while in New Zealand and Australia initial advances date from the 1970s and early 1980s. To a great extent, mass developments went hand in hand with the development and adaptation of ZT drill seed and the use of suitable fertilizers and seeds. Zero tillage is not imposed massively as an isolated technique as such, but rather in the context of a coordinated set of techniques, including biocides, seeds and fertilizers. In initial, experimental developments, there were some common challenges: i) the use of this technique as a way to detain and remedy increasing soil degradation, ii) the need to adapt such techniques to national specifications (Ekboir, 2003, AAPRESID, 2002, Díaz R. 2000; Panigatti. Marelli, Buschiazzo, & Gil, 1998).

12 Analyzing the performance of 59 producers, Oaim and Traxler (2002) indicated that the new agricultural package also reduces machinery use by about 20%.

13 This encourages the apparition and/or strengthening of third parties, that is, of businesses dedicated to sowing as a third party service or sharing risks with the landowner, as an alternative which, on the one hand allows access to new sowing techniques, but on the other hand reduces the landowner's autonomy in making decisions.

• It improves the agricultural sustainability of soils in the mid to long term (Croveto 2001, Peiretti 1999). A similar environmental impact is the reduction of gas emissions arising from the reduction in labour activity.

The features mentioned, especially those that reduce private short-term production costs, work as incentives to the spreading of these techniques. Simultaneously with a sustained demand for zero tillage seed drill and more powerful tractors, producers have begun to use these techniques which necessarily lead to the use of herbicides.

In the first half of the 1980s, the total cultivated surface in Argentina exceeded 20 million hectares, of which scarcely more than 2,000 were sown with soybean crops using ZT, an activity which had recently taken off in Argentina. In this period and in the context of a marked recession in the agricultural machinery industry, some firms started to remodel their conventional drill seed to convert them to ZT seed drill. The process took off in the early 1990s within the context of a new regulatory model. Supply of ZT seed drill machines grew rapidly, both nationally and internationally, herbicide prices fell and international demand for certain grains and oils grew substantially.

TABLE 3. ZERO TILLAGE BY CROPS. ARGENTINA 1986-2001

-in has and %-

Year	Zero tillage					Total Sown	Zero/Total
	Soybean	Maize	Wheat	Others	Total		
1978/86	2.000	–	–	–	2.000	21.315.500	0,01
1990/91	280.000	10.000	10.000	–	300.000	20.211.000	1,48
1995/96	2150000	200.000	200.000	420.000	2.970.000	21.129.000	14,05
1996/97	2859500	266.000	260.000	558.600	3.944.100	21.823.000	18,10
1997/98	3250000	n/a	n/a	.000.000	8.250.000	25.458.000	19,64
1998/99	3782500	1.148.000	1.267.000	1.072.000	7.269.500	24.674.000	29,46
1999/00	5016000	1.385.000	1.740.000	1.109.000	9.250.000	25.203.000	36,70
2000/01	6658800	1.494.700	2.259.000	1.247.50	11.660.000	25.562.200	45,61
2001/02	8670000	1.723.000	3.150.000	1.557.000	15.100.000	27.113.350	55,69

SOURCE: AAPRESID Y CASAFE

This trend can be accounted for almost exclusively by two crops: soybean/wheat and maize. But the definitive leap forward in the trend occurred in the late 1990s when agricultural sowing packages including these technologies were consolidated. As a result, more than 50% of the surface sowed in Argentina is worked using this technology.

In sum, during the 1990s the agrarian sector incorporated extensively a series of product and process technologies aimed at reconfiguring the role of production and producers' tacit knowledge. In some cases, there was an attempt to gain ground with best international practices, while in others, such as the use of transgenic seeds, Argentina was among the first in adopting these techniques. In this context the importance of input-concentrated supply over the primary production process is clear. It is from this perspective, in addition to regulatory, pro-market changes, that the process of the growth of transgenic products in Argentinian agriculture must be analysed.

3. TECHNOLOGY GROWTH PROCESS DYNAMICS: THE CASE OF TRANSGENIC SOYBEAN.

3.1. Transgenic seeds, ZT, biocides and fertilizers: Emerging new technological packages

An overview of the markets analysed above -seeds, biocides and fertilizers- indicates a common profile: a strong presence of multinational enterprises along with the de-structuring of previous domestic supply, an active investment process, control of a significant part of the marketing chain by producers of key materials and an emphasis on imports and the transference of relevant technologies from abroad, with adapting participation from local agents.

TABLE 4. MAIN SUPPLIERS OF HERBICIDES, SEEDS AND OTHERS INDUSTRIAL INPUTS

	Inputs						
	Seed			Biocides		Fertilizers	
	Wheat	Maize	Soybean	Insecticides	Herbicides	Local	Imported
Main Suppliers		Conventional	Conventional				
	Producem	Dekalb	Monsanto	Novartis (Ciba Geigy)	Monsanto	PASA	Cargill
	Buck	Nidera	Novartis	Bayer	Bayer	Profertil	Monsanto
	Klein	Pioneer	Cargill	Hoescht	Cargill	AgrEvo	Ciba Geigy
	Nidera	Zeneca	Producem	Monsanto	Ciba Geigy		Nidera
	Relmó	Cargill	Cyanamid	Pfizer	YPF		Others
	AFA	Novartis	La Tijereta	Dow AgroScience	Dow AgroScience		
	Micogen	AgarCross	Advanta	Ishihara	Tow Elanco		
			Relmó		Basf		
			Don Mario		Ishihara		
			Aventis				
		Druetto	Micogen	YPF	Cyanamid		
		Transgenic	Transgenic	Cyanamid			
		Pioneer	Nidera				
			Novartis				
			Pioner				
		Morgan	Monsanto				
		Novartis	Nidera				
		Monsanto	La Tijereta				
			Don Mario				
			Relmó				

SOURCE: BISANG ET AL 2000.

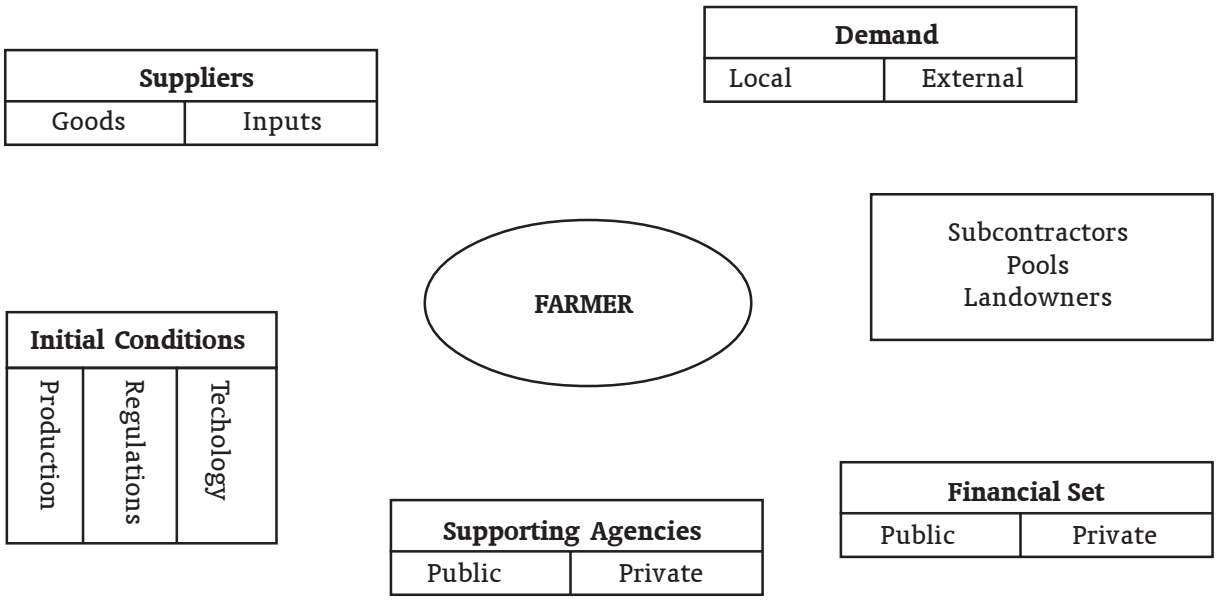
From these transformations, a new supply model tends to appear, characterized by:

- The tendency to concentrate supply -under the logic of the technical package– of a set of inputs that previously came from different sectors. Thus, transgenic seeds such as RR soybean

or BT maize work as coordinating factors in joint supply which includes glyphosate, a pre-emergent for maize, various insecticides and various types of fertilizers[14].

• Diverse international mergers and alliances lead to an increased concentration of local supply of these technological packages[15].

TABLE 5 CHANGES IN THE ORGANIZATION OF THE PRODUCTION



• This model of concentrated supply is compensated for by modifications in commercial circuits coordinated with the end user (subcontractors or landowners)[16]. Inputs packages supplied by service centres habitually include consultancy in techniques currently in use. In this way, the formation of the distribution system establishes a supply network with regional or national coverage which becomes the source of much knowledge, whether codified through inputs or de codified through direct assistance[17].

14 This is reinforced by the possibilities of financing from multinational suppliers. In a context of extreme restrictions on bank loans, whether from public or private institutions, inputs suppliers increasingly finance parts of the working capital associated with future harvests, a strategy that joins financing with the spread of new technologies.

15 Monsanto, a firm originally dedicated to chemicals which began to branch out into pharmochemistry in the 1970s, is associated with Dekalb and Cargill. The use of these seeds, especially Monsanto's RR soybean, demands the application of glyphosate, supplied by the same business but under the brand name Roundup. A similar loophole is found in the recently created Syngenta (Novartis plus Advanta) which supplies seeds (transgenic soybean released for sale to Ciba Geigy), glyphosate (through Novartis), and various insecticides (through Ciba Geigy). A similar model can be identified in the action of Nidera as a supplier of both wheat and soybean seeds and a complete package of biocides and fertilizers. Bayer's recent announcement of its takeover of Aventis Crop Sciences (dedicated to seeds) follows an identical path. To a great extent this trend in the internal market is a reflection of the process of international concentration verified in these activities, in addition to takeovers of local firms by multinational companies.

16 Available data, while fragmented, indicate a trend towards the concept of the Service Centre, where the user can access the complete package of inputs. Unlike the previous model, where seed distribution was independent of fertilizers and biocides, in the model currently in formation the concept of service prevails, where inputs are a relevant but non-exclusive part of the transaction.

17 This is constituted in a network parallel to traditional public technology-diffusion systems, controlled by INTA, or other preexistent private systems, such as the CREA Groups.

• In addition to the concentrated supply of materials there is the growth of ZT. This new technique is in part adopted by the producers themselves who, through the purchase of equipment or through a large number of subcontractors, are induced to use this technology through diverse contract mechanisms.

With this profile of the supply of inputs and services, the structure and functional dynamics of the activity begins to be reconfigured in favour of a model centred on a greater incidence of input suppliers in establishing the role of production (what to sow and how) and in its development (through outsourcing contracts). It is then necessary to assess the dynamics behind the process of formation and diffusion of the new technical package in relation to changes in the way production is organised.

3.2. Evolutionary Dynamics.

The first traces of change in the prevailing agronomical package were identified by the end of the 1960s with the introduction of soybean into the corn belt (Obschatko, E. 1996; Gutman, G. 2002). In the context of an agricultural sector where profitability levels negatively affected aggregate dynamism, land was one of the safe assets in the midst of macroeconomic instability (with investments from firms from other sectors) and the activity on the whole tended to favour conservative behaviour in terms of incorporating technology. Public efforts to introduce new crops were the starting point of a restructuring of production (Penna, J., 1983, b). The lack of profitability led to some changes in attitudes towards new crops. At the same time as developments in soybean, zero tillage began to be used and with it the more intense use of biocides and, in a few cases, fertilizers. As a result, in the 1980s soybean had peaked at 7/8 million tons on the basis of a production model based on conventional sowing using a package of herbicides and insecticides and the restricted use of fertilizers.

In the early 1990s, the adopted economic model meant a substantial change in the previous scenario in two ways: relative prices were modified and changes were consolidated in the supply of inputs.

The effect of exchange rates on prices (due to the 'Convertibility' Law, which pegged the Argentinian peso to the dollar) was initially ambivalent according to the products and inputs. However, this ambivalence ended with the positive evolution of international prices during the first half of the 1980s. The combination of deregulation and exchange rates reduced the price of important inputs. As a result, the sector enjoyed highly favourable prices in the first half of the 1990s which, it must be recalled, did not yet feature the impact of transgenic soybean and maize.

TABLE 6. EVOLUTION OF MAIN RELATIVE PRICES BY CROPS. ARGENTINA 1985/2001

			1985 [1]	1990 [2]	1991 [3]	1992 [3]	1995 [3]	1996 [3]	1997 [3]	1998 [3]	1999 [3]	2000 [3]	2001 [4]
Wheat	Gasoil	QQ[3] x 100 lt.	3,0	7,6	3,2	2,5	1,4	1,2	3,0	4,0	3,0	4,0	4,1
	2 4 D 100%	QQ[3] x 100 lt.	44,7	80,0	60,0	40,0	26,0	24,0	32,0	42,0	31,0	32,0	31,0
	Diamonic Phosphate	QQ[3] x Tn.	-	53,0	34,0	24,0	17,0	16,0	22,0	30,0	29,0	29,0	27,0
	Urea	QQ[3] x Tn.	-	-	28,0	22,0	16,0	14,0	16,0	19,0	16,0	20,0	21,0
	Tractor 100 HP	QQ[3] x unidad	3092,0	4857,0	2955,0	2152,0	1441,0	1226,0	2291,0	2889,0	2496,0	2713,0	2907,0
	Pick Up	QQ[3] x unidad	-	1167,0	1733,0	1390,0	930,0	785,0	1274,0	1687,0	1458,0	1584,0	1506,0

			1985 [1]	1990 [2]	1991 [3]	1992 [3]	1995 [3]	1996 [3]	1997 [3]	1998 [3]	1999 [3]	2000 [3]	2001 [4]
Maize	Gasoil	QQ[5] x 100 lt.	3,1	5,1	3,4	3,2	2,2	1,5	4,4	4,6	4,0	6,1	6,0
	Seed	QQ[5] x 100 lt.	-	7,9	7,8	7,3	6,8	3,1	7,8	6,4	6,4	9,6	8,8
	Urea	QQ[5] x Tn.	-	27,0	29,0	27,0	26,0	18,0	24,0	22,0	21,0	31,0	32,0
	Diamonic Phosphate	QQ[5] x Tn.	-	-	36,0	31,0	28,0	20,0	32,0	35,0	38,0	44,0	40,0
	Atrazine 50%	QQ[5] x 100 lt.	51,4	41,0	36,0	35,0	27,0	23,0	31,0	36,0	28,0	56,0	54,0
	Tractor 100 HP	QQ[5] x unidad	3191,0	3271,0	3140,0	2802,0	2296,0	1589,0	3378,0	3319,0	3302,0	4143,0	4290,0
	Pick Up	QQ[5] x unidad	-	1908,0	1847,0	1810,0	1481,0	1018,0	1878,0	1938,0	1928,0	2420,0	2222,0

			1985 [1]	1990 [2]	1991 [3]	1992 [3]	1995 [3]	1996 [3]	1997 [3]	1998 [3]	1999 [3]	2000 [3]	2001 [4]
Soybean	Gasoil	QQ[5] x 100 lt.	1,8	3,4	1,8	1,6	1,3	1,0	1,7	2,1	2,6	2,8	2,9
	Lazo	QQ[5] x 100 lt.	35,9	31,0	23,0	23,0	20,0	15,0	16,0	21,0	28,0	26,0	25,0
	Roundup	QQ[5] x 100 lt.	119,5	72,0	64,0	49,0	31,0	22,0	19,0	20,0	24,0	18,0	19,0
	Lorsban plus	QQ[5] x 100 lt.	-	99,0	87,0	74,0	79,0	70,0	39,0	73,0	84,0	69,0	67,0
	Tractor 100 HP	QQ[5] x unidad	1871,0	2151,0	1706,0	1408,0	1391,0	1058,0	1311,0	1522,0	2108,0	1880,0	2045,0
	Pick Up	QQ[5] x unidad	-	1255,0	1000,0	910,0	898,0	677,0	729,0	889,0	1231,0	1098,0	1059,0

Notes (1) June, (2) December, (3) July, (4) March, (5) QQ: 100 Kg.
Source: Márgenes Agropecuarios. Several Issues.

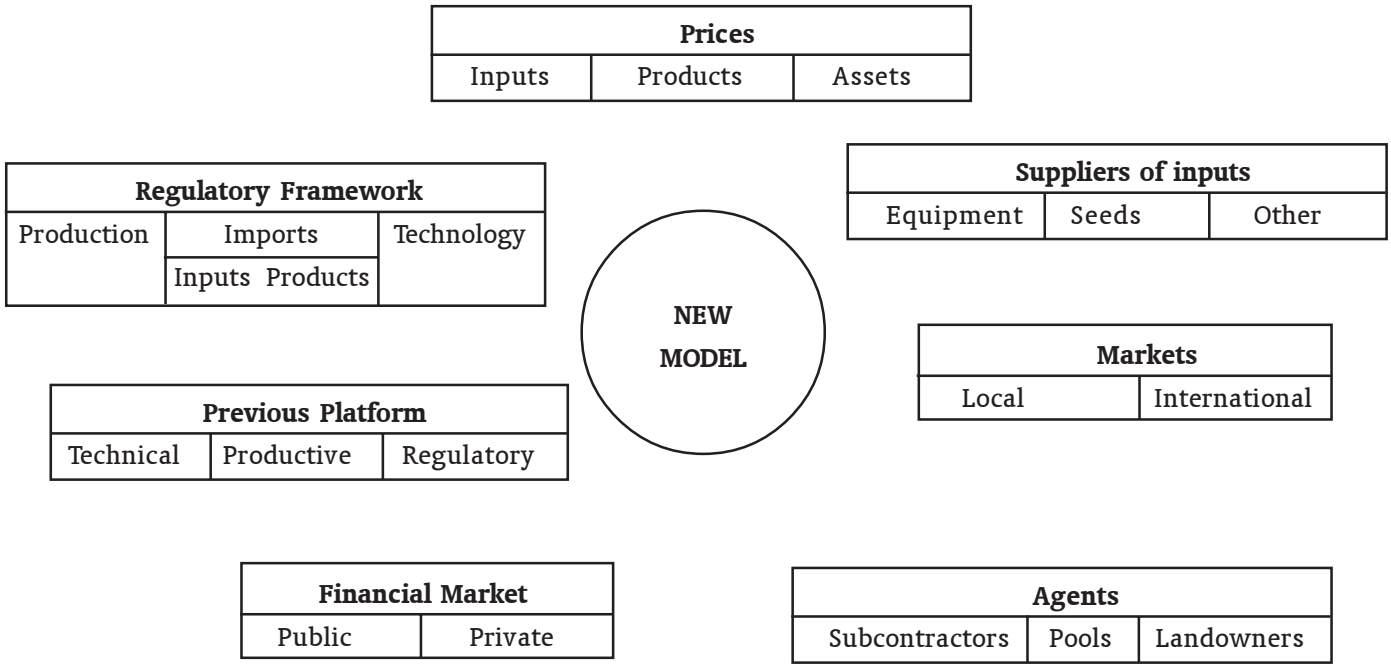
The improvement in relative prices, substantial in some cases, generated expectations of high profitability which, climatic conditions aside, was reflected in:

- an increase in production, which elevated the five-year average to a little over 45 million tons against a little less than 35 million in the last five years of the 1980s; this can be accounted for to a great extent by the leap in soybean production;
- a slight increase in sowed surfaces;
- both of the above tendencies resulted in an increase in average yields which derived both from favourable climatic conditions and the technological impact of an increased use of new techniques, herbicides and fertilizers;
- increases in demand for materials and equipment (tractors, machinery and equipment, biocides and fertilizers)
- a strong revaluation of producers' assets, the central indicator being land prices, which

partially covered macroeconomic uncertainties (land as an investment against inflation). The evolution of land prices started to reflect expectations of the (growing) benefits of the sector[18].

High profitability expectations demand for inputs and equipment, restrained over previous years, the dynamism of the foreign market and the revaluation of assets led to an abrupt credit-based capitalization process (using both public and private loans). Primary production (farmer and subcontractors) began to re-equip with new technologies. The greatest dynamism was to be seen in ZT seed drill, high power tractors and fumigation equipment in line with these new technologies. If, to all this, we add a greater working capital from the increase in production it can be understood how, in the mid-1990s, the sector as a whole simultaneously exhibited technological modernization, concentrated production and fast growing debts.

TABLE 7. TECHNOLOGICAL DYNAMICS



As in other sectors of the economy, but with its own specifications, agricultural activity took a substantial turn in the second half of the 1990s, by which time most productive dynamism was based around conventional soybean. Faced with depreciation in relative prices due to falling international prices, with the previously installed capacity involving high exit costs and affected by high levels of debt, producers' strategies focused on cost reduction and increasing production volumes. It was in this context that in the second half of the 1990s the transgenic, glyphosate-resistant soybean seed was released for commercial use. In other words, the commercial availability of the glyphosate-resistant soybean seed appeared as a technology that would solve –from an individual point of

18 In the mid-1980s a hectare of land in the corn belt of Buenos Aires province cost around US$1,500, while a decade later the same land cost around US$3,600 to US$4,000 (Márgenes Agropecuarios, 2001)

view– various simultaneous problems (reduction of herbicide costs, improvements in production, strengthening double cropping, reducing and simplifying the use of labour) and improving or restoring profitability. This process combined various aspects:

- Favourable profit expectations which had sustained dynamism in the first half of the 1990s were replaced by an abrupt, generalized drop in prices in 1997 and 1998;
- Having a fixed installed capacity, with low exit probabilities on account of recent investments counterbalanced by bank debts, producers or subcontracts redoubled their commitment to increasing production;
- However this had to be done with minimal profitability, which began to put pressure on cost structures and working capital financing models[19].
- At this point a strategic decision was made to make RR soybean commercially available, permitting the replacement of the complete package of triazine-based herbicides and various applications, with a simpler package based on glyphosate[20].
- In addition to this and as a complementary part of the cost-cutting process, zero tillage began to be applied more and more, its increase being inversely proportional to the fall in the prices of final products;
- The use of the new package, which had been present in Argentina but was boosted with the arrival of transgenic seeds, increased in great leaps as it was promoted as a way out of the crisis brought on by the fall in international prices. With a consequent impact on profitability for producers, the response was the rapid adoption of this cost-saving package[21];
- In the following years the model was reinforced by the legal and operational framework surrounding the issue of patent rights and copyrights to RR soybean. Although the law stated that rights be purchased from the original obtentor, the laxity of the copyright system meant a process of expansion based on unauthorized reproduction (brown bagging, or *bolsa blanca* as it is known in Argentina);
- The *onward flight* model with its strong technological impact and improvements in productivity grew in the last five years to such a point that conventional soybean sowing methods (tilling, conventional seeds and multiple herbicides) virtually disappeared.

19 During the same period, a turbulent financial context led public and private banks to reduce their credit capacity in the private sector. This reinforced the trend of inputs suppliers to finance harvests, and the subsequent tendency to create new agricultural packages as a counterbalance against a strong supply concentration.

20 Estimates from 1997 show that with the conventional package the cost per planted hectare was around US$115, while with RR seed techniques and glyphosate the cost was reduced to US$90 per hectare. In the case of maize there were similar reductions. Indeed, conventional methods using herbicides meant going over the same land several times with an estimated cost of US38 to US$43 per hectare, which was reduced to a little more than US$12 to US$16 with the use of glyphosate (Márgenes Agropecuario, Dec. 1996; ASA, 2001 b). Similar information is given by Bocchicchio & Souza, (2001) and more recent estimates by Qaim M. and Traxler G. (2002).

21 Studies into the profitability of soybean and maize crops comparing the use of conventional techniques (using tillage and natural seeds) with the ZT/glyphosate/transgenic package shows a 15% gain from the latter. The analysis of cost estimates reveals another important aspect: on the one hand there is a sharp decrease in labour and biocide costs, but on the other hand there is an increase, albeit to a lesser extent, in seed and fertilizer costs. In the case of seeds this is due to the higher costs of transgenic seeds in comparison with natural seeds, and in the case of fertilizers to the greater intensity of use, given the generalization of double cropping or their extension to less naturally favourable areas (Márgenes Agropecuarios, 2001).

Thus, the microeconomic dynamics, responsive to environment modifications (in final product and inputs markets) and the agents' own survival strategies, are highly compatible with the trend towards a greater innovative dynamics. Under pressing conditions, agents learn to adapt and adopt various innovations which were previously unavailable but which take on meaning when coordinated with certain biotechnological developments, a keen supply of inputs with financial leverage and a technical platform prior to launch. The technological objective has almost exclusively been to cut costs, given pressures from debts and developments in external markets. This behaviour is sustained by the practically free use of transgenic seeds stemming from the particular operational and legal circumstances surrounding their early commercial launch in Argentina[22].

3. PRELIMINARY CONCLUSIONS

Argentinian agricultural production has doubled in one decade. A substantial part of such increase stems from the widespread adoption of a new technological package, based around the use of transgenic seeds and zero tillage, and a new model of organization in production, as the role of production is configured by subcontractors and inputs suppliers. The new technology has spread rapidly, with over 90% of soybean land sowed with transgenic seeds within five years of their commercial launch, while zero tillage accounts for 1/2 of all worked land. The first of these technologies was initial developed by a US firm and was rapidly adapted to Argentinian conditions due to lax property right laws. This technology package was complementary to the development of a zero tillage technique, following a long path of trial and error. As a consequence of a positive public response, it was initially supported by public agencies and further developed by a private association specializing in the diffusion of such techniques. Domestic suppliers of new equipment also participated in the diffusion process, as well as a handful of international and local firms in the herbicide (mainly glyphosate) market

The availability of bio seed, zero tillage techniques and new (and adapted) capital goods were necessary but insufficient conditions for launching the new package. A context of domestic policy plagued by market reforms and under pressure from international markets led to the rapid adoption of the new technology. Indeed, up until the mid-1990s, the agricultural sector witnessed rapid growth, adopting conventional technologies (fertilizers, herbicides, zero tillage, etc.) driven by favourable external prices and by the availability of credit, financed mainly by public banks. The drop in international soybean prices, almost 40% between 1996 and 1998, and growing restrictions in the financial market forced the sector as a whole to rapidly adopt a new cost-cutting technological package. In this context, the farmers were quick to take on pre emerging bio seed and zero tillage technology, resulting in the wide adoption of new technology.

The emergence of a dynamic techno-productive network was a feedback for the diffusion of the new technological package. There are various reasons for this tendency to functioning in a production networks:

The **first** reason is the emergence of a profit meta-function of the networks as whole that includes

22 This issue opens up a wide range of questions to be resolved if agricultural society makes commercial incursions into differenced transgenic products in crops where the seeds are protected by restrictive copyright systems. It also makes the rapid growth in use of the RR soybean in recent years in Argentina quite unrepeatable.

individual or group functions (inputs suppliers, national and international seed breeders and designers, farmers, subcontractors, crushing or agricultural machinery suppliers). In this way suppliers, whether of transgenic seeds or its associated herbicide, induce the process through the suppliers' network in search of benefits. The use of transgenic seeds along with glyphosate in turn brings up the role of local seed producers, who possess heretofore almost unexploited varieties which, in accordance with new techniques, acquire renewed commercial interest. In this way, the interests of local seed producers and of a limited number of international suppliers coincide with their individual objectives. In turn, agricultural machinery suppliers with unused capacity and previous knowledge find in the development of new equipment unexplored niche markets to recapitalize their businesses. It is possible to observe similar behaviours in suppliers of herbicides, especially glyphosate, which in the context of the development of a new technological package, can access an extended market. Moreover, local farmers enthusiastically adopt the new technological package due to: i) cost reductions and improved profitability; ii) revaluation of certain assets (land), and particularly low quality land; iii) simplicity in new operations; iv) better environmental sustainability in the mid to long term. To this it is possible to add the subcontractors, who establish themselves as a highly profitable activity based on the control of certain non-codified knowledge and new machineries. Lastly, downstream crushing industries and especially the oil industry widen their expansion possibilities due to the improvement in their profile as suppliers of raw materials. In sum, the principal interconnected actors operating in the network can improve their benefits as whole; in other words, they cooperate in order to successfully compete (win / win strategy).

The second reason is the generation of **positive externalities**, as a result of working in a network dedicated to the extensive exploitation of the new technological package. For herbicide suppliers, this mass use means a new market for technological developments made with other priorities in mind. In the case of a small number of multinational businesses supplying seeds, fertilizers and herbicides, having a commercial network based on the idea of a service centre generates many externalities. In this case, a single sales channel covers a wide range of products and establishes a longer term relationship of leverage with the producer. Moreover, the high-tech businesses that isolated the gene, and developed the process of addition to different varieties of soy, derive a great number of externalities from repeating the process with new varieties at reduced costs.

Another aspect that leads to associative behaviour is the increasing auto-generation of **club goods** (Buchanan, 1965; Sandler T. and Tschirhart J., 1980). This is based on the development of shared tacit and/or codified knowledge in both transgenic biology and soil biology (now under the ZT system). The combination of transgenics plus ZT means that each soil and climatic area responds differently to the new conditions of retention / use of humidity and fertilizers. Faced with this challenge, system actors such as input service centres, subcontractors, landowners and biocide suppliers generate spaces for communication where experience can be exchanged and specific soil and crop handling practices can be generated.

Lastly, the new operating structure allows a reduction of **transactional costs** emerging from both the activity itself and distortions in the Argentinian economy. The generalized use of contracts between subcontractors and landowners or between subcontractors and mills, and the general trend of paying for services according to percentages of obtained products, have reduced transactional costs related to the risks involved in this activity. One particular case can be found in financial leverage which, through the supply of inputs to farmers and subcontractors, allows the actors to by-pass or counterbalance the inefficiency of the banking credit system. Around 1/3 of the working capital is financed through this network-reinforcing program.

Nevertheless, the shaping of the diffusion and production network also benefited from the existence of a number of basic requisites for such behaviour, which are not likely to occur again:

- The existence of an almost infinitely elastic international demand. This means that the objective of the network is centred on greater quantities and cost reductions that do not lead to reactive behaviours within the network.
- The existence of a weak property right system for the transgenic RR soybean seed and the expiration of the patent of its associated herbicide, which permits a better balance in the distribution of final rents.
- The presence of public agencies which directly or indirectly support the development costs of basic technology at experimental and later stages.

In such a framework the diffusion process had several specific features.

During the process, diverse actors have encouraged behavioural changes. Unlike conventional diffusion models applied to approach the phenomena en others countries, (Moschini 2001, Nadolnyack and Sheldon, 2001), there were different motivations and actors, but all pushing in the same direction. Initially, it was the public sector that promoted these developments under the public good perspective. They were joined by agricultural machinery manufacturers and herbicide suppliers. Later, when soybean crops had already been developed using conventional methods, with all their implied costs, developments began in transgenic crops which would ultimately complete this new productive package. This was promoted by big international firms which, amid mergers and takeovers, supplied transgenic seeds and herbicides in the context of a private commercial and technological network. Then the public sector authorized the sales of modified seeds. At the opposite extreme, farmers and subcontractors, faced with debts and falling international prices, demanded cost-cutting technology. Ultimately it was the commercial network, in many cases under license or through contracts that spread the new technology package, becoming a leader in the development of new tacit knowledge.

In this context there were various incentive mechanisms to guide the behaviour of various network actors. Initially the system was set in motion from an exclusive public goods supply perspective and, therefore, from a long-term, conservative viewpoint. In this phase, different unconnected technologies, such as zero tillage and biotechnology, began to evolve in the context of diffuse market boundaries. Private contributions notwithstanding, the greatest efforts were made by public actors, though these were not from mainstream state research agenda. On an international level, the processes of mergers and takeovers began, as well as international dissemination, within a context of open opportunity windows.

Once technological packages were experimentally established and made available in Argentina, price mechanisms began to operate through pressures from demand for cost cuts. Another factor was at stake here, namely the increasing imperfection of capital markets that facilitated financial leverage in placing complete technological packages. In this way, the private commercial network, in addition to bringing in innovations and becoming the venue for the generation of new tacit knowledge, rapidly promoted the new technological package. In turn, this was facilitated by interests from subcontractors, owners of newly revalued marginal land, and fertilizer and equipment suppliers. Consequently, the speed of change was not due to one single element: in diverse stages each element had a more vital role in relation to others. In other words, the process combines a first step driven by supply push (mainly public) that started the technological path dependence without a clear price action-reaction mechanism, and a second step centred on cost/price pull (mainly private).

Nevertheless the process was not homogenous in capturing the net rents between different players in the network. This bears a close relation to the technological package makeup and the supply involved. The technological package consists both of major and accessory technologies. For example, the use of GM seeds goes hand in hand with the use of herbicides, which are highly compatible with zero tillage. Instead, other technologies, such as fertilization and fumigation, are merely accessory. In this case, major technologies (GM seeds) are highly concentrated among a few multinational companies that frame the technological package thus replacing traditional producers. It constitutes nodes that support the diffusion process (Jarillo J. 1988; Humprey J. and Smitz H. 2000; Bisang *et al*., 2002). Scale phenomena in some fixed capital goods, technological asymmetries in information and knowledge, different financial statements and vertical integration levels (given by contracts or fixed capital possession), re-shaped previous internal balances within soybean networks. Seeds and fertilizer suppliers concentrated in a few international companies, agricultural service providers, or large soybean oil traders prevailed over traditional small and medium farmers, landowners with vertically integrated production. As a result, important changes occurred in the structure of soybean networks *vis a vis* the quick diffusion process.

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