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On the economics of technological change: induced innovation in Argentine agriculture

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On the economics of technological change: Induced
innovation in Argentine agriculture

by

Juan Carlos Martínez

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
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DEDICATION

"Caminante, no hay camino,
se hace el camino al andar..."

To Lilia, my best friend

CHAPTER I INTRODUCTION

The stagnation of the aggregate production of the Argentine agricultural sector, with its implications for the performance of the rest of the economy, has attracted the attention of a large number of economists. In particular, the main concern has been the situation of the Pampean agriculture which has traditionally been the supplier of almost all of Argentine exports.

The Pampean region has an almost unique position in the world in terms of comparative advantage because of the fertility of the land, its climate, and its proximity to sea-ports. The importance of this region goes beyond its mere size; its production accounts for between two thirds and three fourths of the total agricultural output of Argentina. But more important than this is the fact that it occupies a strategic position in the economic structure of the country, providing through its exports of grains, oilseeds and livestock most of the hard currency for the import of intermediate goods required for the industrial sector. In connection with this role, the growth performance of the Pampean agriculture has been, for one reason or another, relatively poor during the last 40 years, which has led to a persistent shortage of foreign exchange that has constrained in considerable degree the performance of the overall Argentine economy. The rest of the country, which is actually a

composite of regions with different ecological characteristics, specializes in industrial crops and fruits. Contrary to the Pampean region, its production is basically oriented toward the domestic market.

During the 1928-32 to 1968-71 period total agricultural output in Argentina increased at an average annual rate close to 0.9 percent. The Pampean region grew at an average annual rate of 0.8 percent; while for the rest of the country the corresponding rate was 1.4 percent.¹ In explaining this low rate of growth, previous studies have attempted to clarify the role of economic incentives and limitations prevailing in the sector, with the emphasis placed in the economic relationships observed in the final product markets. In other words, most of the research has been carried out in terms of conventional supply response analysis.

The estimates of price elasticities for aggregate supply response functions made by Colomé, Olivera, Becker and Reca (1969) ranges between zero and 0.5, indicating a low degree of responsiveness. On the other hand, in apparent contradiction with these results, at the level of individual products the situation is one of high responsiveness of supply to changes in relative prices (Reca, 1967). In summary,

¹The rates of growth have been computed from basic data in Reca and Maffucci, Tables 1, 2 and 3, pp. 3-4.

a lack of response at the aggregate production level appears then vis-a-vis with highly responsive supply functions for individual commodities.

However, this apparent contradiction is resolved if account is taken of the lack of land-saving yield-increasing technological change occurring in the agricultural sector. The available empirical evidence shows that farmers do re-allocate their land to alternative uses, according to the ups and downs in relative price of the different products, but it seems that they do so, using the traditional (extensive) form of production.

Based on the previous arguments, it has been chosen to work at the structural forms level (production surfaces), "going back" in the productive process and approaching the problem from the economics of technological change, trying to explain the process of generation of agricultural innovations by public and private institutions, and the adoption of the new technology by the farmer. In other words, the central objective of this study is to attempt to identify the factors influencing the demand for and supply of innovations in Argentina, providing additional explanation for the relative stagnation of the agricultural sector in this country for the last decades.

It can be visualized that the expansion of the aggregate output could be obtained in three alternative ways

(however not mutually exclusive):

- i. Horizontal expansion (i.e., proportional increase in all the inputs allocated in the sector).
- ii. Factor deepening (in this case, with a rather fixed amount of land resource, increase in labor and/or capital used per unit of land).
- iii. Technological change (change in the parameters of the production function).

The growth of the Pampean agriculture from the second half of the last century up to the late 1920's proceeded basically by horizontal expansion with occupancy of new land (by the inflow of immigrants coming from Europe), replication of technologies, factor proportion relatively fixed and constant returns to scale (Díaz Alejandro) until the extensive land frontier was reached in the Pampas in about 1930. In summary, for this period the growth of agricultural output occurred basically through horizontal expansion; with crop production increasing at an annual rate of 3.6 percent, and livestock production at a rate of 3.1 percent (Díaz Alejandro). From then on, further increases of the Pampean output had to be obtained through an intensification in the use of land; implying the need for factor deepening and/or technological change.

Several pieces of evidence indicate that these prerequisites for an expansion in the aggregate production have

not occurred, or at least have not occurred with enough intensity after 1930. Tersoglio, following Solow's approach, has estimated both the relative contribution of technological change in the explanation of the rate of growth of the agricultural sector, and also the rate of technological change for the period 1930-1965.² The share of technological change in explaining whatever growth occurred during these years is rather substantial, accounting for 49 percent of the growth in total output. This result is consistent with the pioneer's studies of Abramovitz and Solow revealing the fundamental contribution of technological change. On the other hand the rate of output growth was only 1.2 percent during the period, implying then an annual rate of technological change of only

²Tersoglio estimated an aggregated input index (I_t) of the form $I_t = \prod_i X_{it}^{\alpha_i}$; $\sum \alpha_i = 1$ where the X's are estimations of land, labor and three different kinds of capital services (machinery, livestock and improvements); while the α 's are the corresponding factor shares. This aggregated input index is suggested by a linearly homogeneous production function of the form $Y = A \prod_i X_i^{\alpha_i}$; $\sum \alpha_i = 1$ where Y is the aggregate output and A is the intercept of the function. With these elements neutral technological change is estimated as the change in output not accounted for by changes in inputs.

It should be noticed that besides the traditional limitations of this type of estimations, it may be argued that the type of technological change characterizing Argentine agriculture has been labor saving in the aggregate. If this is true, the assumption of a neutral shift in the production function in this study may affect the validity of the measured rate of technological progress obtained.

0.6 percent which appears to be substantially lower than that of most other countries.

The initial step in the accomplishment of this research involves the determination of a conceptual framework (presented in Chapter II), which deals with two basic elements: first the theory of induced innovations is explored to help understand the decision mechanisms which could explain the allocation of resources to research and development activities. Second, a classification of agricultural innovations is developed, based on the fact that different types of technologies will have different impact on the allocation of resources and on the welfare of producers and consumers (according to the corresponding factor bias, the supply elasticity in the input markets, and the demand elasticity of the final products).

Using this classification, each type of innovation is analyzed in terms of the possibility of private appropriability of the social benefits generated by the research, this depending not only on the internal nature of the innovation, but also on the prevailing legal system (patent laws) and on the industrial structure. In other words, the profitability of private research is assessed according to whether or not the firms can capture a return to this research. In the case of research and development activities whose benefits could be privately appropriated, it would be

important to emphasize the role of market signals in the allocations of funds to these activities by the agribusiness firms. For the case of innovations whose social benefits could not be privately appropriated, our effort should be centered on the decision mechanisms which channel public investment through the agricultural research and extension system.

To try to explain the process of generation of agricultural innovations by public and private institutions, and the adoption of the new technology by the farmer, a socioeconomic model of induced innovations for the Argentine agricultural sector is developed in Chapter III. A distinction is made between what is called "latent demand," which is the one that, within the framework of induced innovations will lead the sector toward an optimal technological path given the prevailing relative prices; and "actual demand," which is the one that actually guides the allocation of resources to research and development activities.

Two sources of supply of innovations are identified, private business firms, and the public agricultural research network. The first one will materialize provided that the innovation is privately appropriable, and if so, the supply by private firms is largely guided by the expected payoff for the required investment in research and development. In

the case of nonappropriable innovations the supply will be restricted to the public research network.

While the generation of innovation can result from a social decision process, the adoption of new technologies, once available, is a decision for the individual producers that essentially depends on their economic behavior, given the profitability and risk conditions surrounding the new technology.

The situation of relative technological stagnation is basically conceptualized through the existence of a gap between latent and actual demand. This will imply a lag in the generation of socially optimum innovation. However, this gap will tend to disappear in the long run, through the interaction of the mechanisms of generation and adoption of technologies. This process, conceptualized as a land induced technological treadmill, results from a dynamic play of coercive elements in interaction with the market mechanism and the behavior of profit seeking farmers.

In the following three chapters some empirical evidence supporting part of the propositions presented in the socioeconomic model of induced innovations is provided. In Chapter IV the basic characteristics of the actual technological path that Argentine agriculture has been following for the last decades are described. The "success story" of the innovative effort in this country corresponds basically

to the technologies that will be classified as mechanical and biological. The use of hybrid seeds and the process of mechanization have spread rapidly in the farms of Argentina during the last decades.

In the next chapter, a more detailed and self-contained study of the case of hybrid corn in Argentina is developed as a good example of an appropriable and congruent innovation. The internal nature of this technology is described, also the different steps of its generation and diffusion, and finally, a testing procedure is developed and implemented to see whether or not market forces played any role in this process.

On the supply side we advance the hypothesis that the agribusiness firms were guided by the expected payoff of their investment in research. On the demand side, we attempt to assess how important the economic variables could be in explaining the rate of adoption. In particular, we advance the hypothesis that a substantial proportion of the variation in the rate of acceptance of hybrid corn is explainable by differences in the profitability of the shift from open pollinated to hybrid varieties in different regions of the country.

In Chapter VI the potential technological path that is relevant for the Argentine agriculture is explored. In particular, the case of a nonappropriable land saving innovation

(i.e., fertilizer) is taken to try to present some supporting evidence of the existence of the gap between latent and actual demand for this technology, its actual lack of availability, and the degree of incongruence of this technology in terms of the factor ratios prevailing in the traditional production structure.

The conclusions and policy implications of the research are presented in Chapter VII.

CHAPTER II

A CONCEPTUAL FRAMEWORK FOR ECONOMIC ANALYSIS OF
TECHNICAL CHANGE IN THE ARGENTINE AGRICULTURAL SECTOR

Technological Change and the Production Function

Technological change is usually treated in the context of production functions. Thus, the starting point of this conceptual framework is given by the alternative specification of the production function and the role attributed to technological change in each one of them. Taking into account the temporal horizon of the function and the degree of stability attributed to the states of technical and scientific knowledge, a distinction is made among four alternative specifications. They are summarized in Table 1.

The Solowian, or typically neoclassical specification, is the one more widely used. It describes the current relationship between a set of inputs and the corresponding set of outputs given certain fixed technological level represented by the parameters and the functional form of the relationship. In this context, technological change is defined as a change in the production function (i.e., a change in its parameters), without possible distinction in the origin of the change.

Schumpeterian definition of production function refers to the universal set of technologies available at present

Table 1. Alternative specifications of the production function

Production Function	Technology Used	Technical Knowledge	Scientific Knowledge
Solowian or typically neoclassical	fixed	fixed	fixed
Schumpeterian	variable	fixed	fixed
Innovation Possibility Curve (IPC) or "Meta" Production Function	variable	variable	fixed
Historical IPC	variable	variable	variable

for the physical production of goods and services. In this case, the entrepreneur faces all the spectrum of available technological alternatives implied by the given state of technical and scientific knowledge; in other words, the firm faces a set of Solowian production functions which are available and "known" at the present, given the state of technical and scientific knowledge.

For the purpose of this research, a distinction is made between technical and scientific knowledge. The first one defines the general framework of scientific development, allowing a certain capacity or inventive skills which, in turn, can be applied in the generation of direct technical knowledge of production methods or production functions.

By contrast to the Solowian definition, a clear distinction between innovation and adoption of new technologies is found in Schumpeter's work. Innovation characterizes an entirely new production process at a universal scale, while its adoption by other producers is not a case of technological change but a case of successive replications. His concept of technological progress is rather restrictive, since it does not include as such the diffusion process.

The Innovation Possibility Curve (IPC) or "Meta" Production Function was introduced by Kennedy and Ahmand and extensively used by Hayami and Ruttan. In the case of the IPC, the fixity of technological knowledge is relaxed, while the state of scientific knowledge remains fixed. As defined by Hayami and Ruttan (1971):

In the secular period of production, in which the constraints given by the available fund of technological knowledge is further relaxed to admit all potentially discoverable designs (for given scientific knowledge), production relationships can be described by a meta-production function which describes all conceivable technical alternatives that might be considered given the present state of science (p. 83).

Hence, the meta-production function can be regarded as the envelope of commonly conceived neoclassical production functions which may be either presently known or potentially discoverable with the present state of scientific knowledge.

Then, the Schumpeterian production function is a restrictive version of the meta-production function since it

is only applied to the universal set of production methods (or Solowian production functions) currently known. The contrast between technological progress and adoption of new technologies is the same as that under the Schumpeterian definition, that is, technical progress consists in the knowledge of additional neoclassical production functions. But now we may distinguish, at least conceptually, the sources of technological progress: one consisting in the discovery of new neoclassical production functions within the same meta-production function, and the other due to displacements in this latter function, originated by changes in the state of scientific knowledge.

Finally, Ahmad's concept of the historical Innovation Possibility Curve, allows changes in the stock of scientific knowledge. Thus, we arrive at a concept in which even the stock of scientific knowledge is variable. Since the specification of an agricultural development model based on the theory of induced innovations is essentially of long-run nature, the concept of historical IPC will be used, following at the same time, the Schumpeterian viewpoint about the distinction between innovation and adoption of new technologies.

In summary, technological progress has been analyzed in different frameworks. In close relation with the Solowian specification of the production function, there exist some

attempts to obtain an ex-post measure of the contribution of technological change to economic growth. Most of the empirical studies following this approach have considered technological change as a neutral residual, commonly called unexplained residual, and measured by the difference between growth in output and growth in some weighted index of inputs. A consistent result of all these studies is that technological change is the major source of economic growth.

On the other hand, explanations of the generation of technologies have treated innovations as exogenous or endogenous according to the recognition given to the existence of some mechanisms for the allocation of research and development activities, and the relation between the funds allocated to them and the production of new techniques.

An intermediate case between the endogenous and exogenous theories of technological change is Arrow's "learning-by-doing." Production involves in itself a learning process, which results in an increase of efficiency in the use of factors, apparently without a cost counterpart related to eventual research expenditures.

The works of Griliches, Minasian, Mansfield and Katz have evidenced the existence of a systematic relationship between the rate of technological change and the level of investment in research and development activities. However, analysis of the endogenous processes of generation of

technological change is still scarce though we may find notable exceptions to this, as for example the works of Nordhaus and Katz. But, while these authors consider such processes as neutral shifter of the production function, the interest in this research is centered in the factor biases of technological change, as it will be seen in the following sections of this chapter.

The Theory of Induced Innovations

The theory of induced innovations is based on Hicks proposition that changes in the relative price of the factors of production will induce the generation of new technologies with a determinate factor bias, that is, a new technology which will save the factor which has become relatively more expensive. In his "Theory of Wages" Hicks stated: "The changed relative prices will stimulate the search for new methods of production which will use more of the now cheaper factor and less of the expensive one" (p. 120). This will occur partly by a process of factor substitution within the prevailing production function and partly by providing a stimulus for the discovery of new production technologies.

This proposition of Hicks has been criticized by Salter and Fellner on the argument that:

The entrepreneur is interested in reducing costs in total, not particular costs such as labor costs or capital costs. When labor cost rises, any advance that reduces total cost is welcomed, and whether this is achieved by saving labor or capital is irrelevant. There is no reason to think that we should concentrate our attention in labor saving technologies, unless, by some internal characteristic of the technology, the labor saving knowledge is easier to acquire than capital saving knowledge (Salter, pp. 43-44).

Ahmad showed that, without considering the cost of the innovation, or more specifically assuming that the cost and the generation time is the same for all the possible alternatives,

...a rise in the price of labor would lead to an innovation which is necessarily labor saving, if the innovation possibility is technologically unbiased. On the other hand, if the historical innovation possibility is biased in one direction or the other, the response to a change in the relative price of the factors will still be a tendency to economize on the factor which has become relatively more expensive, but this tendency will be modified by the bias of the historical innovation possibility (p. 349).

The theory of induced innovation is defended by Ahmad with the assumption that there exists a convex innovation possibility curve which can be perceived by entrepreneurs.¹

¹Hayami and Ruttan (1970) have attempted to show that this was not a strong restrictive assumption: "The innovation possibility curve need not be of a smooth well-behaved shape....The whole argument holds equally well for the case of two distinct alternatives." However, we believe that this is not necessarily true; if the assumption of a well behaved IPC is released and a set of two distinct innovation alternatives is admitted then the point of minimum cost with generation of technologies will not necessarily be one which saves the factor which has become more expensive; this will also depend on the magnitude of the isoquant shift implied by each one of the alternative innovations perceived by entrepreneurs.

Let's consider now this concept in a more detailed fashion with the historical innovation possibility curve. We can see in Figure 1 the determination of a new sectorial equilibrium with generation of technologies (initially without research cost) as a response to a change in factor price ratios. Say that there are only two factors of production, land (T) and "other factors" (X). In the period $t-1$ the unit isoquant of the innovation possibility curve is ICP_{t-1} , AB is the unit cost line² and the isoquant of the neoclassical production function used is I_1 . The sector is in initial equilibrium at 1 where Schumpeterian profits are zero.

Suppose that the land price increases while the price of the other inputs decreases so that the net effect is to shift the unit cost line to CD. Without innovations the individual producers will adjust to the new situation of relative prices through factor substitution along the isoquant I_1 , reaching the point 1' but here profits are

²The unit cost line is $P_t T + P_x X = P_y Y$ where P_t , P_x and P_y are the land price, the price of "other inputs" and final product price respectively. Making $Y = 1$ (we are working with unitary isoquants), $\frac{P_t}{P_y} T + \frac{P_x}{P_y} X = 1$, is the locus of points where profits per unit of output are zero. It can be easily seen here that changes in P_y will only change the position of the line, while changes in the relative factor prices will affect its slope.

negative,³ Given IPC_t as in Figure 1 it will be said that there exists a latent demand for innovations generating isoquant I_2 tangent to IPC_t at point 2 where producers will maximize profits. Since at this point Schumpeterian profits are positive, further price and/or innovation adjustments are necessary to bring the sector to a new equilibrium.

If final demand is inelastic and the supply of factors is elastic the adjustment will be mainly via final product prices; in the extreme case of elasticity equal to zero and infinity respectively, prices will drop, shifting CD in a parallel fashion until C'D' and the producers will be in a point of final equilibrium in 2 with zero profits. If the final demand is elastic, the supply of land is inelastic and the supply of "other inputs" elastic, the adjustment will be mainly via increase in land prices until they internalize all positive profits. In the extreme case of elasticity values equal to infinity, zero and infinity respectively the increase in the relative price of land (illustrated in the graph by a change in the slope of CD shifting now to CE), will provide incentives for the generation of additional innovation which would lead to the production alternative given by I_3 in which the producer will find the

³For profits to be nonnegative, a unit level of output should be produced on or below the line CD. In the later case $P_t T + P_x X < P_y Y$ (for example in point 2 of Figure 1), and profits will be proportional to the distance, along a ray from the origin, between the unitary isoquant and the unit cost line.

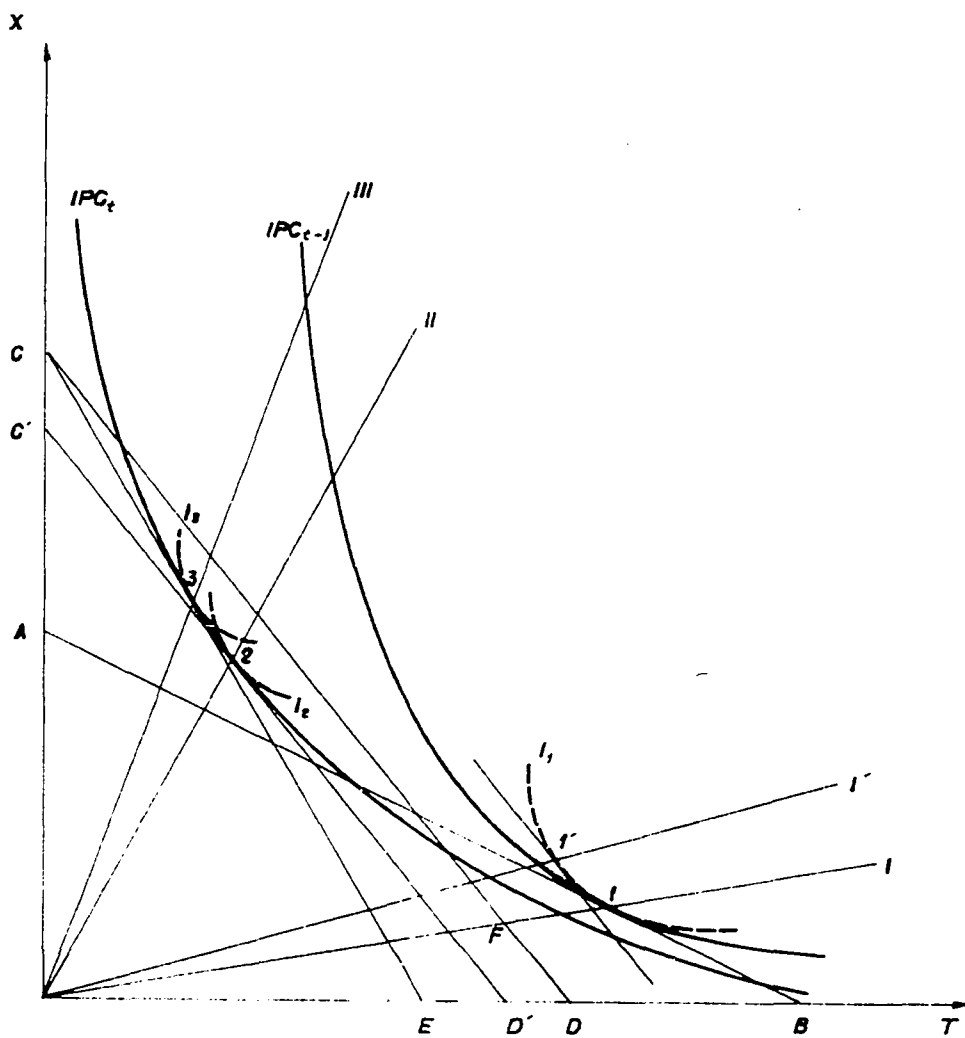


Figure 1. Sectoral equilibrium with costless innovations

equilibrium at 3, in the point of tangency with the envelope IPC_t . Intermediate situations in terms of elasticities will lead to equilibrium positions between 2 and 3 along the envelope IPC_t .

In summary, the factor ratios have changed in terms of comparative statics, from I to I' because of the traditional factor substitution, and from I' to II or III due to technological change induced by the changes in the relative price of the factors.

Research cost could be introduced in the solution by postulating, for example, that the cost of innovation increases as we move away from the factor ratios of the traditional, well-known technologies, that is, as we move away from the set of neoclassical isoquants in the neighborhood of the point of actual factor proportions. An innovation cost function will then be

$$R = F \left[\left(\frac{X}{T} \right) - \left(\frac{X}{T} \right)_I \right]$$

where R is the research cost per unit of output and I denote the traditional factor ratio. Suppose research costs are internalized, through a tax on output; in Figure 1 the unit cost line will pivot around F shifting downward and displacing the final equilibrium point to the right of 2 along IPC_t .

In the illustration of Figure 1 the isoquant I_1 corresponds to a traditional technology where land is used extensively; while isoquants I_2 and I_3 correspond to modern land saving technologies that we have shown as being in

latent demand. With the problem of technological stagnation in mind it is important to specify the shifters of the latent demand for innovations, which may displace the final sectorial equilibrium away from the land saving technologies and toward points of traditional ones. The most important factors are:

- a. Distortions in the relative price of final products and inputs; like for example the divergence between the set of domestic relative price for final products and inputs, and the corresponding levels prevailing in the international market. In this sense the most important factor would be given by an indiscriminated industrial protectionism, that, arising from a policy of import substitution, raises the relative price of nontraditional capital inputs for the agricultural sector, displacing latent demand toward traditional technologies.
- b. The risk attached to the knowledge of relative prices. For example, take the price of input X; the analysis so far has been carried using implicitly the principle of certainty equivalence; in other words, working with expected values. The introduction of risk aversion will lead to base decisions on a price of X sufficiently high as to

be 100% confident that it will not be exceeded. This would be equivalent to an increase in the price of X and will displace latent demand toward traditional technologies.

- c. Higher research costs per unit of output will also shift the latent demand toward traditional technologies. Because learning by doing and economics of scale in research, costs will tend to be higher in less-developed countries. If research costs are internalized in the sector via an output tax, it has been seen that latent demand will be closer to traditional technologies. In other words, the shift in latent demand due to changes in relative prices will be of smaller magnitude than in the eventual case of costless innovations. Alternatively, if the research budget were fixed and predetermined, the size of this budget will determine an interval of feasible innovations around the traditional technology. The point of latent demand could lie inside or outside this interval. In the latter case, the budget allocated for research will be incompatible with an optimum use of agricultural resources, given the prevailing relative prices.
- d. The stock of scientific knowledge--as mentioned previously--determines the position of the IPC_t .

Developed countries and international research centers will tend to have an IPC_t closer to the origin of the factor space than in the less-developed countries. If the secular pattern in which the IPC shift has in itself a land-saving bias (as it seems it has been the case historically), the implication of this would be that the latent demand in less-developed countries would be more for traditional technologies than in developed countries.

A Classification of Technologies for Agricultural Production

A wide spectrum of specific technologies, could be defined with different impact on the allocation of resources, on the level of yields and on the welfare of producers and consumers. Technologies are classified here into four categories: 1) mechanical (tractor, harvester), 2) biological (hybrid seeds, purebred herd), 3) chemical (fertilizers, herbicides, pesticides), and 4) agronomic (cultural practices in general, crop rotation, fertility test).

Given this grouping and using a comparative statics framework, the differential impact of each type of innovation on the allocation of resources in the sector is analyzed. In a market economy, the necessary condition for

the adoption of a new technology is the economic return that could be obtained by the individual firm. The ultimate impact on the optimal level resources used in the sector will be a function not only of the internal nature of the innovation--basically referred to its factor bias--but also will depend on the elasticity of demand for the final products, and on the supply elasticity for the agricultural inputs.

It is reasonable to assume that the elasticity of the aggregate supply of land is rather low. Taking a historical prospective, the expansion of the agricultural sector in the first decades of the present century has taken place mainly by occupancy of new land, with replication of technologies, constant return to scale, and a relatively fixed factor proportion, until the decade of the 1930's, in which the sector reaches the "extensive land frontier" in the Pampean region. On the other hand, it also seems reasonable to think in terms of a relatively high supply elasticity for the rest of the agricultural inputs. On the demand side for the final products, Argentina faces, for some of the most important exportable goods (meat, corn, sorghum) a long-run demand from the international market which is highly elastic.

Under these conditions, if the technological change is generated specifically for products whose demand elasticity is low, the ultimate effect of the adoption of such new

technology will be to free resources originally allocated to the production of these products, and to reallocate them in the production of items of higher elasticity of final demand. On the other hand, if the new technology developed applies directly to the production of products with a high demand elasticity the result will be a more direct expansion in their production.

With these considerations in mind the analysis goes into more detail on the ultimate impact of the different technologies on the relative level of land, labor, capital and management used in the production, and also on the levels of yield per acre. Following Seckler it is distinguished between what is called "on line management," which consists in the actual supervision of the daily activities of production, and "staff management" referred to the allocation of resources decisions and to the choice of technologies (mainly investment decisions, financial and fiscal administration and commercial activities).

In Table 2 the characteristics of the four categories of innovations considered are summarized; the sign in each cell indicates the direction in which the factor ratio would change, and the number of signs gives an idea of the magnitude of the corresponding factor bias.

Mechanical innovations mainly substitute labor in the production process. By doing so, they decrease the labor/

Table 2. A classification of agricultural innovations: factor bias and potential yield effect of the different types of technologies^a

Changes in Factor Ratios	Mechanical	Biological	Chemical	Agronomic
Capital/Land (K/T)	++	+	++	+
Labor/Land (L/T)	--	0	++	++
Capital/Labor (K/L)	++	+	0	-
On Line Management/Land	--	0	++	++
Staff Management/Land	+	0	++	+
Changes in Yield per Hectare	0	+	++	++
Examples	Harvester	Hybrid Seeds Purebred Herd	Fertilizers Herbicides Pesticides	Cultural Practices Management Practices

^aThe direction in which the factor ratio would change is indicated in each cell of the table as follows:

- 0 = no change
- + = small increment
- ++ = large increment
- = small decrease
- = large decrease.

land factor ratio, increasing consequently the productivity of labor. The substitution of labor by mechanical devices facilitates the supervision of workers substantially decreasing the relative requirements of "on-line management." At the same time staff management requirements may increase somewhat as the firm becomes more capital intensive. As pointed out by Sen and other authors, while mechanization raises considerably the yield per unit of labor, it does not generally lead to yield increases per unit of land.

The decision mechanisms for the induction of innovation will follow different channels according to the degree of private appropriability of the benefits generated in the research; this will depend not only on the internal nature of the technology but also the legal-institutional system (basically the existence of patent laws) and on the structure of the industry.

In the case of mechanical innovations the conditions for private appropriability of part of the benefits generated by the research would strongly depend on the legal-institutional system, since any new mechanical device could be disassembled and copied by any of the competing firms in the market--unless the invention is covered by a patent. Argentine law N^o 111 of invention patents does include, among the items that could be patented, all the spectrum

of agricultural mechanical devices (first grouping of the law items 3, 15 and 16). The patents are issued for a maximum period of 15 years and according to some of the patent agencies they provide a reasonably good cover against potential "replicators" of the innovation. The fee charged by the government to issue the patent is practically negligible.

Biological innovations are relatively neutral in land and management requirements. Also, they are slightly capital using and will increase only moderately yields when used out of a package of new techniques. In this group we have the most clear case of an innovation whose returns can be privately appropriable: the case of hybrid seeds. This is so, basically due to the internal nature of this innovation. The genetic characteristics of hybrid seed are only valid for the first generation, and consequently the seed cannot be reproduced (at least with the same genetic characteristics) either by the farmers or by other firms in the market-- unless they can get the inbred lines which constitute the "parents" of the hybrid seed which goes to the market. So, provided certain degree of industrial secrecy, the preconditions for private firms to invest in this kind of genetic research would exist.

The possibility for private firms to capture the returns from research on hybrids in Argentina is further

enhanced by the legal institutional setting, in spite of the fact that there is no provision for genetic innovations in the national system of patents (law N^o 111 of Invention Patents and complementary decrees). There exists a legal system of control of the seed breeders through the Ministerio de Agricultura y Ganadería, which supports the proposition that hybrid corn could be considered an appropriate innovation.

Given the high cost involved in the development of innovations consisting of "packages" of new technologies (mechanical-biological-chemical-agronomic) and the fact that the firms could capture only a small part of the benefits generated by this research, it is not likely to find private companies engaged in research and development of packages of integrated technologies. They will tend to concentrate on innovations adapted to the prevailing production conditions, rather than concentrating in innovations that could eventually be part of a completely new package of techniques. For example, seed companies will tend to put the emphasis on the development of hybrid varieties of maximum performance under the prevailing production conditions. That is, they will concentrate on the development of a seed whose genetic characteristics are adapted for the production under declining fertility conditions, if the package of techniques which includes fertilizer is not currently used, as it is

the case in Argentina. In the opposite case where such package (with fertilizer) is widely diffused in the sector, the efforts of the companies will go mainly to the production of high fertilizer responsive varieties.

Going back to Table 2, we can see that chemical innovations are mainly of land saving nature, allowing the substitution of capital and labor and increasing the yields per unit of land. The new allocation of resources will require relatively less land and more capital and labor. On the other hand, using relatively more labor will require more on-line management. Also in some degree the requirements of staff management will increase since the innovation increases the intensity of use of capital.

Finally, agronomic innovations are land saving and will require more labor and on-line management. As chemical innovations, the agronomic ones will be definitively yield increasing, but they will differ in the degree of capital requirements.

In general, the benefits of the research in chemical and agronomic innovations are not subject to private appropriability and consequently the bulk of the investment in these activities will be channeled as public investment through the agencies of the agricultural research system such as the Instituto Nacional de Tecnología Agropecuaria (INTA) in Argentina. It should be mentioned as exception in

this group that the returns from herbicides and pesticides could be privately appropriable if protected by patent law (as it is the case in Argentina). On the other extreme, the pure knowledge about cultural and management practices appears to be the most clear case of nonappropriable innovations. A similar statement would apply for the agronomic research on fertilizer application, where the results of experiments on fertilizer response for example, could be capitalized by any of the firms selling fertilizer in the market. Another aspect of fertilizer technology would be the one referred to the industrial research on fertilizer production and to the technological changes going on in the fertilizer industry which could decrease its market price, shifting the latent demand for fertilizer towards a more intensive use of it. Here it is needed to set the "frontier" of the concern of this research. It will not go in detail into the analysis of innovations accruing to the industrial sector and whose results from the point of view of the agricultural production function will be just a change in the relative price of a well-known input; rather, it will concentrate on the agricultural research and innovations shifting the neoclassical agricultural production functions along the innovation possibility curve.

Packages of innovations with technologies from two or more of the four groups considered will combine the factor

biases of their components; in general, there will be certain complementarity among them. This will be particularly true for packages of biological-chemical-agronomic technologies in which case the eventual "interaction effect" will reinforce the corresponding factor bias resulting from a purely additive consideration of the different elements in the package.

These packages will tend to be land saving, capital and labor using and very strongly yield increasing. As an example it could be mentioned the package of modern technologies in corn production that CIMMYT (International Center for the Improvement of Corn and Wheat) has proposed to Argentine institutions to be tested for agronomic and economic feasibility in this country. The package basically consists of fertilizer-responsive hybrid seed, weed control with herbicides, fertilizer, and a set of cultural practices.

CHAPTER III

A SOCIOECONOMIC MODEL OF INDUCED INNOVATIONS
FOR THE ARGENTINE AGRICULTURAL SECTOR¹

Introduction

In Chapter II, two alternative sources of supply for agricultural innovations were indicated. One is the agribusiness firms, which obviously will supply innovations only if it is possible to appropriate profits from investment in research. The other is the public sector which in the case of appropriable innovations could complement the private innovative effort. In the case of nonappropriable innovation, however, the public sector will be the only source of potential supply for this type of innovation.

On the demand side a latent demand for innovation was conceptualized and distinguished from actual demand. This distinction will be discussed in more detail in the present chapter.

In addition, once a technology is available, the problem of its adoption by the farmer should be considered; this may or may not be influenced by the same factors that have determined the generation of the technology and its availability for adoption.

¹This chapter draws heavily on Alain de Janvry and Juan Carlos Martinez (1972).

Among the problems included above, the ones arising from the use of public funds to finance the work of "non-market" research centers not oriented towards profits have not been completely clarified in the economic literature. Among other things it appears to be rather important: 1) to clarify the criteria that guide the public investment in these research activities; ii) to describe the channels by which the research is oriented to meet the farmers demand for innovations; iii) to analyze the form in which it can be conceptualized a demand for innovations from the society as a whole via sectorial objectives of economic policy; iv) also the form in which this policy materializes, in particular, the existence or not of a systematic policy directed toward the agricultural inputs side; and v) the consistency (or inconsistency) of both demands, from the farmers and from the society as a whole. These problems will be at least considered as part of the model that is about to be postulated.

In this context, the work of Hayami and Ruttan (1971) represents a significant contribution; they place the operation of the supply and demand mechanism for new technologies at the center of their theory of agricultural development.

...technical innovations that save the factors characterized by an inelastic supply, or by slower shifts in supply, become relatively more profitable for agricultural producers. Farmers are induced by shifts in relative prices to

search for technical alternatives which save the increasingly scarce factors of production. They press the public research institutions to develop the new technology and, also, demand that agricultural firms supply modern technical inputs which substitute for the scarce factors. Perceptive scientists and agricultural entrepreneurs respond by making available to farmers new technical possibilities and new inputs that enable farmers to profitably substitute the increasingly abundant factors for increasingly scarce factors, thereby guiding the demand of farmers for unit cost reduction in a socially optimum direction (Hayami and Ruttan, 1971, p. 57).

In the Hayami-Ruttan model, the generation of innovations is studied at the supply-and-demand level and not at the level of the decision function of government, farmers and researchers. Their approach is satisfactory because they work in a comparative statics framework which compares equilibrium points before and after innovation and are not overly concerned with a specification of the dynamic adjustment path generated by the successive interplays of individual adoption decisions and of public innovation decisions. However, specification of this path is important because the existence of major lags in the generation of innovations that would be consistent with prevailing factor and product prices may further influence the use of resources in agriculture away from a social optimum.

The first step in the specification of the socio-economic model of induced innovations consists of distinguishing between latent and actual demand for innovations.

If expected profits are being maximized, a change in prices and/or a change in the IPC will create a latent demand for innovations corresponding to the neoclassical production function tangent at 2 or 3 to IPC_t in Figure 1. As shown earlier in Chapter II, higher and more variable prices of industrial inputs, lower stock of scientific knowledge, and higher costs of innovations will all shift the latent demand toward the more traditional technologies and away from a socially optimum use of agricultural resources. The second step consists of specifying the decision processes that underlie the actual demand for innovations.

The Actual Demand for Innovations

As mentioned in Chapter II, actual demand is the one which in fact guides the allocation of public and private resources in research and development. This demand will materialize essentially under three aspects:

1. a flow of information from agricultural producers to the experiment stations and other research centers (including the agribusiness firms);
2. a flow of information from the government policy makers to the same research centers; and
3. the budget allocated for research both in its absolute size and in its allocations among the different research alternatives.

An important question here is whose demands will finally affect the size and allocations of funds and constitutes a source of information for the researcher as to the type of innovations currently desired.² This can be important since different technologies will affect differently producer and consumer surpluses. The demand of the public at large is supposedly voiced through the government; however, in Argentina there is a virtual inexistence of a long-run technological policy directed toward the agricultural sector and instrumented in a systematic way. In other words, the situation is one of a virtual inexistence of a demand for agricultural technologies originated in the public sector and derived from global or sectorial goals of economic policy.

Thus, in Argentina the actual demand for innovations originates in the agricultural sector. This is important for two reasons: first, the prevalence of this demand originated in the agricultural sector will tend to increase the producer surplus and not necessarily the consumer surplus; second, the farmers composing the agricultural sector are not equally represented, since large landowners have dominated agricultural interest.

²As mentioned before, the response of the private source of supply will be conditioned by the possibility of appropriating profits from the investment in research.

Consequently it can be argued that the actual demand for innovations which determines the size and allocation of public research funds derives from the maximization of utility of these dominant farm interests; i.e., large landowners. The same is true for information conveyed to the scientists since educated, large farmers are the ones that are in closest contact with the experiment station (see Obschatko).

The specification of the utility function of the dominant farm interests should be attempted. Unfortunately little is known on it since economists and sociologists have usually concentrated on adoption instead of generation of innovations (i.e., Griliches, 1957a,b; Haven and Rogers; Brander and Strauss); on the occurrence of instead of the demand for innovations--ex-post growth accountancy--on innovation by private firms instead of public institutions (i.e., Griliches, 1957a,b; Mansfield, 1968; Minasian, 1962; Nordhaus), and on the latent demand instead of the actual demand (i.e., Hicks; Ahmad; Kennedy; Fellner; Salter).

Two elements should undoubtedly enter the utility function for innovations: expected profits and risk aversion. Rosenberg's historical review of induce of innovations lead to a specification of the other elements that enter into the decision process: one is stress and the other congruence.

Quoting Rosenberg's conclusions:

It is possible, furthermore, that threats of deterioration or actual deterioration from some previous state are more powerful attention-focusing devices than are vague possibilities for improvement. There may be psychological reasons why a worsening state of affairs, or its prospect, galvanized those affected into a more positive and decisive response than do potential movements to improved states. The same sort of asymmetry which Duesenberry postulated for consumer units confronted with the need to adjust to a downward revision in their incomes may hold for decision makers who control the allocation of resources for exploring the technological horizon. Such asymmetrical behavior may possibly be treated more approximately within a "satisficing" model of extreneurial behavior and response, where alternative technologies are explored only when a firm's profit position falls below some minimum acceptable level. In any case, it is clear that threats to an established position have often served as powerful inducements to technical change (p. 23).

Hence, stress is defined as negative or falling profits, and it would tend to appear as a powerful inducer of innovations. If stress acts as a focusing device and accelerates the rate of technological innovations, it must be because a goal exists, explicit or implicit, that dominates the profit maximization goal lexicographically and which, in turn, is dominated by the goal of stress removal. To determine this goal, intermediate between stress and profits, attention is given again to the literature on innovations.

Rosenberg mentions that:

If we would like to understand the kinds of problems to which technically competent personnel are likely to devote their attention,

we must come to grips with their inevitable preoccupation with day-to-day problems posed by the existing technology. We might here invoke what March and Simon call Gresham's Law of Planning which, succinctly stated, amounts to the proposition that daily routine drives out planning. If we pay more attention to the cues thrown out by this daily routine, we may gain a clearer understanding of the process of technical change (p. 24).

Similarly, Eckaus pointed out that in a "demand theory" of inventions, these are "for the most part produced to order by step-by-step refinement of the known state of the arts" (p. 107). The implication is that the actual demand for innovations is primarily geared at improving existing designs and at inducing innovations that are compatible with prevailing factor ratios, provided there is no economic stress. This shall be called the (implicit) congruence goal.

In summary, three elements enter into the decision mechanism of the inducement of innovations: congruence that dominates expected profit (Π) maximization, lexicographically, and stress that dominates congruence, also lexicographically. If a risk aversion goal is also introduced in the form of a survival constraint like $Pf(\Pi \geq 0) = \alpha$ (that is, a high probability of not having negative profits) that also dominates congruence, the utility function for innovations will be:

$$LU \{ E(\Pi) \geq 0 ; Pr(\Pi \geq 0) = \alpha ; \text{Max congruence} ; \text{Max } E(\Pi) \}$$

(stress) (survival) (congruence) (profits)

It is postulated that the actual demand for innovations will result then from the maximization of this utility function corresponding to the dominant farm interests. It should be mentioned at this point that while the generation of innovations is characterized here as the result of a socioeconomic process, the adoption process will be an individual matter essentially determined by profit maximization objectives of the firm. With this proviso the initial implications of the decision mechanism provided by the use of this utility function for the actual demand for innovations, can be illustrated.

For this a similar line of reasoning to the one used in Chapter II, Figure 1, can be followed. Now in Figure 2, K_T is used instead of X in the ordinate axis. Positive profits are priority goal, the part of IPC_t that satisfies this dominant goal is below the unit cost line CD, that is the arc between A and B. This segment of the IPC_t may be further restricted to meet the next goal of risk aversion. Once stress is eliminated and survival insured, maximum congruence with prevailing factor ratio II becomes priority goal. Once this is done, expected profits are maximized.

If the new unit cost is CD (following the lines of reasoning of Figure 1 in Chapter II), the generation of the new isoquant I_2 will eliminate stress which still existed in I_1 ; it will also be congruent with the factor proportion

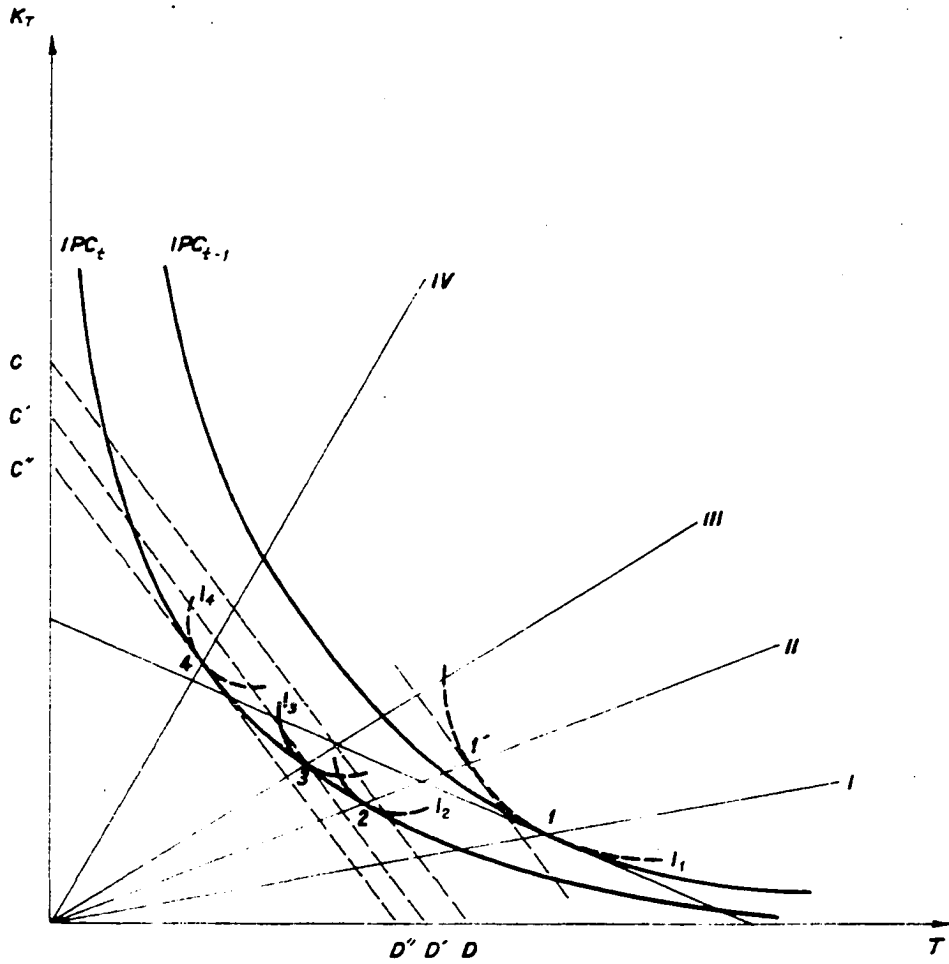


Figure 2. The actual demand for land-saving technological innovations

II and will maximize expected profits given the congruence restriction. Hence the actual demand for innovations applies to isoquant I_2 .

If on the other hand the unit cost line is at C'D', elimination of stress requires changing the factor ratio from II to III, that is, in this case, congruence will have to be sacrificed if one wants to cover the priority goal of eliminating stress. The actual demand which arises from the lexicographic utility function is given by technology I_3 . Hence, stress shifts the actual demand away from congruence with "daily routine" and focuses innovations on more advanced technologies. Only if unit cost is at C"D" will the actual and latent demand be coincident in aiming at technology I_4 .

The decision mechanism just specified generates a lag between actual and latent demand and hence implies a social cost; the implicit cost of not being in an optimal technological path.

All the elements identified as shifters of latent demand will also affect actual demand; but the latter will depend in addition on:

1. The representativeness of the dominant farm interests from whose utility function derives the actual demand for innovations. The more representative they are the weaker the congruence goal

since a wider spectrum of prevailing factor ratios is induced. If, by contrast, farm interests are dominated by large land-owners, congruence requirements with low X/T ratios, and hence traditional technologies, will prevail. The influence of nonfarm interest on the budgeting of agricultural research, through, for example, the national development plan could also shift actual demand presumably towards latent demand since it constitutes a social optimum; but this has not been the case in Argentina. As we mentioned before the lack of a systematic technological policy directed towards the agricultural sector had implied the prevalence of the farm interests in the determination of actual demand for innovation.

2. The intensity of interactions among farmers, researchers and administrator (this will be valid not only for the actual demand but also for the supply side for innovations). As pointed out by Hayami and Ruttan "the dialectic interactions among farmers and research scientist and administrators is likely to be most effective when farmers are organized into politically effective local and regional farm 'bureaus' of farmer associations" (demand side). "The response of the public sector research and

extension programs to farmer's demand is likely to be greater when agricultural research system is decentralized as in the United States" (supply side) (p. 57).

Finally, before concluding this section on actual demand, the utility function used should be qualified in two directions. In the first place, the difficulties implied in handling the concept of congruence should be mentioned (difficulties basically derived from the impreciseness of its own definition); actually congruence is not thought as goal in itself but rather its inclusion in the utility function allows to capture an observable phenomenon which will significantly explain the lag between actual and latent demand.

In the second place, it is rather obvious that the lexicographic dominance is the most restrictive relation that can be defined between congruence and profit maximization. Actually there will probably exist a certain degree of substitutability between them, that is, we can find level of profits and flow of information such that the producer could be willing to give up congruence and induce innovations which will lead him away from the traditional factor ratios. The implicit assumption of no trade offs emphasizes the lag between actual and latent demand, for which some empirical evidence can be cited (see Chapter V).

Consequently, an element of normative content as the objective function, is used in a positive sense. It is just pretended with it to conceptualize aspects of the behavior of a group of producers which could explain in considerable degree the direction followed in the research.

The Supply of Innovations

Given the specification of actual demand, the picture of generation of technologies will be completed, going briefly into some aspects of the supply of new technologies.

As mentioned before, we have two sources of supply, one given by the private business firms and the other corresponding to the public sector. The first component of the supply will derive from the economic behavior of private firms, in particular of the ones providing agricultural inputs to the sector, and is rather obvious that it will materialize, only if the internal nature of the innovation, the legal-institutional system (basically patent laws) and/or the structure of the industry makes it possible for these firms to appropriate certain profits from their investments in certain types of research. Provided the innovation is appropriable, our hypothesis is that its supply by private firms will be largely guided by the expected pay off for the required investment in research and development. Chapter V provides a test of this hypothesis with the case of hybrid

corn. The public source of supply for innovations will have absolute prevalence in the case of research and development activities whose social benefits cannot be privately appropriated, in other words, for nonappropriable innovations the supply will be restricted to the public research network.

The actual demand will guide the allocation of the research budget of public institutions, and will also provide a flow of information to research scientists. In Argentina, the main institution which has the responsibility of "producing" innovations for the agricultural sector, and hence, the most important source of public supply of new technologies is the Instituto Nacional de Tecnología Agropecuaria (INTA) whose activities are financed by a tax of 1.5 percent on the value of agricultural exports. Oslak, Sábato, Roulet and Lavergne have pointed out in their work that the lack of concrete and explicit government directives had led the direction of INTA to elaborate and fix the goals and objectives of its own activity. However, the initiative for research and extension projects and the corresponding demand for funds originates basically at the level of the experiment station.

The initiative is then originated in the researchers and extensionists of INTA who are exposed to the influences of the farm environment in which they work. The present planning system is not based necessarily on a set of

priorities rationally established but rather on a process of accumulation of initiatives and decisions about them.

On the other hand, there exists some evidence that most of the farmers who are in the closest contact with the experiment stations are precisely the large ones (Obschatko, Tandeciarz).

Without going into more detail in this section, it is understood that previous considerations support the hypothesis that the public research system is flexible enough as to allow the research funds to be channeled in the direction indicated by actual demand.

The Adoption of New Technologies

Once the new technology has been made available to the agricultural sector by private business firms or public research institutions the adoption of it by farms entrepreneurs is an individual matter which is essentially determined by profit maximization objectives. On the other hand, the rate at which the new technology is adopted will be conditioned by a set of economic and noneconomic factors. However, a prerequisite for the adoption of a technology will be given by the economic benefit that a producer would expect to derive from it. Differences in profitability conditions will largely explain differences in the rate of adoption. This proposition has been internationally tested, and it

will also be tested here for Argentina using the case of hybrid seed (in Chapter V). In the meantime, it will be used as a maintained hypothesis for the rest of this chapter.

The Dynamics of the Technological Treadmill

The decision mechanism specified for actual demand generates a lag between the latter and the latent demand for innovations. However, there will be an interaction between generation and adoption of new technologies. This will result in a long-run adjustment path that will bridge the gap between both demands leading the economy towards an optimal point of generation and use of technologies. This section presents in a more detailed fashion the possible properties of such adjustment path.

The process is illustrated in Figure 3. Let's suppose that the unitary cost is CD and that the technology represented by the isoquant I_3 has been generated according to the description made in Figure 2. Once the technology I_3 is available, the producers will tend to displace along I_3 to the left of point 3 towards positions of maximum profits with $\Pi > 0$. If the supply of land is inelastic (elasticity = 0) with certain elasticity for the supply of the other inputs (in particular for K_T) and a high elasticity of product demand, positive profits will be capitalized in the value of

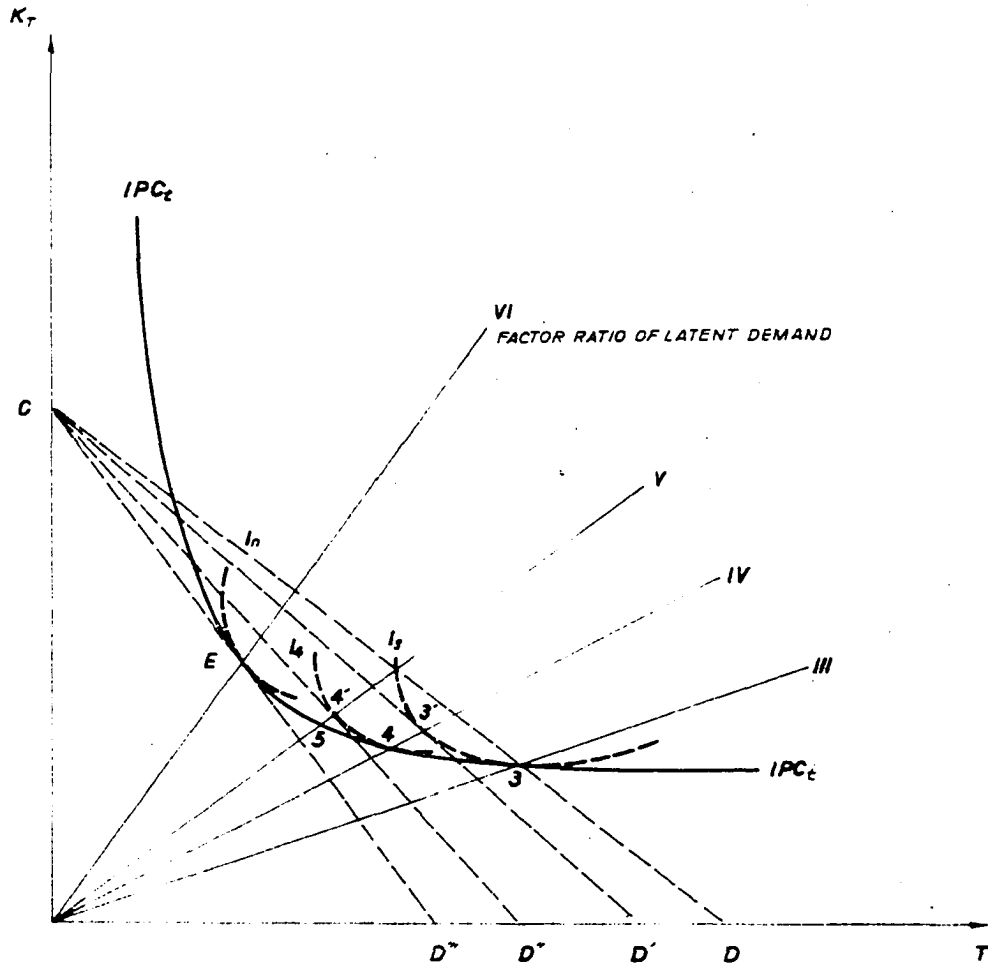


Figure 3. Dynamic adjustment path between actual and latent demand

the factor whose supply is inelastic. That is, the price of land will increase until Schumpeterian profits have been eliminated. The unitary cost line CD will pivot on C to the left as the producers try to displace along I_3 to the left of 3 until by successive adjustment the point 3' is reached with a unitary cost equal to CD' and $\Pi = 0$.

At this point the actual demand for innovations will guide the allocation of resources to research and development in such a way that the technology I_4 will be generated, since it is congruent with factor proportion prevailing in 3' and maximizes expected profits, satisfying then the maximization of the lexicographic utility function. Once I_4 is available and provided certain time for its adoption, the producers will tend to move toward 4' maximizing profits and provoking additional adjustments in the price of land which will lead to a short-run equilibrium in 4', being now CD'' the unitary cost line and again $\Pi = 0$. But as point 3', point 4' is not a final equilibrium point since actual demand for innovation will push for the technology given by I_5 which will be available after certain period and similar adjustments will lead the process towards technology I_n converging actual to latent demand in point E, where the sector reaches a stable equilibrium at least for the period t in the tangency point between the unitary cost and the innovation possibility curve.

In summary, the introduction of stress and congruence in the decision making process for the generation of innovation results in a gap between actual and latent demand; but this lag tends to disappear through the interaction of the process of generation and the process of adoption of new technologies via an entrepreneurial behavior in the process of adoption of the available technologies and the consequent adjustments provided by the market system.

Coercion in adoption has been known as the "technological treadmill" (see Cochrane). The mechanism proposed here is conceptually similar to the dynamics of the "technological treadmill" postulated by Cochrane in a framework of inelastic demand for farm products: output-increasing, average cost-reducing technological changes are adopted by some profit-seeking farmers; supply shifts to the right and prices drop as do profits of all other farmers who are in turn forced to adopt the new technology to lower their costs and maintain their income position; in the process, the rent of the early adopter is wiped out and they are induced to look for other technological opportunities. They do so by pressing the agribusiness firms and the agricultural experiment stations to produce innovations further. In this model, a minority of active profit seekers can throw the whole sector on a persistent disequilibrium course of rapid technological changes. Argentina, since it faces highly elastic

long-run demand schedules in the world market for its exports of beef and cereals, cannot depend on the product-market treadmill. Still the coercive mechanism can exist through a land market induced treadmill; but with properties that are distinct from the ones described by Cochrane.

Assume that average costs reducing land saving new techniques are available and adopted by some farmers. For these farmers, the rate of return on resources increases. If the capital market was previously in equilibrium, this increase in rate of return has to be capitalized in land values in order for the capital market to return to an equilibrium situation. Adopters will bid up the price of land until rates of return are again at par with opportunity costs. As land values increase, both the opportunity cost of holding land and the flow of capital gains increase. The net effect on profits depends upon the magnitude of the rate of increase in land values (τ) relative to the opportunity costs of capital (r). If, as is usually the case, $r > \tau$, profits of owner-operators and of tenants who do not adopt the new technology will collapse.

This can be seen as follows:

If land values increase at a constant rate τ , profits in the first period are:

$$\Pi_1 = PY - WL - (r + \delta) P_K K - (r - \tau) P_T T$$

where W is the wage rate and δ is the rate of depreciation of capital, while in the second period they will be

$$\Pi_2 = PY - WL - (r + \delta) P_K K - (r - \tau) (1 + \tau) P_T T .$$

Hence, $\Delta\Pi = \Pi_2 - \Pi_1 = -\tau (r - \tau) P_T T$ is negative if $r > \tau$. The user cost and rental value of land have increased from $(r - \tau) P_T T$ to $(r - \tau) (1 + \tau) P_T T$.

Adoption of new technologies by some farmers raises the price of land and depresses the income position of non-adopters. The basic difference, though, between product market and land market treadmills is that, while a product treadmill affects the cash income position of nonadopters, a land treadmill only affects the noncash income position of owner-operators, land cost increases are changes in opportunity costs and not in cash costs. And the perception of a deterioration in noncash income will probably be much slower than the one of changes in cash income. There are only two categories of farmers on which the impact is immediate. One is the new entrants in the farm sector who have to buy their land at the inflated values; the other is the tenants who have to rent their lands at the increased user costs.

In summary, it is argued here that a technological treadmill effect exists even when product demand is elastic. This treadmill occurs through the land market instead of

through product markets (provided land is in fixed aggregate supply), and it is of such longer run in its impact on the rate of adoption even though ultimately as inescapable as Cochrane's.

Whatever the form of the treadmill, market forces impose a dynamic coercive mechanism of change upon the agricultural sector. Hence technology appears as a powerful agent of structural and behavioral changes. In the context of the Argentine Pampean region the generation of highly profitable technological packages may generate diseconomies of large scale and force landowners to manage their operations more intensively, thus acting in the direction of a land reform process that can be accelerated by a land taxation scheme.

In the following chapters, some empirical evidence will be provided, in support of part of the propositions presented in our socioeconomic model of induced innovations. In Chapter IV the "success story" of the innovative effort is covered, the basic characteristics, in terms of our model, of the actual technological path that the Argentine agriculture has been following for the last decades. Some indicators are presented in order to provide a quantitative idea of the process of diffusion of mechanical and biological technologies. Also the analysis goes briefly into the characteristics of these technologies which are relevant in terms of

our model of induced innovations.

In Chapter V the analysis goes into some detail in the case of hybrid corn, as a good example of an appropriable innovation, describing the internal nature of this technology, also the different steps of its generation and diffusion and finally, testing whether or not the market forces had played any role in this process. In particular whether or not the behavior of the agribusiness firms was guided by the expected pay off for their investment in research. On the demand side, it is attempted to assess how important the economic variables could be in explaining the rate of adoption. In Chapter VI, the potential technological path for Argentine agriculture is explored. In particular, a non-appropriable innovation, fertilizer, is taken, and some supporting evidence of the existence of the gap between actual and latent demand for this technology, the actual lack of availability for the Pampean farmer, and the degree of incongruence of this technology in terms of the factors ratios prevailing in the traditional production structure, is presented.

CHAPTER IV

ACTUAL TECHNOLOGICAL PATH IN ARGENTINE AGRICULTURE

Introduction

In Argentina, the "success story" of the innovative effort corresponds basically to the technologies that we have classified in Chapter II as mechanical and biological. The use of hybrid seeds and purebred cattle and the process of mechanization have spread rapidly in the farms of Argentina during the last decades.

The purpose of this chapter is to analyze briefly whether or not these technologies do have common characteristics which are relevant in terms of the model of induced innovations. Also, some indicators are presented in order to provide a quantitative idea of the process of diffusion of these technologies. Then the analysis will go in the next chapter to the case of hybrid corn and proceed to a somewhat more detailed study of the process which leads to its generation and diffusion in Argentina.

The generation of these technologies has been the result of the joint effort of public research institutions and private agribusiness firms. If there has been public investment in research and development activities directed toward these innovations, it is, in terms of the model, because there existed an actual demand for these innovations

which guided the allocation of funds in this direction. The existence of such demand could be explained in terms of congruence and profitability associated with these technologies. The congruence concept is understood here in the sense that the innovation is consistent with the prevailing traditional production structures or, more specifically, it does not change the ratio of land to "other factors."

Simultaneously there was private investment in research and development activities directed toward these innovations. This was so because in all the cases (mechanization, pure-bred cattle and hybrid seeds) there was an a priori possibility of private appropriation of some part of the social benefit generated by the research. In any case the new technology is used by the farmers only if it is profitable for them to do so; and this ultimately acts as necessary condition not only for the adoption of the technology but also for the mere existence of private investment in specific types of research.

Hybrid Corn

Now, let's take the example of hybrid corn. Why has there been private investment in this genetic innovation? Basically because both the internal nature of this technology and the legal institutional conditions prevailing in the sector permitted to the firms to appropriate part of the benefit

generated by the innovation. At the same time, the realization of these benefits required the adoption of the new technology by the farmers and this was possible, in a market economy like Argentina, only because the technology was sufficiently profitable and secure for them.

The biological process of hybridization is such that it allows the company investing in this research to keep "control" of the innovation inasmuch as they can keep the secrecy about the pedigree of their hybrids.

On one hand, contrary to the open-pollinated varieties, the hybrid variety cannot be reproduced with the same genetic characteristics after the first generation. That is, the farmers cannot make their own selection from the corn produced on their farms and then use it as seed for the next crop season because the hybrid seed loses in the successive generations its vigor and characteristics which make it superior to the open-pollinated varieties; in other words, the farmer will have to buy the seed from the seed breeders every year, insuring the firms a continuous return to their innovations.¹

¹Notice that this is not the same for the new synthetic corn varieties where seed characteristics are maintained through successive generations. For this reason, the returns from innovations to private firms are substantially reduced, explaining the lack of research and interest by seed companies in this type of innovation.

On the other hand, competing seed breeders are not able to appropriate the results of the research efforts of any other firm since all the firms can keep the pedigree of their hybrids secret.

The possibility for private firms of capturing the returns from research on hybrids is further enhanced by the legal institutional setting, in spite of the fact that there is no provision for genetic innovations in the national system of patents (Argentine law N^o 111 of Invention Patents and complementary decrees). However, there exists a legal system of control of the seed breeders, instrumented by the Ministerio de Agricultura y Ganadería, which helps to consolidate the idea that hybrid corn could be considered an appropriable innovation.

In summary then, the internal biological nature of the technology and the corresponding legal-institutional system make hybrid corn an appropriable innovation; and, consequently, it is natural to find the participation of private investment in the research activities directed toward its development.

Table 3 and Figure 4 provide an approximate idea of how the diffusion of hybrid corn has proceeded at national level. They show the production of hybrid corn as declared by the public and private producers in the Ministerio de Agricultura y Ganadería. It could be observed that the growth in the

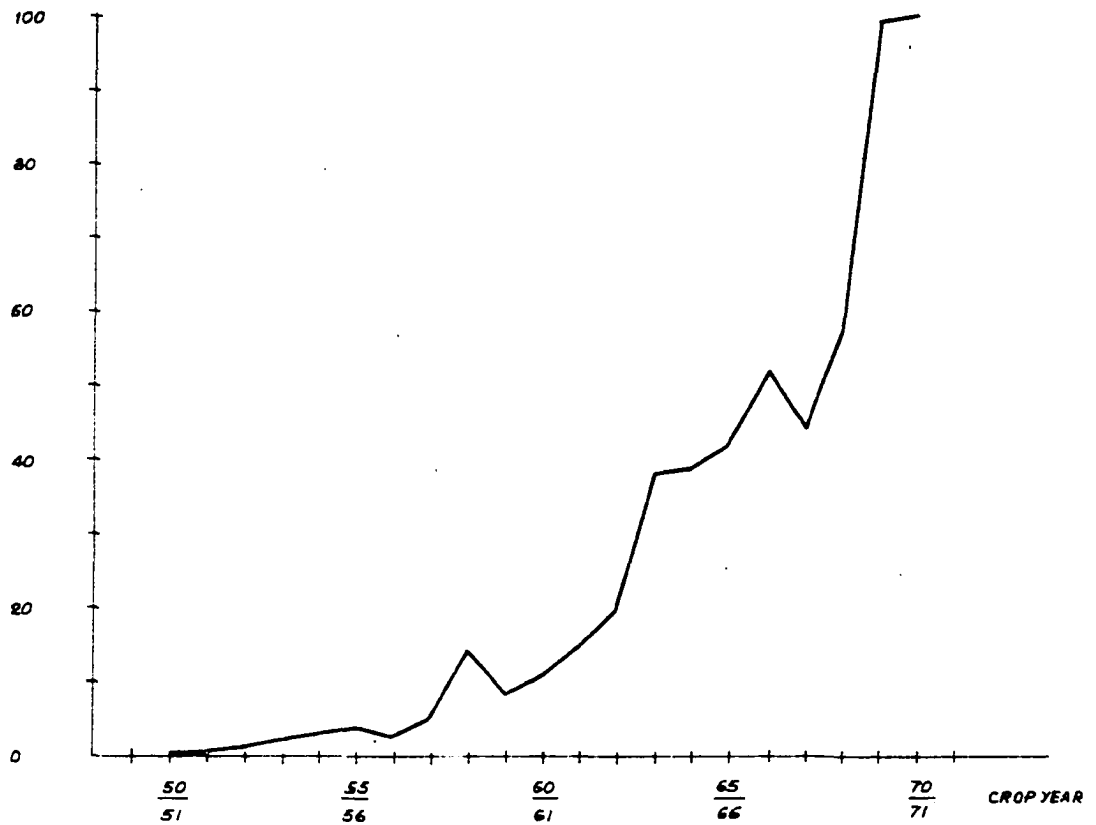
Table 3. Production of hybrid corn in Argentina

Crop year	Total production in tons ^a	Index 1970/71=100
1949-50	2.5	- ^b
1950-51	435.7	0.4
1951-52	559.0	0.5
1952-53	1,644.7	1.6
1953-54	2,780.0	2.6
1954-55	3,458.0	3.3
1955-56	4,517.3	4.3
1956-57	3,109.0	2.9
1957-58	5,505.0	5.2
1958-59	15,778.3	14.9
1959-60	9,386.0	8.9
1960-61	11,393.5	10.8
1961-62	15,936.5	15.1
1962-63	21,485.5	20.3
1964-65	40,863.0	38.7
1964-65	41,408.0	39.2
1965-66	44,786.0	42.4
1966-67	55,180.0	52.2
1967-68	47,092.0	44.6
1968-69	61,345.3	58.0
1969-70	105,015.7	99.4
1970-71	105,695.0	100.0

^aSource: Ministerio de Agricultura y Ganadería.

^bNegligible.

PRODUCTION INDEX 1970-71 = 100



SOURCE: MINISTERIO DE ABRICULTURA Y GANADERIA

Figure 4. Production of hybrid corn in Argentina

production of hybrid seed roughly approximates a logistic growth pattern² with the exception of the peaks produced in the crop years 1958/59 and 1966/67.

Mechanization

In the case of mechanical innovations the conditions for private appropriability of part of the benefits generated by the research would strongly depend on the legal-institutional system. Any new mechanical device could be disassembled and copied by any of the competing firms in the market, unless the invention is covered by a patent. The Argentine law N^o 111 of invention patents does include, among the items that could be patented, all the spectrum of agricultural mechanical devices (first grouping of the law items 3, 15, and 16).

The patents are issued for a maximum period of 15 years and according to some of the patent agencies they provide a reasonably good cover against potential "replicators" of the invention. The fee charged by the government to issue the patent is practically negligible.

Going through the files of the agricultural mechanical devices patented it is observed that a high percentage was

²The properties of the logistic growth curve are specified in Chapter V.

issued to foreign firms, in particular during the last decade; this is just another indication of the intensity of the international transfer of mechanical technologies. In addition there has been a significant contribution of the domestic firms.

Most of the investment in research and development directed toward mechanical innovations (in particular the "adaptive" research of basic designs) has been carried out by private firms.

Mechanization in Argentina has proceeded rather slowly since the beginning of the century until 1947. This was in part due to the existence of a relatively cheap and abundant supply of labor. After this year, the rate of diffusion of mechanical technologies, as indicated by the number of farm tractors in stock, starts to grow at an increasing rate. This can be seen in Table 4 and Figure 5 where the evolution in the stock of farm tractors is presented based on alternative sources (National Census and unpublished data from Ministerio de Agricultura y Ganadería).

Figure 5 shows that the growth in the number of farm tractors is not too far from a logistic pattern. The vast majority of the units are found in the Pampean region (see Fienup, Brannon, and Fender, pp. 169-170).

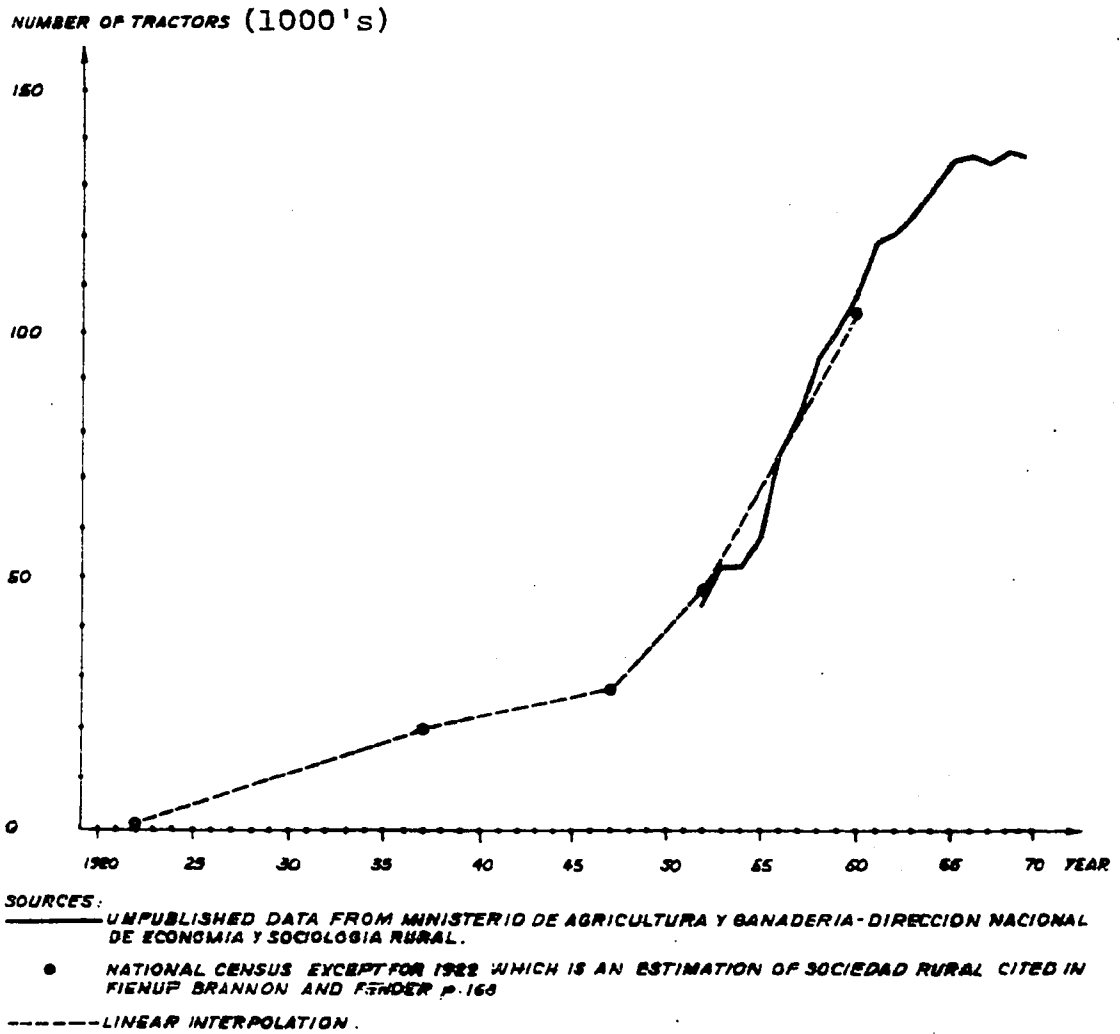
It has been indicated in Chapter II that mechanical innovation mainly substitute labor in the production process.

Table 4. Number of tractors in stock at the end of each year

Year	Number of tractors in stock			
	(1) ^a	(2) ^b	Index 1947 = 100	
			(1) ^a	(2) ^b
1922		1,800		6.2
1937		21,254		72.9
1947		29,150		100.0
1952	46,709	49,759	160.2	170.7
1953	53,539		183.7	
1954	53,691		184.2	
1955	60,033		205.9	
1956	76,276		261.7	
1957	85,515		293.4	
1958	96,114		329.7	
1959	102,204		350.6	
1960	108,629	104,156	372.7	357.3
1961	119,009		408.3	
1962	121,901		418.2	
1963	125,502		430.5	
1964	131,805		452.2	
1965	136,319		467.6	
1966	137,423		471.4	
1967	136,871		469.5	
1968	138,261		474.3	
1969	137,946		473.2	

^aSource: Unpublished data from Ministerio de Agricultura y Ganadería, Dirección Nacional de Economía y Sociología Rural.

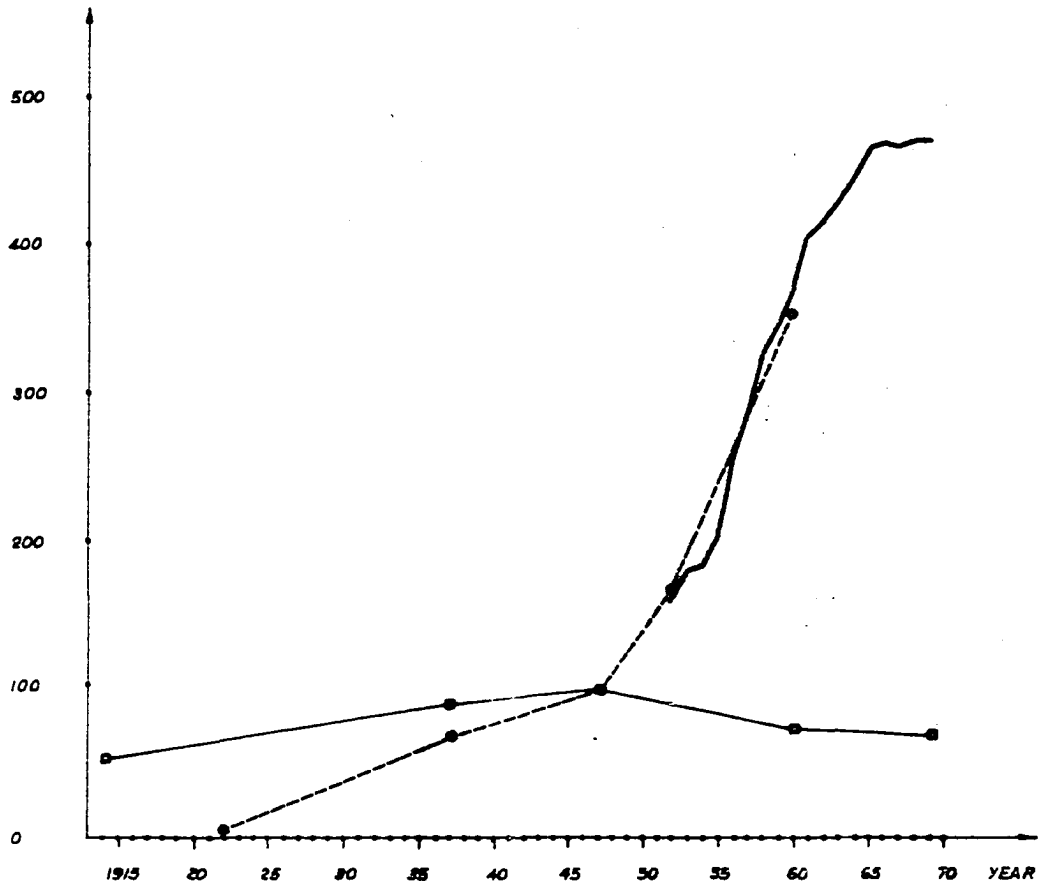
^bSource: National Census. Except for 1922 which is an estimation of Sociedad Rural cited in Fienup, Brannon, and Fender, p. 168.



The available data for Argentina appears to be consistent with this proposition. The year of 1947 in which a rapid rate of growth in the number of farm tractors is observed is the same year in which the agricultural labor force started to decline. This is particularly true in the Pampean region, where the process of mechanization was concentrated.

Figure 6 shows the evolution of the aggregate number of tractors in stock vis-a-vis with the one corresponding to the agricultural labor force in the Pampean region. Unfortunately, it was not possible to disaggregate by regions most of the data on farm tractors. However, the data on Figure 6 still has some meaning, provided that there is indication that the process of mechanization has been far more important in the Pampean region (Fienup, Brannon and Fender, and Gallo Mendoza and Tadeo). As indicated by the graph, the diffusion of mechanical technologies in the Argentine Pampa has played a rather important role in the decline of the agricultural labor force of the region.

INDEXES 1947=100



SOURCES:

— FARM TRACTORS UNPUBLISHED DATA FROM MINISTERIO DE AGRICULTURA Y GANADERIA - DIRECCION NACIONAL DE ECONOMIA Y SOCIOLOGIA RURAL.

- FARM TRACTORS, NATIONAL CENSUS, EXCEPT FOR 1922 WHICH IS AN ESTIMATION OF SOCIEDAD RURAL CITED IN FIENUP BRANNON AND FENDER p.168

----- FARM TRACTORS LINEAR INTERPOLATION

- AGRICULTURAL LABOR FORCE, NATIONAL CENSUS, FOR 1969 PROVISIONAL FIGURES

———— AGRICULTURAL LABOR FORCE LINEAR INTERPOLATION.

Figure 6. Indexes of the aggregate number of farm tractors and agricultural labor force in the Pampean region, 1947=100

CHAPTER V

ACTUAL TECHNOLOGICAL PATH OF ARGENTINE AGRICULTURE:
THE CASE OF HYBRID CORN

The Hybridization Process, Characteristics and Origin

Hybrid corn is the result of a controlled and systematic crossing of self-pollinated lines selected according to desirable characteristics. The first step in the hybridization process is the development of the so-called inbred lines or self-pollinated lines for eventual use in crosses. In this first stage of self-pollination which lasts for about five years, the plants and the lines having the more desirable combinations of characters are selected. As Haynes indicated:

The particular objectives are vigorous inbred lines, free from abnormalities, that excel in vigor characteristics, that have good pollen and ear development, desirable seed characters, ability to withstand lodging (usually correlated with root development) and that have as great resistance as possible to diseases and insect pests (p. 66).

Most of the "desirable" characteristics are for adaptation to the environmental condition, where the particular hybrids will be grown. These superior lines are then used to make the hybrids.

The initial idea of improving the yield of corn through the development and crossing of inbred lines goes back to the beginning of the present century in the United States

and is attributed to G. H. Shull who outlined the value of selected crossings in 1908. But the method of Shull, based on single crossings did not appear satisfactory for practical use, since the inbred parents were low in productivity and consequently the massive seed production for the commercial crop was too costly to be economically feasible.

The actual turning point in the economic history of hybrid corn is associated with the work of Donald F. Jones in Connecticut, who proposed in 1918 the double-cross plan, which is now used extensively by the seed producers. In this method, two single crosses are used as parents and these are crossed to produce double-cross seeds that are sold to the growers. The double cross has the advantage over the single cross in that the yield of seed in the crossing plot is much greater than from the inbred parents, making possible the commercial production of hybrid corn at a cost such that its use by farmers became economical.¹

The next decade witnesses an increase in public and private projects of corn hybrids development, and the process reaches its momentum in the 1930's. As Griliches pointed out:

Once the development got started, it grew by leaps and bounds. More money was appropriated for research by various experimental stations.

¹For a more detailed description see: H. K. Haynes, A. R. Crabb; and H. A. Wallace and W. L. Brown.

Stations began to release new hybrids almost every year. The number of commercial hybrid seed companies mushroomed, with almost everybody scrambling to get on the bandwagon. For example in 1935 only five different producers of hybrid seed had entries in the sixth district of the Iowa Corn Yield Test. In 1938 there were 37; in 1940, 45; and in 1941 a peak was reached with 50 different firms submitting entries. During the same period the percentage of the total corn acreage planted with hybrid seed in Iowa rose from 6 percent in 1935 to 90 percent in 1940. The development in other Corn Belt States was similar to that of Iowa (p. 4).

The Initial Stage of the Transfer of this New Technology to Argentina

Research in hybrid corn had an early start in Argentina under the form of public research. In 1923 an American scientist, Thomas Bregger, was hired by the Argentine Department of Agriculture to work on the development of hybrid corn for Argentina in what is now the Experiment Station of Pergamino.

Unfortunately, this research was discontinued after three years of efficient work in which Bregger had developed inbred lines of four and five generations with the help of R. Richey from the United States; the reasons of this discontinuity were given by the budget constraint and the fact that wheat improvement was the main concern at the time.

A man who had been in contact with Bregger, the geneticist S. Horovitz, entered in 1930 as a professor in

the University of Buenos Aires where he worked in genetic research and went later on to the United States for graduate studies in this field. Under his influence research on hybrid corn was resumed. In 1945 two of his students, A. E. Marino and J. T. Luna, working for the Department of Agriculture of the Province of Santa Fe, developed successfully the first double-cross hybrids for Argentina, the "Santa Fe" No. 2 and the "Santa Fe" No. 3 which were registered in 1949 in the Ministerio de Agricultura y Gandería.

Also, researchers at the University of Buenos Aires and at the Experiment Station of Pergamino developed and registered several double-cross hybrids between 1949 and 1960. In addition the private seed breeders were simultaneously developing their own hybrids. Cargill Inc. from the United States established a breeding plant in Pergamino in 1946 and registered its first hybrids in 1949. In the same year J. T. Luna working in a private breeding plant of Argentine origin (La Lucila) registered three additional double-cross hybrids.

Later on more national and international firms entered into the hybrid seed business: Morgan Hnos.; Sarasa; Baracco Hnos.; H. Copello; Promahis Agrícola, a subsidiary of Funks Brothers and Corn Products Latin America; Dekalb; Asgrow Llorente S.A.; "Rumbos" from Venado Tuerto; Proagro

S.R.L. ; and others.

Two measures have eased the entry of private firms in hybrid corn research and breeding: the first one was the release to the public of the inbred lines developed by the public sector, so that the private firms could use these inbred lines in their experiments and in their production. The second one was the establishment, in 1959, of the closed pedigree for the private seed breeders, which allowed them not to declare the pedigree of their hybrids, and also exempted the experiments and the production of inbred lines and single crossing from public control, reducing such control only to the production of the double-cross hybrids.

On the Economics of the Generation and
Adoption of Hybrid Corn in Argentina

Objectives of this section

It is the purpose of this section to verify again² that the process of supplying an innovation to different markets, and its adoption by the different producers in those markets could be subject to economic analysis basically through considerations of supply and demand for the new technology.

²Griliches (1957a, b) and Mansfield (1968, 1969) have done it for the United States.

But more important than this, it will be attempted to identify the factors which could explain the availability and adoption of hybrid corn and to examine the effects they could have had on the past and current use of this new input in the different corn regions of Argentina.

The basic questions to be answered here are why the process of diffusion has started earlier in some areas than in others and why the use of hybrid corn has increased faster in some regions than in others. Could these questions have an economic answer?

The basic methodology

This part of the research follows the general lines of Griliches' methodology for his study of hybrid corn in the United States. Logistic growth functions are obtained for the diffusion of hybrid corn in each of the corn regions of Argentina. Then it is attempted to provide some economic explanation for the interregional differences among their parameters.

Those functions are interpreted as describing a dynamic path of adjustment between supply and demand of the new technology represented by hybrid corn. The function proposed is defined as:

$$p_i(t) = K_i \left[1 + e^{-(\alpha_i + \beta_i t)} \right]^{-1} \quad (1)$$

where

$p_i(t)$ is the proportion of total corn acreage planted with hybrid seed in region i at time t

α_i parameter positioning the curve in the time scale

β_i rate of growth coefficient, in other words the rate of acceptance of the innovation

K_i certain constant such that $0 \leq K_i \leq 1$. Conceptually it will be certain proportion close to one which, following Griliches, it is called "ceiling" of the adjustment function. In other words, K_i is given by the

$$\lim_{t \rightarrow \infty} K_i \left[1 + e^{-(\alpha_i + \beta_i t)} \right]^{-1} .$$

This curve is asymptotic to 0 and K_i and symmetric around the inflexion point; its slope is

$$\frac{dp}{dt} = \beta \left(\frac{P}{K} \right) (K - P) , \quad (2)$$

that is, the increase in the diffusion percentage per unit of time is proportional to the level already achieved as a percentage of the ceiling $\frac{P}{K}$ and to the distance from the ceiling $(K - P)$. Given these two elements the rate of

growth will be higher the higher the parameter β .³

Now, why is the logistic the particular function selected for the purpose of this section?

In the first place because this function has provided a good fit for similar works done in other countries, such as for example the studies of Mansfield for the industrial sector in the United States and the one already mentioned of Griliches'.

In addition, the partial data available about temporal diffusion of hybrid corn in Argentina visibly approaches a logistic pattern. This is the case with the data on diffusion of hybrid corn in the whole country proxied by the total volume of hybrid corn production as declared by seed breeders; and also with the data existing for some small

³In the work of Griliches (1957a, p. 10 and 1957b, p. 504) the expression given for $\frac{dP}{dt}$ is $\frac{dP}{dt} = -\beta \frac{P}{K} (K - P)$; that is with a minus sign on the right hand side.

The expression 2 is derived as follows:

$$\frac{dP}{dt} = P [1 + e^{-(\alpha + \beta t)}]^{-1} \cdot e^{-(\alpha + \beta t)} \cdot \beta$$

replacing the term between brackets,

$$\frac{dP}{dt} = \frac{P^2}{K} e^{-(\alpha + \beta t)} \tag{3}$$

also from (1)

$$\frac{K - P}{P} = e^{-(\alpha + \beta t)}$$

substituting in (3)

$$\frac{dP}{dt} = \beta \frac{P}{K} (K - P) .$$

localities, obtained from farms surveys.

Finally, the mathematical properties of the logistic function makes it particularly suited (as it will be seen later) for an economic treatment of the process of technological change.

It has been shown in a previous section of this chapter that hybrid corn is the result of a controlled and systematic crossing of selected inbred lines, aimed at the production of a variety of maximum expected yield and minimum production risk, that is, minimum variance for the expected yield, taking into account the prevailing ecological and climate conditions of the region for which the hybrid is developed.

Development of hybrid corn required first basic research on the method of hybridization; as Griliches (1957a) pointed out: Hybrid corn..."was an invention of a method of inventing, a method of breeding a superior corn for specific localities" (p. 6).

On this matter, Argentina has capitalized from the basic research done elsewhere (mainly in the U.S.). Then, applied research is needed for the continuous development and provision of hybrids adapted to the different regions according to the diversity of ecological and climate circumstances prevailing in them.

In accordance to this two aspects of the problem of diffusion of this new technology can be visualized:

a) on one hand the problem of availability of the new technology for each of the corn regions; not only in reference to the knowledge of its existence, but rather to the development and supply of hybrids adapted for each specific region, that is, the problem of the supply of the new technology; b) on the other hand we have the problem of acceptance or adoption of the new technology, given by the farmers' response, that is, the problem of the demand for the new input.

The availability of a hybrid variety for a particular area will generally be the result of the joint action of INTA's experiment stations and of private seed companies.

However, it will be understood that the commercial availability of seed will ultimately depend on the decisions of "entry" of the seed producers in the particular region or market. Differences in the date of origin or availability will be explained by supply considerations.

Using the logistic form, the date of origin in region i (ta_i) will be given by the expression:

$$ta_i = \beta_i^{-1} \left\{ \log_e \left[\frac{P_i(t)}{K_i - P_i(t)} \right] - \alpha_i \right\}$$

where $P(t)$ will be arbitrarily determined as some small percentage for which it is considered hybrid corn to be commercially available for the area. For this the

percentage $P(t) = .1$ will be used. In other words, the point of 10 percent diffusion is taken as an indicator of commercial availability in the region. Then ta_i will be the date in which hybrid corn was commercially available in region i .

It is postulated that different regions will be entered at different time as a result of some ranking of them done by the seed producers based on expected profitability conditions for the area.

Furthermore, relative profitability of entry will be characterized as depending upon the "market potential" of the area; the marketing cost for the distribution of the seed and the cost of the innovation (i.e., cost of adapting the hybrid) for the area.

Provided hybrid corn is available in a region, the response of the farmers will be then the basic element in determining the dynamic path in the diffusion process.

The value of the parameter β_i will provide a good indication for the speed of adjustment to the new equilibrium position. Regional differences in the slope β_i will be interpreted as differences in the rate of adjustment of demand to the new equilibrium position. In summary, the slope β_i will be interpreted as largely governed by conditions of demand.

As mentioned before, the process of diffusion is

viewed as depicting points of intersection of short-run supply and demand, moving toward the long-run equilibrium position given by the ceiling of the logistic. However, it will be assumed--following Griliches--that "while shifts on the supply side determine the origin of the development, the rate of development is largely a demand or acceptance variable" (Griliches 1957a, p. 35).

It will be postulated the rate of adjustment to be a function of the magnitude of the profitability of the shift from open-pollinated varieties to hybrid ones. It will also depend on the regional conditions of production risk, which will qualify for each region the expected absolute level of profitability with the variability attached to it. Also, the extension activities of the INTA stations together with the advertising and promotion activities of the seed companies may contribute to the speed of response in the adoption of the innovation in the different corn areas.

The ceiling of the logistic will be viewed as the long-run equilibrium level for the percentage of hybrid corn seeded over the total corn acreage in the area. Being consistent with the previous arguments, the regional differences in the ceilings should be explained by long-run demand considerations. Some of the factors that will explain the regional differences in the rate of adjustment, supposedly, should also explain the regional differences in the ceiling.

Limitation in the availability of data for the adjustment of the logistics

The first problem that was faced in the implementation of this part of the study was a complete lack of data on regional diffusion of hybrid seed. The volume of total seed production based on the amount declared every year by the seed breeders in the Division of Seed Fiscalization of the Ministerio de Agricultura y Grandería was available.

Assuming that all the hybrid seed produced in one corn season is sold in the next season, and using an average seeding rate for the country, the figure for the total acreage seeded with hybrid corn can be obtained. Comparing this with the total acreage seeded with corn an estimate is obtained of the temporal diffusion of hybrid seed for the whole country. The possibilities of breaking these figures down to regional level was explored, but in the way the data was obtained, it was not possible to do so.

Another possible alternative was also explored without success; it was attempted to get the volume of sales and the five more important firms discriminated by its marketing regions or by county; but it just happens that this was a "strategic" data which they did not want to get out of the firm, given the oligopolistic organization of the hybrid seed production and the competitive relationship among the firms. Another element that made difficult the

"working" of this alternative was the considerable computational effort which was necessary in some cases to get the required data by county.

Finally, a process of trial and error leads to the only alternative left for getting the data: a survey by the Instituto Nacional de Tecnología Agropecuaria (INTA).

The survey by INTA

In order to get the basic data a survey was conducted with the cooperation of INTA in all the experiment station and extension agencies located within the corn regions. The corn regions used for the survey and later on the rest of the analysis were determined based on the INTA regions of the Corn Program of 1971 complemented with additional information from the Ministerio de Agricultura y Gauadería; they are shown in Figure 7.

The questionnaire covered not only hybrid seed but also as a by-product some questions about fertilizers and herbicides. The questionnaire was sent in October 1971 to all the 134 stations included in the Corn Program; we cover on purpose not only the most important regions of the corn belt (like for example, 1, 21 and 6 in Figure 7), but also the more marginal ones (like for example 13, 14, 15 in Figure 7). The survey was directed to the persons in charge of extension in each one of the stations and this person

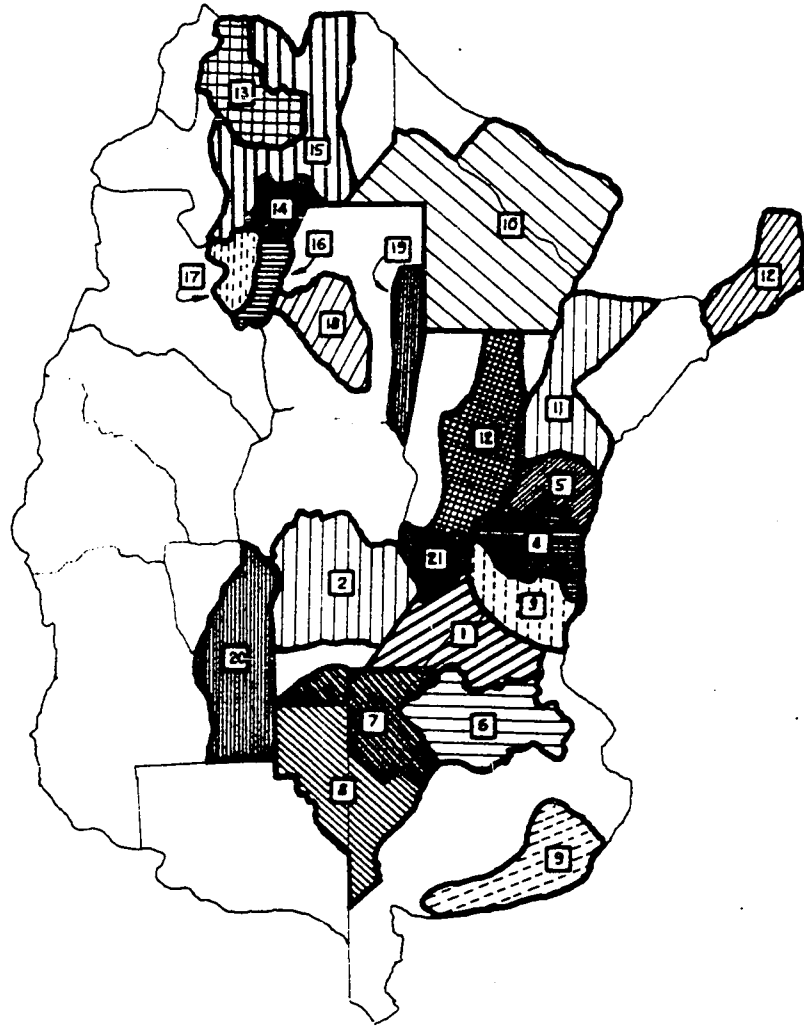


Figure 7. Argentine corn regions

was supposed to answer a set of questions for his "area of influence." In general this "area of influence" was given in terms of counties (partidos or departamentos). The aggregation of the data in order to get the regional figures was done weighing the answers by the importance of the sub-region in terms of corn.

In Figure 8 the geographical distribution of the experiment stations and extension agencies to which the questionnaire was sent is shown. In Figure 9 the corresponding extension districts of the regional experiment stations included in the Corn Program are presented.

The "return" coefficient for the survey was of 69 percent; from 134 questionnaires sent to the stations 92 were answered. As it can be seen in Figure 8, the distribution of extension agencies is more concentrated in the center of the corn belt and consequently in general we have more observations for the central regions than for the marginal ones.

A method for adjusting the logistics with limited information: the results

With the limited information that a cross-sectional survey could provide, it was felt that it was not reasonable to estimate logistics by least squares because of the problem of degrees of freedom. Instead a more crude mathematical

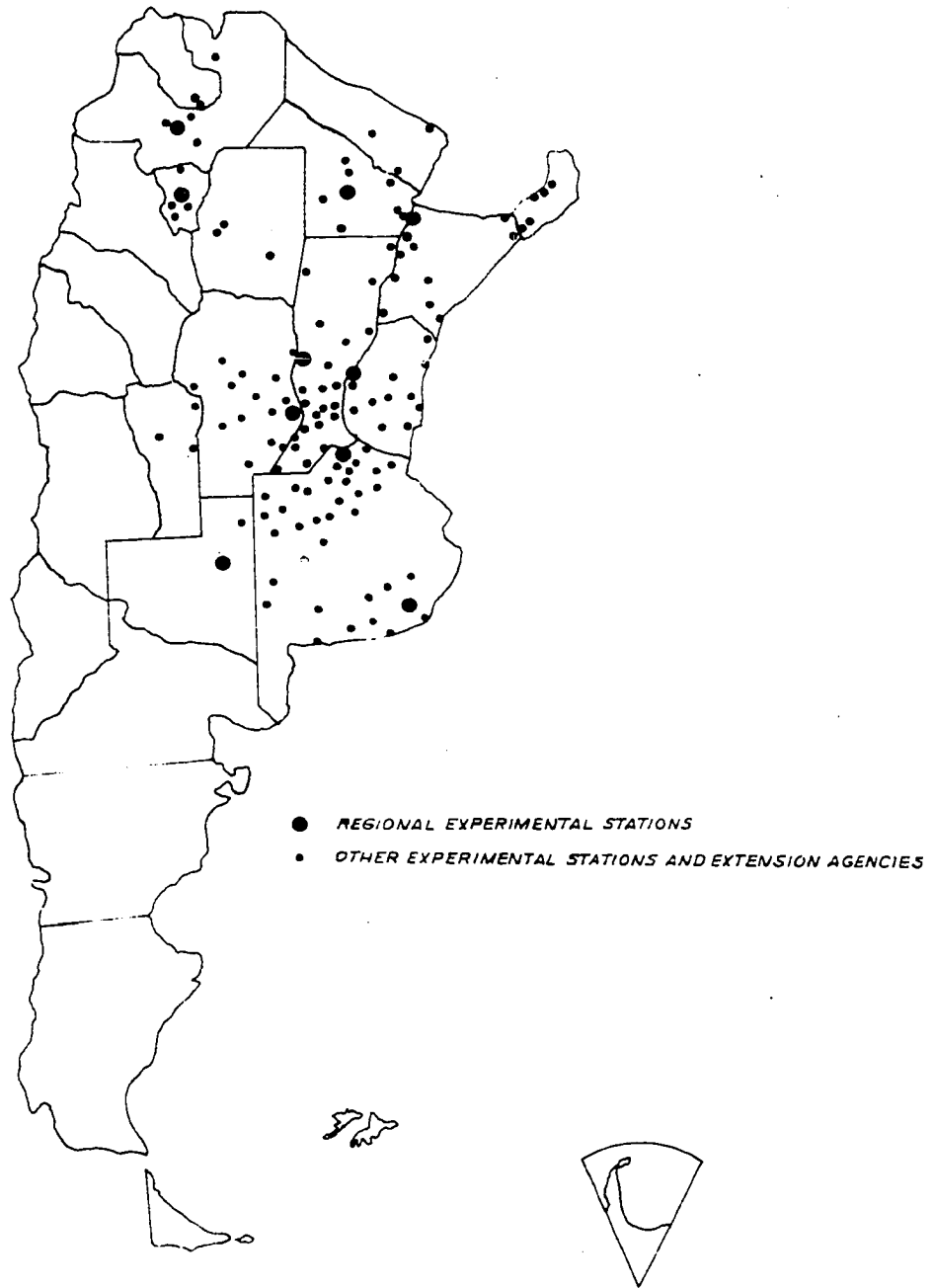
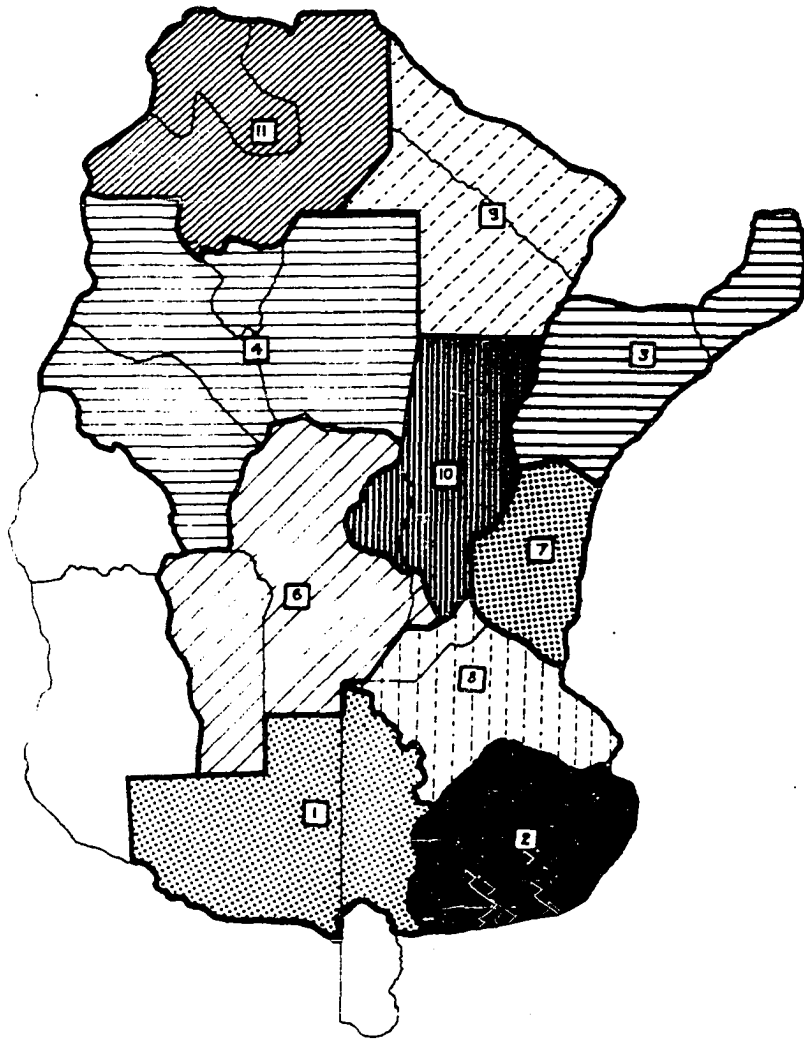


Figure 8. Regional distribution of the experiment stations and extension agencies included in the corn program



- 1 ANGUI
- 2 BALCARCE
- 3 CORRIENTES
- 4 FAMILIA
- 6 MARCOS JUAREZ
- 7 PARANA
- 8 PERGAMINO
- 9 PCIA ROQUE SAENZ PEÑA
- 10 RAFAELA
- 11 SALTA

Figure 9. Extension districts of the regional experiment stations included in the corn programs

method was proposed and used.

The survey provides the following information on the diffusion of hybrid seed:

1. The percentage of hybrid seed planted over the total corn acreage, from 1966 to 1970; that is $P_i(t)$ for $t = 1966$ up to 1970. This is provided by question 2a.⁴
2. Question 3 gives the year at which diffusion reached in the area the 10 percent and the 50 percent points. That is t such that $P_i(t) = .1$ and t such that $P_i(t) = .50$. Notice that question 2a and 3 allow for some consistency checks.
3. The value of K_i is provided by questions 4 and 2a. In some cases, for those regions which have reached the ceiling, it could be detected with the information included in question 2a. In case the ceiling were not reached at the time of the survey, an estimate of such value was asked for (question 4). Again, questions 2a, 3 and 4 have been checked for consistency.

With the preceding information it was proceeded to obtain the regional logistics using a simple mathematical method which basically consists of solving a two-equation,

⁴See survey form in Appendix, p. 151.

two-unknown system for the unknown parameters, α_i and β_i , of the logistics.

The value of the regional K_i enters the system, but was predetermined by the survey; it was obtained as the weighted average of the questionnaire responses according to the importance in terms of corn of the corresponding area of influence for the extension agency. In other words,

$$K_i = \frac{n_i}{\sum_{j=1}^{n_i} W_{ij}} K_{ij}$$

$$\sum_{j=1}^{n_i} W_{ij} = 1$$

$$W_{ij} = \frac{\overline{AS}_{ij}}{\sum_{j=1}^{n_i} \overline{AS}_{ij}} \quad (4)$$

and

$$t = 1970$$

$$\overline{AS}_{ij} = \frac{1}{11} \sum_t = 1960 \quad AS_{ij}(T) \quad (5)$$

where

- i stands for region i
- j stands for subregion j or area of influence of extension agency j

- t stands for year
- W_{ij} weight for the K estimate corresponding to the subregion j, region i
- $AS_{ij}(t)$ area seeded with corn in region i subregion j at time t.

As it can be seen in Equations 4 and 5 the weights are based on the average area seeded with corn in the corresponding subregion during the period 1960-1970. A similar weighting procedure was used for the information corresponding to P (1966) up to P (1970) and also for the points of 10 percent and 50 percent diffusion. For the $P_i(t)$'s it was used

$$P_i(t) = \sum_{j=1}^{n_i} V_{ij}(t) P_{ij}(t)$$

$$\sum_{j=1}^{n_i} V_{ij} = 1$$

$$V_{ij}(t) = \frac{AS_{ij}(t)}{\sum_{j=1}^{n_i} AS_{ij}(t)}$$

So, in this case the weights for obtaining the regional $P(t)$'s are given by the area seeded with corn in the corresponding subregion at time t over the total area seeded

in the region in the same year.

Finally, the regional 10 percent and 50 percent diffusion points were obtained as

$$t_i(.1) = \sum_{j=1}^{n_i} r_{ij} t_{ij}(.1)$$

$$\sum_{j=1}^{n_i} r_{ij} = 1$$

$$r_{ij} = \frac{\overline{AS}_{ij}}{\sum_{j=1}^{n_i} \overline{AS}_{ij}}$$

and

$$\overline{AS}_{ij} = (1 + tu_i - te_i)^{-1} \sum_{t=te_i}^{t=tu_i} AS_{ij}(t)$$

where

$t_{ij}(.1)$ time of the 10 percent diffusion point in the subregion j of region i

$t_i(.1)$ time of the 10 percent diffusion point in the region i

r_{ij} weight of the subregion j for the aggregation of $t_{ij}(.1)$'s

te_i earliest time of the 10 percent reported within

the region by any of the corresponding subregions

tu_i latest time of the 10 percent reported within the region, by any of the subregions.

The weights were in this case based on the average area seeded in the subregion for a period covering the years from the earliest 10 percent reported in the region (te) to the latest 10 percent reported in the same region (tu); in other words, the number of years in which the weight was based varied over regions and was equal to $(1 + tu_i - te_i)$. The same method was used for the 50 percent diffusion point.

With the information from the survey aggregated by regions using the previous procedure, the estimation of the logistics was attempted. This function is a three parameter curve given by α_i , β_i and K_i . The last parameter (K_i) is estimated from the survey. Given K_i , the other parameters α_i and β_i could be estimated by solving the system provided by the equations

$$\left. \begin{aligned} P_i(t_1) &= K_i [1 + e^{-(\alpha_i + \beta_i t_1)}]^{-1} \\ P_i(t_2) &= K_i [1 + e^{-(\alpha_i + \beta_i t_2)}]^{-1} \end{aligned} \right\} \cdot \quad (6)$$

Where the $P_i(t)$'s are given by the survey and obtained by the aggregation procedure described above. In general, the two points used were $P_i(t_1) = .1$ and $P_i(t_2) = .5$; both given by question 3 in the survey.⁵ The K 's as mentioned before, are predetermined by the survey. Consequently, a system of two equations and two unknowns is set, as shown in Equation 6. One equation for each of the two points selected from the diffusion data obtained from the survey (in general the corresponding at the 10 and 50 percent diffusion); and the two unknowns being α_i and β_i .

The first question to be asked is whether or not this system has a unique solution. Making a logarithmic transformation, the expressions in Equation 6 will be considerably simplified. Dividing both sides of the first equation by $K_i - P_i(t_1)$ and similarly, dividing both sides of the second equation by $K_i - P_i(t_2)$, and then taking the logarithm

⁵In some regions $P_i(t_2) = .5$ were not reached at the time of the survey, and consequently another percentage point from question 2a was used.

in both equations, the system is reduced to⁶

$$\left. \begin{aligned} \alpha_i + \beta_i t_1 &= \log_e \frac{P_i(t_1)}{K_i - P_i(t_1)} \\ \alpha_i + \beta_i t_2 &= \log_e \frac{P_i(t_2)}{K_i - P_i(t_2)} \end{aligned} \right\} \quad (7)$$

The expressions on the right hand side of Equation 7 are given by the survey and from the point of view of the system they could be considered as constants different from zero. The system has been reduced to a linear one. There will be a unique solution as long as $t_1 \neq t_2$. Obviously

⁶In general given the logistic form

$$(*) P_i(t) = K_i \left[1 + e^{-(\alpha_i + \beta_i t)} \right]^{-1}$$

dividing both sides by $K_i - P_i(t)$

$$\frac{P_i(t)}{K_i - P_i(t)} = \frac{K_i}{K_i - P_i(t)} \left[1 + e^{-(\alpha_i + \beta_i t)} \right]^{-1}$$

replacing $P_i(t)$ on the right hand side by (*)

$$\frac{P_i(t)}{K_i - P_i(t)} = \frac{K_i \left[1 + e^{-(\alpha_i + \beta_i t)} \right]^{-1}}{K_i - K_i \left[1 + e^{-(\alpha_i + \beta_i t)} \right]^{-1}}$$

then dividing by the term between parentheses and simplifying

$$\frac{P_i(t)}{K_i - P_i(t)} = \frac{1}{e^{-(\alpha_i + \beta_i t)}}$$

finally, taking the logarithm we get

$$\log_e \left[\frac{P_i(t)}{K_i - P_i(t)} \right] = \alpha_i + \beta_i t \quad .$$

this will always hold since we chose two different points in the diffusion pattern. Then a unique solution for the parameters α_i and β_i will exist. From Equation 7, the solution will be:

$$\alpha_i = (t_2 - t_1)^{-1} \log_e \left\{ \left[\frac{P_i(t_1)}{K_i - P_i(t_1)} \right]^{t_2} \left[\frac{P_i(t_2)}{K_i - P_i(t_2)} \right]^{-t_1} \right\} \quad (8)$$

and

$$\beta_i = (t_2 - t_1)^{-1} \log_e \left\{ \frac{P(t_2)}{K(t_1)} \left[\frac{P - P(t_1)}{K - P(t_2)} \right] \right\} \quad (9)$$

The results of the computation for the expressions 8 and 9 for all the corn regions are given in Table 5. For some of the regions the logistics were not obtained due to the low degree of diffusion at the time of the survey, and/or because the information obtained through the survey was not enough for estimating the corresponding logistic. Figure 10 gives an intuitive idea of how the method works. In the three cases presented as examples the points used for adjusting the logistic are the ones corresponding to question 3 from the survey. The rest of the points in the graphs correspond to question 2a and are placed relatively close or far from the ceiling according to the regional degree of diffusion of hybrids in the latest years. As it

Table 5. Parameters of the regional logistics

Region	α_i	β_i	K_i
1 North Buenos Aires South Santa Fe	- 7.587	0.666	0.996
2 Center of Córdoba	- 8.270	0.503	0.824
3 South Entre Ríos	- 7.313	0.429	0.073
4 Center of Entre Ríos	- 9.663	0.574	0.951
5 North Entre Ríos	- 9.073	0.449	0.673
6 Northcentral Buenos Aires	-10.600	0.723	0.955
7 Northwest Buenos Aires South of Córdoba	- 8.428	0.460	0.626
8 West Central Buenos Aires Northeast La Pampa	_a	_a	_a
9 South Buenos Aires	-12.497	0.663	0.802
10 Formosa and Chaco	- 7.996	0.461	0.870
11 West Corrientes	-10.667	0.527	0.782
12 Misiones	_a	_a	_a
13 Jujuy	_a	_a	_a
14 South of Salta	-12.636	0.620	0.950
15 West and Central Salta	-11.001	0.542	0.700
16 East Tucumán	-13.532	0.682	0.800
17 West Tucumán	-13.482	0.711	0.672
18 West Central Santiago del Estero	-10.870	0.515	0.643
19 Southwest Santiago del Estero	_a	_a	_a
20 Northeast San Luis	- 7.398	0.400	0.618
21 Center of Santa Fe	- 8.793	0.647	0.994
22 Northwest Santa Fe	- 8.035	0.510	0.777

^aIt was not possible to obtain the logistic for these regions due to the low degree of diffusion in the area and/or because the minimum amount of information required for computing the logistic was not obtained through the survey.

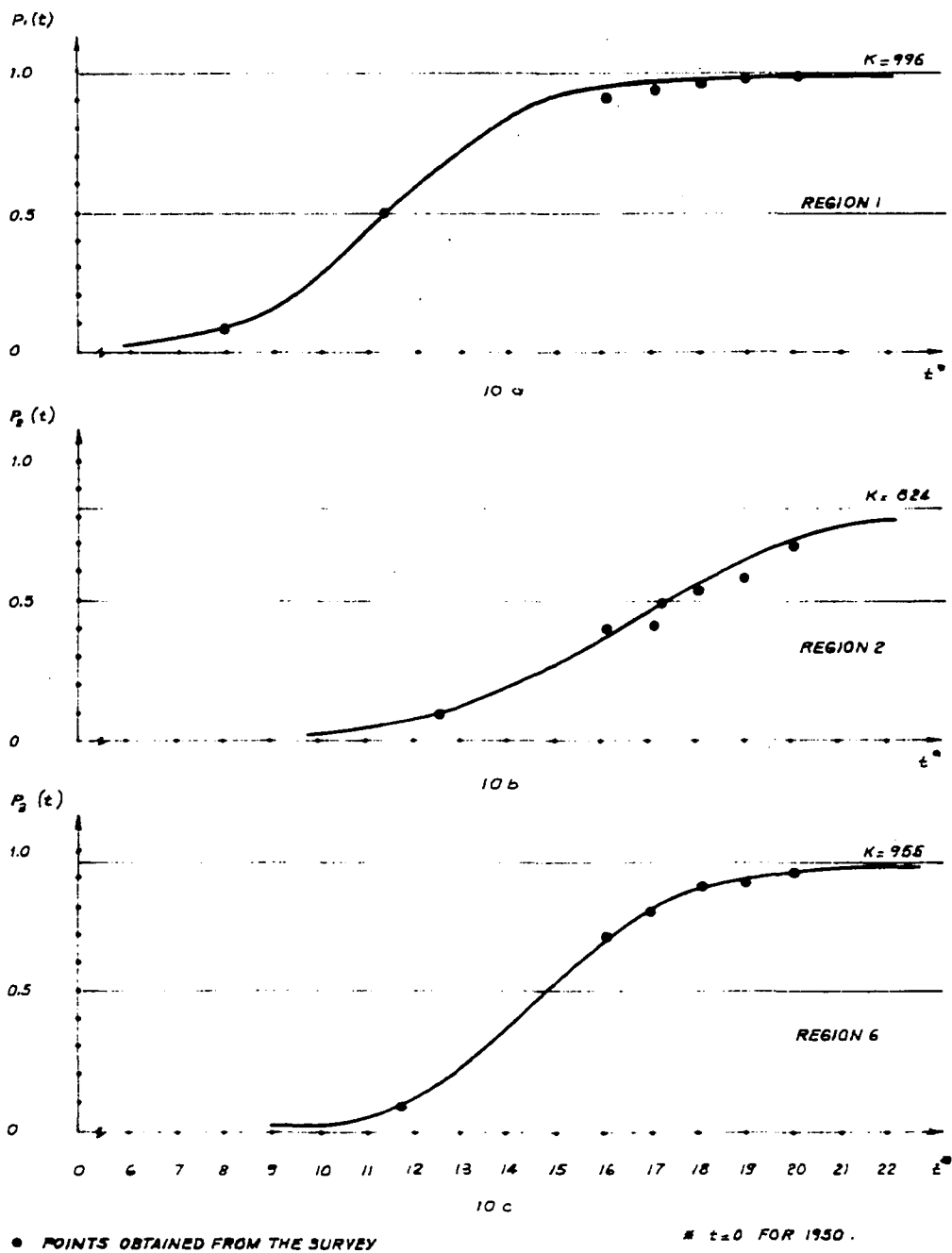


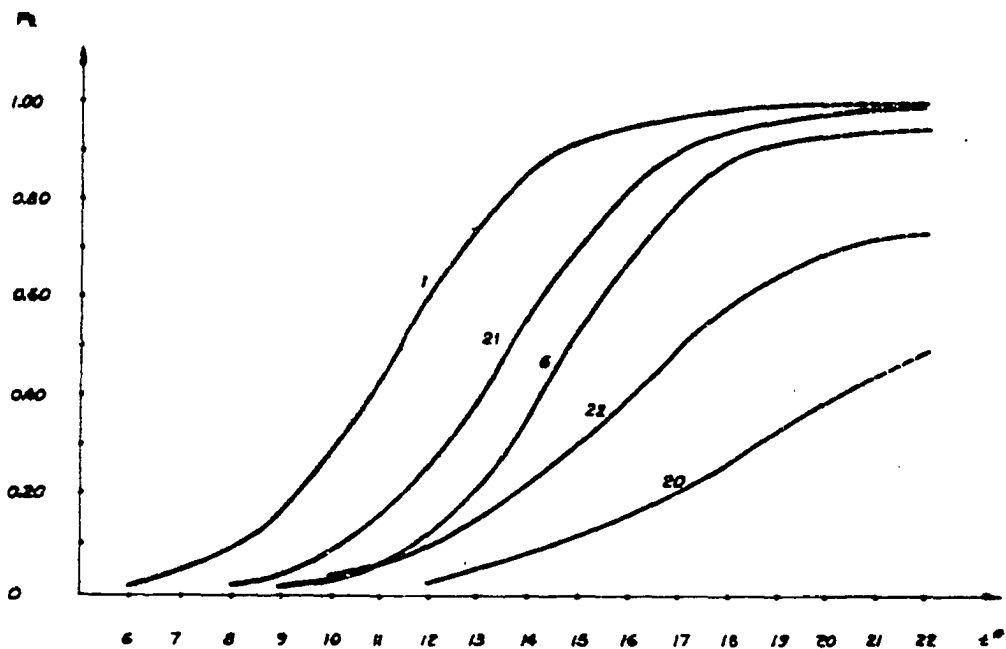
Figure 10. The adjusted logistics and the diffusion points estimated by the survey

be seen, the logistics obtained are not too far from what it would be a least square fit, in particular, 7b and 7c.

In Figure 11 the regional diversity in the position, slopes and ceiling of some of the logistics can be appreciated. They correspond to regional differences in the data of origin in the rate of acceptance and in the final equilibrium level respectively. Next some economic explanation for such differences is provided.

The supply of the new technique: "origin" of the development of hybrid corn

Development of hybrid corn requires basic research on the method of hybridization. It was mentioned in previous sections that Argentina essentially has capitalized the basic research done elsewhere (mainly in the U.S.). However, applied research was needed for the development and provision of hybrids adapted to the Argentine corn regions according to the diversity of ecological and climate circumstances prevailing in them. In accordance to this it was attempted to isolate in the diffusion process, the problem of availability of this new technology for each of the corn regions; not only referred to the knowledge of its existence, but rather to the development and supply of hybrids adopted for each specific region. In other words, it was tried to isolate from the diffusion process, the



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Figure 11. Regional diversity in the estimated diffusion patterns

problem of the supply of the technology.

The availability of a hybrid variety for a particular area results from the joint action of INTA's experiment station, and of private seed companies. The action of INTA reduces the cost of innovation of the firms not only by the development of hybrids but also by the free provision of any related research results and the maintenance of certain stock in inbred lines.

However, it is understood that the commercial availability of seed ultimately depends on the decisions of entry of the seed producers in the particular region or market. Differences in the date of "origin" or "availability" can be explained by supply considerations. When referring to the properties of the logistic it was mentioned that it was asymptotic to zero; consequently it does not have a "beginning." The date at which an area reached certain percentage of diffusion $P_i(t)$ will be used as the date of "origin." Using the logistic form, the date of origin in region i (denoted by ta_i) will be,

$$ta_i = \beta_i^{-1} \left\{ \log_e \left[\frac{P_i(t)}{K_i - P_i(t)} \right] - \alpha_i \right\}$$

where $P_i(ta)$ will be arbitrarily determined as some small percentage for which it is considered hybrid corn to be commercially available for the area. The point $P_i(t) = .1$ will

be used (that is, the point of 10 percent diffusion) as an indicator of commercial availability in the region.⁷ In other words,⁸

$$ta_i = \beta_i^{-1} \left[\log_e \left(\frac{.1}{K_i - .1} \right) - \alpha_i \right] .$$

The hypothesis tested is that different regions will be entered at different time as a result of some ranking of them done by the seeds producers based on expected profitability conditions for the area. Furthermore, relative profitability of entry will be characterized as depending on the "market potential" of the area; the marketing cost for the distribution of the seed and the cost of the innovation (i.e., cost of adopting the hybrid) for the area. It was rather difficult to find operational definitions of these variables, due to problems of aggregation and also limited availability of data. In most cases the regional figures for the variables used have been obtained by aggregation of data from county level in accordance to the

⁷Griliches (1957a, b) also used ta_i as the date on which an area planted with hybrid seed has reached 10 percent of its ceiling acreage.

⁸The analysis of this section has been repeated redefining the date of "origin" with $P_i(t) = .05$ and $P_i(t) = .01$ and it was possible to conclude that the results were not sensitive with respect to changes in the definition.

geographical division of the corn regions.

As an approximation of market potential and also providing some indication of marketing cost the average corn acreage in the area at about the time of entry over the total land in the region was used. In other words, the variable "corn density" was defined as

$$CD_i = \frac{\sum_{t=1955}^{t=1965} \sum_{j=1}^{n_i} AS_{ij}(t)}{10 \sum_{j=1}^{n_i} T_{ij}}$$

where

CD_i denotes corn density in region i

$AS_{ij}(t)$ is the area seeded in county j of region i at time t

T_{ij} is the total land in county j of region i .

Also as an alternative for CD_i , another variable was defined, which results from adjusting the latter by differences in the ceilings. That is,

$$CDA_i = CD_i \cdot K_i \quad .$$

A better indicator would be obtained if CD_i could also be adjusted by differences in the average seeding rates for

each region, but this data was not available. Anyway, since corn density is closely associated with the acreage seeded in the region, the higher the CD, the higher will be the "market potential" of the region. Also the higher the CE (the higher the corn acreage per unit of land in the region), the cheaper will be the distribution cost of a given amount of seed. In other words, the higher the CD, ceteris paribus, the smaller will be marketing cost for the distribution of the seed.

It also seems to be important to introduce some spatial considerations in the analysis, since the dates of entry in one area may be related to its "proximity" to another area in which the firms have already entered. In fact, ceteris paribus, it may be cheaper from the point of view of the research needed⁹ as well as from the point of view of the marginal cost of extending the marketing network, to enter an area contiguous or close to another already entered, than to enter some other further away. With this purpose in mind the variable t_e was defined as the earliest date of entry

⁹In general, it will be assumed that the closer two regions are, the smaller the ecological diversity among them, and consequently the smaller the differences among their adaptable hybrids. It was not found any other way of estimating the relative cost of developing a hybrid adapted for the region; however, it is believed that these cost differences would not be too significant if compared to the regional differences in returns.

in the closest neighborhood.

In addition it was reasonable to introduce some indicator of the degree of existence of subsistency farming in the area in question. The larger the proportion of corn on noncommercial farms, the more difficult will result the "penetration" of the firms with advertising and extension activities. The closest indicators found are given by the number of farmers in farms under five hectares, over the total number of farms in the region (SF_1); and as an alternative, the total acreage in farms below five hectares over the total farm land in the region (SF_2) were used. Both figures have been obtained aggregating county data from the 1960 census.

The results of the regression of ta_i on the independent variables are presented in Table 6. As it can be seen all the variables appear with the expected sign, and most of them significantly different from zero. The exception to this is given by SF_1 and SF_2 which in Equation 3, 4, 7 and 8 did not perform so well being only marginally significant (or significant at a level of 0.30).

The higher contribution to the explanation of the differences in ta_i corresponds to the "corn density" variables, CD and CDA, and also to the spatial lag te . The value of R^2 for the overall regression have not depended on any of these variables in particular; the observation of the partial R^2

Table 6. Differences in the date of entry "explained" by the independent variables CD, CDA, t_e , SF_1 and SF_2

Dependent variable	Constant term ^a	Coefficients of the independent variables ^a					R ²
		CD	CDA	t_e	SF_1	SF_2	
1. ta	10.18 (8.27)	-26.73* (4.15)		0.45* (5.08)			.89
2. ta	9.99 (8.33)		-26.34* (4.14)	0.45* (5.19)			.89
3. ta	10.70 (8.19)	-27.53 (4.28)		0.37* (3.38)	2.81** (1.12)		.90

^aThe figures between parentheses under the coefficients are the corresponding "t" values.

CD Corn density

CDA Corn density adjusted by differences in the ceiling

t_e Earliest date of availability in the closest neighborhood

SF_1 Degree of subsistency farming given by the percentage of farms under 5 hectares in the region

SF_2 Degree of subsistency farming given by the percentage of the acreage in farms under 5 hectares in the region.

* Significant at a level of 0.05.

** Only marginally significant (significant at a level of .30).

Table 6 (Continued)

Dependent variable	Constant term ^a	Coefficients of the independent variables ^a					R ²
		CD	CDA	t _e	SF ₁	SF ₂	
4. ta	10.57 (8.30)		-27.35* (4.33)	0.37* (3.38)	3.03** (1.21)		.90
5. ta	14.83 (24.57)	-40.39* (5.98)			7.98* (3.08)		.82
6. ta	14.61 (25.41)		-40.01* (6.03)		8.28* (3.23)		.83
7. ta	10.56 (8.51)	-27.54* (4.35)		0.40* (4.27)		6.56** (1.29)	.91
8. ta	10.39 (8.61)		-27.23* (4.36)	0.40* (4.35)		6.74** (1.33)	.91
9. ta	15.64 (30.39)	-45.05* (6.37)				15.10* (2.20)	.78
10. ta	15.42 (31.01)		-44.64* (6.30)			15.56* (2.26)	.78

for both variables in each equation indicated that they share a similar importance in the explanation of the dependent variable. In the case of the degree of subsistency farming variable, its contribution was rather marginal in all the equations.

With all the data limitations and the problems of aggregation, still, the results being consistent with the hypothesis formulated, permit us to conclude that the development of hybrid corn was largely guided by expected profitability for the firms involved, better areas being entered first. This is also consistent with Griliches' results for the United States (1957a, b).

The demand of the new technology: the rate of acceptance of hybrid corn

Provided hybrid corn is available in a region, the response of the farmers will then be the basic element in determining the dynamic path in the diffusion process. In other words, the rate of adjustment, given by parameter β , will be interpreted as largely governed by conditions of demand. Differences in these β 's slopes will be explained then by factors operating on the demand side.

It is postulated the rate of adjustment to be a function of the magnitude of the profitability of the shift from open-pollinated varieties to hybrid ones. It will also

depend on the regional conditions of production risks. That is, the expected absolute level of profitability for each region should be qualified with the variability attached to it. Also, the extension activities of the INTA stations together with the advertising and promotion activities of the seed companies may contribute to the speed of response in the adoption of the innovations in the different corn areas.

As in the case of the "origin" of the development, some difficulties are faced here, in the operational definition of these variables. However, the difficulties arise in this case from a general picture of a stronger limitation in the data availability at regional level, and from similar problems of aggregation.

Per acre profitability of hybrid corn could be defined as the increase in gross income due to the use of hybrid (that is, increase in yield per acre times the price of corn), minus the additional cost implies in the use of hybrid seed over and above the cost of open-pollinated varieties. The superiority of hybrids is given in general as a percentage increase in yield over the open-pollinated varieties; there are no significant differences in such percentage over regions, provided adapted hybrids are available in each case. Similarly there are small cross-sectional differences in the price of corn, the seeding rate or the price of seed

which will not be considered for two reasons: there would not be significance compared to the yield differentials, and, in any case reliable estimates of them could not be obtained.

In summary, the main indicator for the differences in absolute profitability by regions is given by the differences in the expected level of absolute superiority of hybrids over open-pollinated varieties. Three alternative measures of such superiority were used, all of them based on the long-run pre-hybrid yield of corn:

- (a) The average pre-hybrid yield per hectare harvested over 10 years before the date of "origin" in the region, that is,

$$\overline{YAH}_i = \frac{1}{10} \frac{1}{n_i} \sum_{t=ta_i-9}^{t=ta} \sum_{j=1}^{n_i} YAH_{ij}(t)$$

where

$YAH_{ij}(t)$ is the yield per hectare harvested in county j of region i at time t .

- (b) The average pre-hybrid yield per hectare harvested adjusted by differences in the average long-run percentage of area actually harvested over the total area seeded in the region. This percentage is understood as basically determined by climatic conditions; and consequently a longer period of time was taken in order to get a representative

average.

$$\overline{YAV}_i = \frac{\overline{YAH}_i}{36} \cdot \sum_{t=1935}^{t=1970} \left[\frac{AH_i(t)}{AS_i(t)} \right]$$

where

$AH_i(t)$ is the area harvested in region i at time t

$AS_i(t)$ is the area seeded in region i at time t .

- (c) The average pre-hybrid yield per hectare seeded over 10 years before the date of "origin" in the region

$$\overline{RAS}_i = \frac{1}{10 n_i} \sum_{t=ta_i-9}^{t=ta_i} \sum_{j=1}^{j=n_i} RAS_{ij}(t)$$

where

$RAS_{ij}(t)$ is the yield per hectare seeded in county j of region i at time t .

In addition an indicator of production risk given by the regional variance of the percentage of the area actually harvested over total area seeded in the region was used. This variance is essentially determined by climate conditions.

In some cases the production risk due to climate conditions is such that the farmers make the seeding with a double purpose. If the weather appears to be very good for the crop as to obtain a reasonable yield the farmer will

harvest the crop, and the yield in terms of grain will be relevant for him.

On the other hand, if the weather is unfavorable he will use the crop as pasture, without trying to harvest a grain crop, in which case the yield in terms of grain loses its importance. In addition there will also be cases in which the crop is simply lost due to weather conditions.

One would expect that the more severe the prevalence of these situations the slower will be the response of the farmer in the adoption process. Then, in order to capture this, the following variable will be used.

$$\text{VAR } V_i = \text{VAR} \left(\frac{AH_{it}}{AS_{it}} \right) .$$

It was not possible to get reliable proxies for the rest of the variables, in particular, it was not possible to obtain a good indicator of the regional intensity of the advertising and promotional activities of the seed companies and the same was true for the regional corn extension expenditures of INTA.

With these limitations linear regressions were calculated with the computed variables. The results are shown in Table 7. It can be seen that the value of the R^2 is rather low; indicating that the postulated variables provide only a partial "explanation" of the differences in the slopes.

Table 7. Regression of slopes on "profitability" variables

Dependent variable	Constant term ^a	Coefficients of ^a				R ²
		\overline{YAH}	\overline{YAV}	\overline{RAS}	VAR.V	
1 β	.544 (2.072)		0.0001 (2.072)		-2.856 (2.507)	.57
2 β	.508 (6.076)	0.0001 (2.444)			-3.242 (3.222)	.61
3 β	.544 (7.183)			0.0001 (2.233)	-3.175 (3.030)	.59

^aAll the coefficients are significantly different from zero at a level of 0.05 with the exception of the coefficient of \overline{YAV} , whose computed "t" equals the theoretical one at a level of significance approximately equal to 0.07. The figures between parenthesis under the coefficients are the corresponding "t" values.

The similarity in the value of the coefficients for all the alternatives used for pre-hybrid yield is striking. All the coefficients have the expected sign and with the exception of the one corresponding to \overline{YAV} they are all significantly different from zero at a level of 0.05. The coefficient of \overline{YAV} is significant at a level of significance of 0.10.

The hypothesis has been that the rate of acceptance is a function of the magnitude of the profitability of the shift and of the prevailing production risk. With all the limitation of the data with which the test had to be done, still, the results tend to support the hypothesis advanced.

Concluding Comments

The results of the previous two sections provide some partial support for the hypothesis advanced in Chapter III. In particular, provided the innovation is appropriable, its supply by private firms is largely guided by the expected payoff for the required investment in research and development. The complementary role of the public investment was materialized by the public release of the inbred lines developed by the government research network. Once the new technology was made available, the response of the farmers in the adoption process was essentially determined by the economic conditions surrounding the new technology. Consistent with Griliches (1957a, b) conclusions our results indicate that a substantial proportion of the variation in the rate of acceptance of hybrid corn is explainable by differences in the profitability of the shift from open-pollinated to hybrid varieties in different regions of the country.

CHAPTER VI

THE LATENT TECHNOLOGICAL PATH OF ARGENTINE AGRICULTURE:

THE CASE OF FERTILIZERS

Introduction

When exploring the potential technological path of the Argentine agricultural sector the "failure story" appears in the model. An interpretation of the stagnation of this sector is that it results from the actual unavailability of yield-increasing, land-saving new technologies for adoption by the farmers. This, in terms of the socioeconomic model of induced innovations, could, in principle, be explained by the existence of a lag between actual and latent demand for innovations. Going back to the classification of innovations, it can be recalled that chemical, agronomic and integrated packages of new technologies are mainly of land-saving nature and definitively yield increasing. In general, the benefits from research in chemical, agronomic, and packages of innovations are not subject to private appropriability, and consequently, the bulk of the investment in these activities will be channeled as public investment through the agencies of the agricultural research system as the Instituto Nacional de Tecnología Agropecuaria.

Using the case of fertilizer, the existence of a gap between latent and actual demand for land-saving technologies

will be shown. In particular, the relative prices prevailing in the sector generate a latent demand for land-saving yield increasing technologies. On the other hand, these new technologies will be incongruent with the factor proportions prevailing in the farms representatives of the dominant agriculture interests from whose utility function it is assumed that the actual demand is derived. Consequently, without economic stress, the actual demand for these technologies directed to the public agricultural research system will be weak or virtually inexistent; determining an orientation of the research away from land-saving technologies.

The lack of adoption of these technologies will be due simply to its virtual inexistence at farm level; to their actual unavailability for their adoption by the farmers, as a result of a relative lack of agronomic and economic research in this direction.

As a contrast, it was shown in Chapter IV, that genetic innovations embodied in the hybrid corn spread rapidly in the Argentine Pampas, and the same was true for the case of mechanization. Both types of innovations are congruent with the prevailing factor ratios of the dominant farm interests leading to the existence of actual demand for them. On the supply side, there was in addition to public investment, a considerable share of the private source of supply, given

the appropriable nature of these innovations. Once available, the profitability conditions of these techniques determined its rapid adoption by the farmer.

The technology of fertilizer is practically unused in cereal production in Argentina. In the last three years there has been several studies attempting to evaluate the present potential of fertilizer use in cereal production. Reca (1970), de Janvry (1971a, 1972), and Peterson and Fienup have made in different studies the economic evaluation of experiments on fertilizer response for corn (de Janvry did it also for wheat). If these studies are interpreted in terms of the hypothesis advanced in Chapter III, some additional empirical evidence can be drawn in support of the socioeconomic model of induced innovations.

First, it should be mentioned that Argentine corn hybrids have a limited capacity for nitrogen response, simply because they have not been selected for that kind of performance, on the contrary, they were selected to perform well under declining soil fertility conditions as is the case in Argentina. The study of Peterson and Fienup provides some conclusive evidence of this situation. If this is so, an increase in the available nitrogen could be utilized mainly by an increase in plant population. This should be taken in account for making the economic evaluation of fertilizer response. On the other hand, it

constitutes in itself another indicator of the actual unavailability of a land-saving, yield increasing technological package combining the characteristics of genetic, chemical and agronomic innovations.

Second, the interaction between present fertility of the land (usually measured by the organic matter content), and fertilizer response cannot be neglected due to the importance of its implications, as it will be seen later. The lower the present fertility of the land, measured by the organic matter content, the higher the expected fertilizer response.

The first evidence of this interaction is provided by the "First Annual Report of the Cooperative INTA-CIMMYT-Ford Foundation Corn and Wheat Improvement Program, 1969," which summarizes the results of corn experiments done in 11 locations during the crop season 1968/69. The report indicates that the yield response to fertilizer application was statistically significant in a group formed by six locations, where the organic matter content of the soil oscillated between 2.7 percent and 3.5 percent. On the other hand, in the other group, in which the organic matter content oscillated between 3.6 percent and 5.5 percent, the fertilizer response was nonsignificant.

A considerable share of the corn production comes from small and medium-size farms whose size prevents them from

implementing a rotation pattern between crop and cattle activities. In general, the land in these farms has been under continuous cropping activities which have depressed its natural fertility. Consequently, the soils of the small and medium-size farms, present a picture of low levels of organic matter content.

Potential Use of Nitrogen in Corn Production

With previous consideration in mind, the optimal level of fertilizer and the internal rate of return are computed for different nitrogen/corn price ratios, using the production functions estimated by Reca (1970) and de Janvry (1971a, 1972), both based on fertilizer trials carried out in the area of INTA Experiment Station of Marcos Juárez in the crop season 1967/68. Reca estimated a Cobb-Douglas production function of the form

$$Y = A F^{a1} M^{a2} D^{a3} HS^{a4} HD^{a5} PW^{a6}$$

where

Y corn yield in tons per hectare

F fertilizer level (nitrogen) in kilograms per hectare

M organic matter content of the land expressed in percent

D plant density at harvest in thousands of plants

per hectare

HS percent of soil humidity at seeding

HD percent of soil humidity at tasseling

PW permanent wilting point in percent of water.

The results obtained are the following:

$$\begin{aligned} \text{Log } Y = & -15.449 + 0.043 \text{ Log } F + 1.783 \text{ Log } M \\ & (5.25) \quad (5.02) \quad (3.77) \\ & + 0.393 \text{ Log } D + 3.557 \text{ HS} + 2.046 \text{ Log } HD \\ & (11.13) \quad (6.21) \quad (3.76) \\ & - 1.340 \text{ PW} \\ & (3.65) \end{aligned}$$

where the figures between parenthesis are the corresponding t values. All the coefficients are significantly different from zero at a level of 1 percent. The R^2 is 0.76.

Even though Reca recognizes the interaction between chemical fertilizer and natural fertility of the soil, the production function postulated does not capture that phenomenon. On the contrary, the functional form leads to the erroneous implication that the marginal productivity of fertilizer shifts to the right when natural fertility of the soil increases and that the optimal fertilizer usage is higher for higher levels of natural soil fertility.

With this limitation, the optimal level of fertilizer for different nitrogen/corn price ratios can be computed fixing M and PW at an average level; HS and HD at the

"normal" level in the area and D at the relatively high level of 60 thousand plants per hectare. With these values let's define the constant

$$B = \bar{M}^{\alpha_2} \bar{D}^{\alpha_3} \overline{HS}^{\alpha_4} \overline{HD}^{\alpha_5} \overline{PW}^{\alpha_6}$$

where the bars indicate that the variable is entered at the values specified above.¹ Then, the optimal fertilizer usage is:

$$F^* = \left[\frac{P_F}{P_C} \cdot \frac{1}{A \cdot B} \right]^{\frac{1}{\alpha_1 - 1}}$$

On the other hand, the internal rate of return on fertilizer application is:

$$IRR = \left[\frac{P_C (Y^* - AB)}{P_F F^*} - 1 \right]$$

where Y^* is the yield resulting from an optimal level of fertilizer application. Varying the price ratio in a reasonable range, the optimal levels of fertilizer can be obtained, and also the internal rate of return implicit in each case. The results are presented in Table 8.

¹These values are: $\bar{M} = 2.78$ percent; $\bar{D} = 60$; $\overline{HS} = 21.76$ percent; $\overline{HD} = 19.46$ percent; and $\overline{PW} = 13.80$ percent.

Table 8. Optimal levels of nitrogen and internal rate of return for different nitrogen/corn price ratios^a

$\frac{P_F}{P_C}$	F*	IRR %
1	243	389
2	118	331
3	77	296
4	57	271
5	45	251
6	37	235
7	32	221
8	28	209
9	24	199
10	22	189

^aDerived from Reca's response function with $\bar{M} = 2.78$ percent.

The nitrogen-corn price ratio has been around a value of 8 for Argentina during the last period. The corresponding value for the United States is close to 3. It can be seen on Table 8 that even at the relative prices prevailing in Argentina there is room for nitrogen application in corn, even though the optimal doses is at a rather low level of 28 kilograms per hectare. The corresponding rate of return

for this price ratio is close to 200 percent. With the limitation given by the fact that this is derived from experimental data and not from actual farming practices, still, the results indicate that there exists a latent demand for this technology at the prevailing relative prices.

Of course, the picture will be more clear if the international relative prices are considered. For a price ratio of 3 the optimal doses of nitrogen more than duplicates, while the rate of return increases in approximately 50 percent. The results are referred to "normal" levels for the weather variables, and average level for the rest of the variables excluding F. The analysis cannot be expanded to analyze the effect of the variability of the organic matter content on the optimal doses of nitrogen. As mentioned before, the functional form of the response function considered implies a positive relation between F and M. This does not seem to be so, according to the soil fertility specialists (see Novello), at least for a relevant range of organic matter content for which the degree of depletion has not destroyed the structural characteristics of the soil. This aspect was emphasized in the de Janvry (1972) study. He fitted a production function of the form

$$Y = A \cdot F^{\beta_0 + \beta_1 M^2} M^{\alpha_2} D^{\alpha_3} HS^{\alpha_4} HD^{\alpha_5} PW^{\alpha_6} .$$

The functional form permits to analyze the interaction of nitrogen and organic matter content (used as a proxy for natural fertility of the land). The level of M will not only have a direct effect on yields through the coefficient α_2 , but also will affect the fertilizer response, entering in the coefficient of F, where β_1 is supposed to be of negative sign.

The estimated response function in this case is:

$$\begin{aligned} \text{Log Y} = & -15.031 + 0.117 \text{ Log N} - 0.010 M^2 \text{ Log N} \\ & (-5.19) \quad (3.00) \quad (-1.95) \\ & + 2.116 \text{ Log M} + 0.392 \text{ D} + 1.940 \text{ HS} \\ & (4.27) \quad (11.32) \quad (6.10) \\ & + 1.940 \text{ Log HF} - 1.379 \text{ Log PW} \\ & (3.62) \quad (-3.82) \end{aligned}$$

$$R^2 = 0.77 \quad .$$

Defining

$$C = \bar{D}^{\alpha_3} \overline{HS}^{\alpha_4} \overline{HD}^{\alpha_5} \overline{PW}^{\alpha_6}$$

where the bar has the same meaning as before. Then the optimal fertilizer level will be in this case

$$F^* = \left[\frac{P_F}{P_C} \frac{1}{(\beta_0 + \beta_1 M^2) A M^{\alpha_2} C} \right]^{\frac{1}{\beta_0 + \beta_1 M^2 - 1}}$$

and the internal rate of return will be given by

$$IRR = \left[\frac{P_C (Y^* - A M^{\alpha 2} C)}{P_F F^*} - 1 \right] .$$

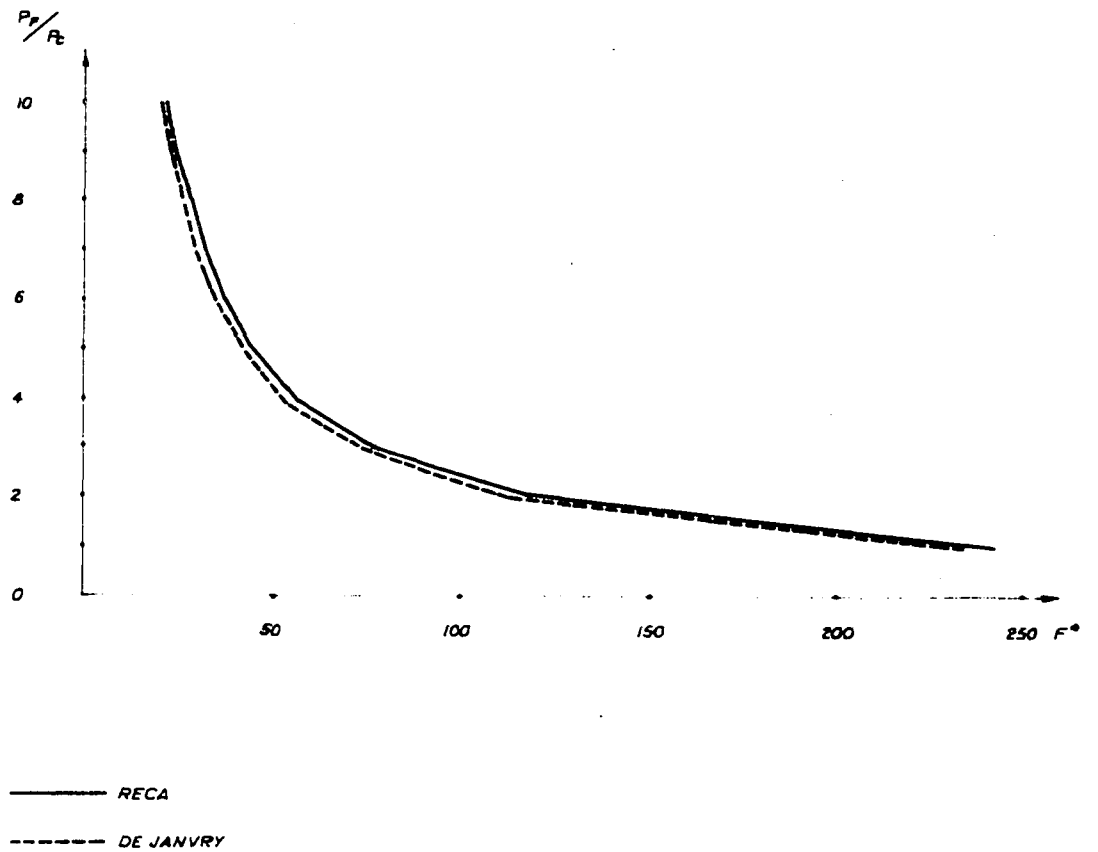
In order to obtain results which could be compared with the ones derived from Reca's (1970) response function, first we computed F^* and IRR for the level of organic matter content $\bar{M} = 2.78$. Table 9 summarizes the results.

Again, from de Janvry (1972) study it can also be concluded that there exists a latent demand for this technology in Argentina, even at the prevailing relative prices. In fact, for the average organic matter content of 2.78 percent the results are practically equivalent to the ones derived from Reca's production function. This is clearly appreciated in Figure 12, where the curves derived from both production function for the given \bar{M} are practically coincident. However this will not be true for other values of M ; the curve derived from Reca's production function will shift to the right as M increases reflecting the complementarity of organic matter content and chemical fertilizer. On the other hand, the one derived from de Janvry function will shift to the left reflecting the negative interaction between both factors. This can be seen in Figure 13, where the same curves are derived for alternative values of M .

Table 9. Optimal levels of nitrogen and internal rate of return for different nitrogen/corn price ratios^a

$\frac{P_F}{P_C}$	F*	IRR %
1	231	389
2	112	330
3	73	295
4	54	269
5	43	250
6	36	233
7	30	219
8	26	207
9	23	196
10	21	186

^aDerived from de Janvry response function with $\bar{M} = 2.78$ percent.



* DERIVED FROM RECA AND DE JANVRY PRODUCTION FUNCTION WITH $\bar{M} = 2.78$

Figure 12. Optimal usage of nitrogen for different nitrogen/corn price ratios

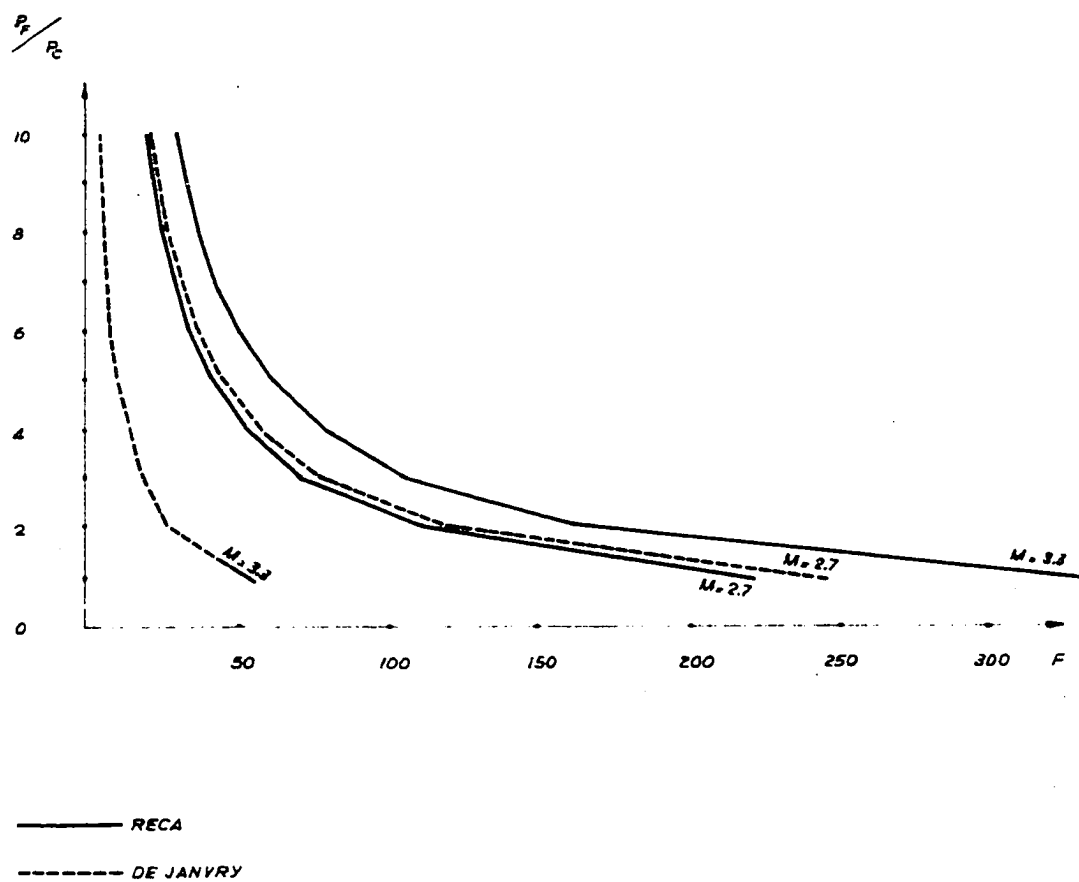
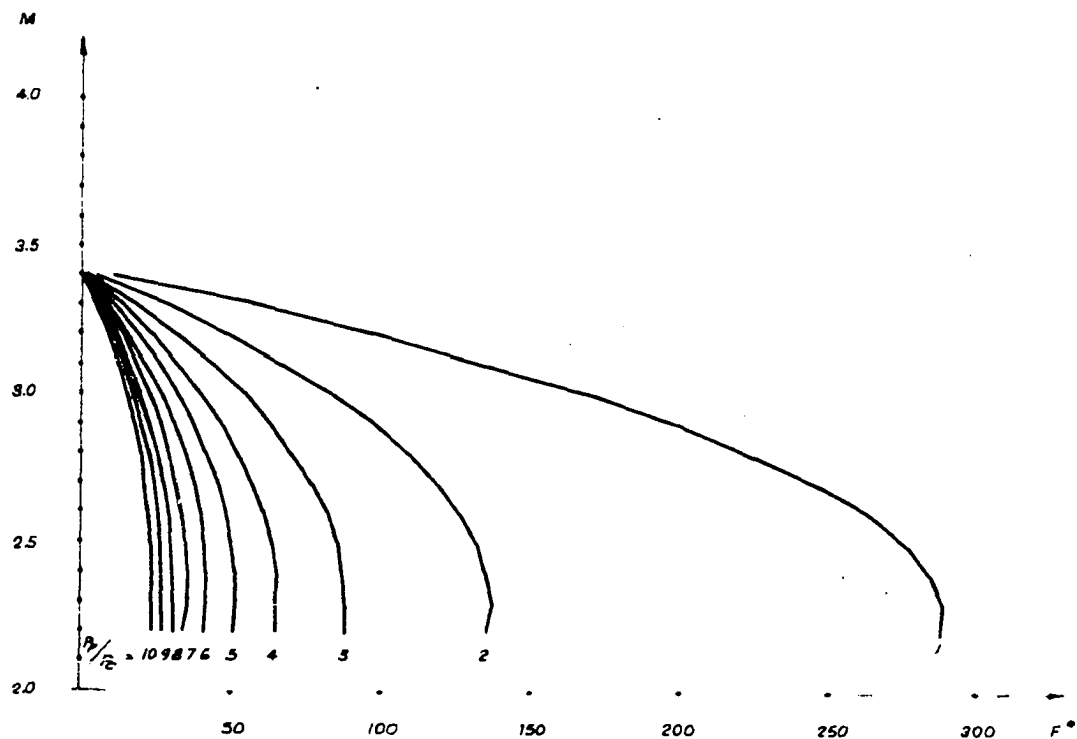


Figure 13. The role of organic matter content in Reca (1970) and de Janvry (1972) production functions

Chemical Fertilizers and Natural
Fertility of the Land

Consequently, with the de Janvry production function, the analysis can be extended in a meaningful way into the consideration of the role of the natural fertility of the land (proxied by M). In Figure 14 each curve shows the relation between the optimal level of nitrogen and the percent of organic matter content, for a given relative price. In all cases it can be seen that the optimal level of F increases as M decreases, being the magnitude of the change a function of relative prices. In other words, for the relevant range the slope of the curves is negative reflecting the relation between M and F^* , and on the other hand as P_F/P_C decreases the curves shift in a nonparallel fashion, decreasing the slope of the curves for each level of M . In addition it can be observed how all the lines converge to a level of organic matter content of about 3.4; for which, given the high level of natural fertility of the land is not profitable to apply chemical fertilizer disregarding of its price. In Figure 15 the internal rate of returns are also included. The curves depict in this case for each relative price, the locus of combinations of IRR and M implied in the use of optimal doses of nitrogen. In other words as we go to the right along the curves the level of fertilizer application decreases as indicated in Figure 14. Two



DERIVED FROM DE JANVRY RESPONSE FUNCTION

Figure 14. Relation between optimal usage of nitrogen and organic matter content of the soil for different relative prices

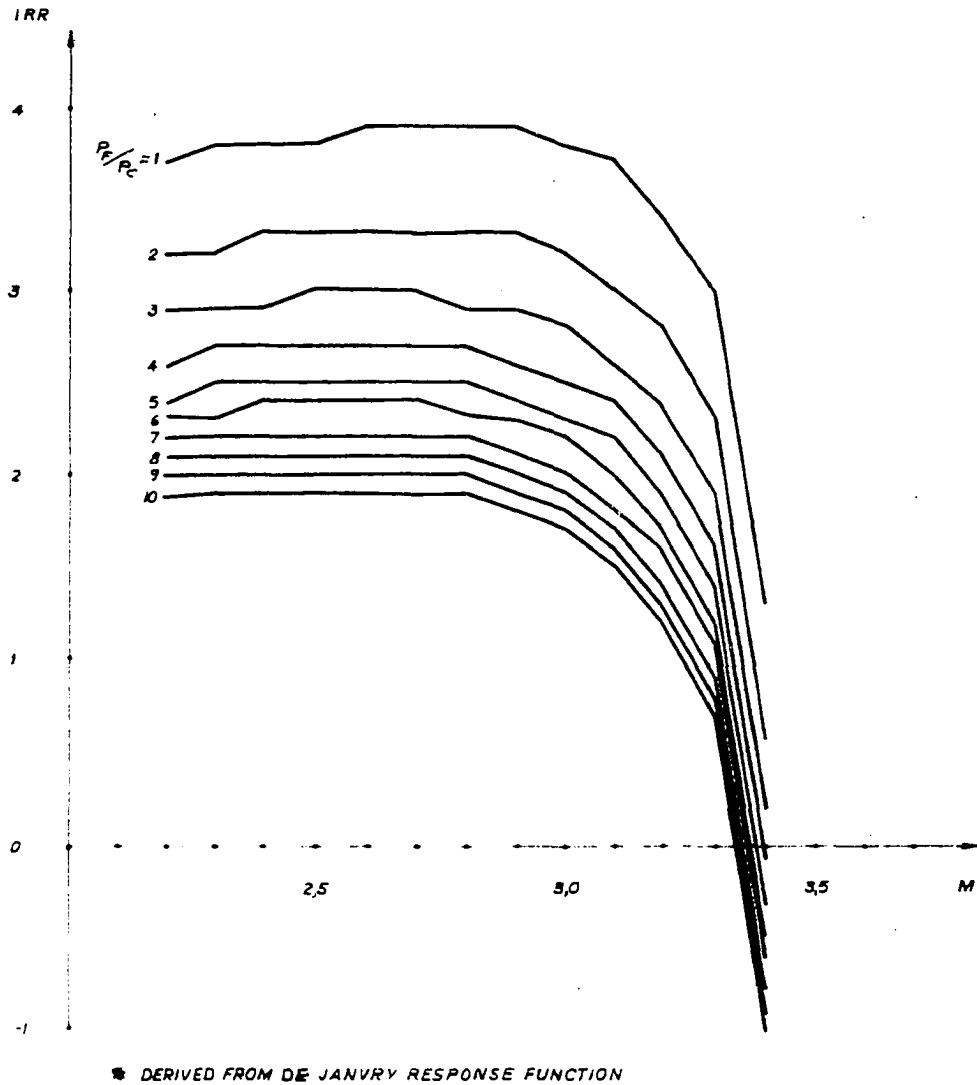


Figure 15. Internal rate of return for the use of optimal levels of nitrogen and alternative values of organic matter content and relative prices

characteristics should be noted; one is that the curves are rather flat for low levels of organic matter content indicating that the IRR responds only to prices for extreme (low) values of M. The other characteristic is that the rate of returns goes down to zero for values of M relatively high, and they do so disregarding the price ratio.

Previous arguments lead to the point that in order to be able to make more valid inferences about the latent demand for fertilizer in the Argentine case, the present natural fertility of the land (percentage of organic matter content was used as an indicator of this fertility) in the traditional cereal area must be considered.

In the Argentine corn belt the levels of organic matter content, which oscillated between 4 and 6 percent 50 years ago, have decreased to a range of between 2 and 3 1/2 percent in the small and medium-size farms of the region, whose lands have been subject in general to continuous cropping activities. Only in the larger farms, which usually combine cropping and cattle activities with natural or artificial pastures, higher levels of 4 to 6 percent of organic matter content can be found (INTA, 1966, p. 13). In other words, larger farms have the alternative of implementing an adequate rotation pattern between crop and cattle activities which can be understood as the traditional and "extensive" method for conservation of the natural fertility of the

land. The importance of this should not be underestimated since for example in the central corn region (which produces about 40 percent of the total corn of the country), 76 percent of the farms are below 100 hectares (small size in Argentine patterns), according to the National Census of 1960.

Implications in Terms of the Socioeconomic
Model of Induced Innovations

The available empirical evidence supports the hypothesis that there exists a latent demand for the technology of fertilizers in Argentina, even at the prevailing relative prices. Furthermore, the possibility of fertilizer application will increase if the alternative of international relative prices are considered.

Now, what are the implications for actual demand? The big farmers, representatives of the dominant farm interest, will carry in general an extensive type of production and it will be feasible for them the instrumentation of some rotation pattern as a method of fertility conservation. This method is, on the other hand, perfectly congruent with their land/other inputs factor ratios. In doing so, they place their lands out of the relevant range of fertilizer response, shown in Figures 14 and 15. Without economic stress, and having congruence with the prevailing factor

ratios as a dominant goal, there is no actual demand for the fertilizer technology deriving from the dominant farm interest.

As a result, systematic research on fertilizer was only initiated by INTA in 1962 and not given the right priority. The experimental design of the trials was such that an economic evaluation of them was not possible. Economic analysis had not been present at all. The situation improves somewhat about 1967/68; a more comprehensive control of the relevant variables is attempted. Also, around 1969 a cooperative program INTA-CIMMYT-Ford Foundation starts to produce some results.

But still, an ex-post inspection of the location of the INTA fertilizer trials (from 1962 up to the present) indicates that a high percentage of them were done on soils of high natural fertility. From all the experiments for which the soil fertility was controlled (and this was not done until 1966), about 75 percent of them were located in soils of more than 3.5 percent of organic matter content; in other words, most of them were done on larger farms.

This was not just a random process; it can be explained within the socioeconomic model of induced innovations, with the environmental bias mentioned in Chapter III. Big producers, typically better educated, with land to spare for experiments, were the ones in closest contact with the

experiment station (Obschatko).

This environmental condition that the scientist of INTA had to face, together with the fact that the planning system in INTA was not based necessarily on a set of priorities rationally established,² had determined in considerable degree the bias in the location of the trials. In addition, since land fertility was not taken into account in the analysis of the data, the conclusion that fertilizer use was indeed of dubious economic worth in Argentina was inevitably reached.

In summary, there exists a latent demand for fertilizers in Argentina. The actual demand for research on this technology is rather weak or inexistent; supporting the existence of the gap between latent and actual demand for this type of research. The lack of adoption of fertilizer can be attributed then to the actual unavailability of the technology at farm level, because of lack of enough agronomic and economic research in this direction.

²However, at the present there is an increasing concern about this in INTA. In a recent National Meeting of the INTA economists, the establishment of such priorities have been discussed in some detail. See for example INTA, 1972.

CHAPTER VII CONCLUSIONS

In an attempt to provide additional elements for the explanation of the controversial issue of the stagnation of the Argentine agricultural sector, the factors influencing the demand for and supply of innovations in this country have been identified. The analysis tried also to explain the process of generation of agricultural innovations, by public and private institutions and the adoption of the new technology by the farmer.

The possibilities for additional growth of the Pampean agriculture through horizontal expansion are limited, since the extensive land frontier was reached around the 1930's. Further increases in the aggregate output of the area have to be obtained through an intensification in the use of land; implying the need for factor deepening and/or technological change. The prerequisites for an expanded production have not occurred--or at least have not occurred with enough intensity. This provides enough justification for present emphasis in the process of generation and adoption of new technologies.

A sharp distinction was made between the decision mechanisms that underlie the generation and the adoption of new techniques. While the generation of innovations results from a social decision process, the adoption of new technologies, once available, is a decision for the individual

producers that essentially depends on their economic behavior, given the profitability and risk conditions surrounding the technology. In both cases it has been tried to assess the relative contribution of economic incentives and of economic stress. In the attempt to find the determinants of the technological stagnation of the sector, the concepts of latent and actual demand for innovations were defined and compared, expliciting also some of the most important shifters of each. It has also been shown that actual demand tends to lag behind latent demand, but converging to the latter one in the long run through the interplay of the generation and adoption processes.

It was specified that latent demand corresponds to an optimal generation of technologies within the spectrum given by the Innovation Possibility Curve, provided certain relative prices. Even though in this work the gap between latent and actual demand has been emphasized, it has not been pretended to ignore the importance of eventual shifts in the latent demand, in particular, if we take into account the fact that in the case of Argentina the relative prices of agricultural inputs are in considerable degree the result of the import substitution policies. Without going into considerations of a benefit-cost type for this policy, it is understood that, if we agree on the treatment of technological change as a powerful agent of structural

changes in the agricultural sector, it would be extremely important for policy making to evaluate the impact of different tariffs levels affecting the inputs embodying land saving technologies.

For the case of nitrogenous fertilizers Aguirre has evaluated in a recent study the costs and benefits of alternative policies. He concludes that the best policy to follow is one to be developed in two stages. In the first stage he proposes a free importation of nitrogen during an estimated period of 10 years along which the fertilization technology will be adopted by farmers. At the end of this time he estimates that the demand for fertilizer will be enough to justify--in a second stage--the construction of a domestic plant of economic size, and then import substitution appears to be the most convenient course of action.

The gap between latent and actual demand arises in the model from the introduction of economic stress and congruence in the decision mechanisms for the generation of innovations; in particular, from the introduction of these variables in the utility function of the dominant farm interest, from which the actual demand is derived. However, this gap would tend to disappear in the long run through the interaction of the generation process and the one of adoption, via an entrepreneurial behavior in the adoption of new available technologies and the consequent adjustments

provided by the market mechanism.

On the supply side, the distinction between its public and private component completed the picture for the generation of new technologies. The latter source of supply derives from the economic behavior of private firms, in particular of the ones providing agricultural inputs to the sector. The detailed analysis of the case of hybrid corn have shown that, provided the innovation is appropriable, its supply will be largely guided by the expected payoff for the required investment in research and development. In the case of appropriable innovations, the public source of supply will play a complementary role in the generation process, and in the case of research and development activities whose social benefits cannot be privately appropriated, the public research network will obviously acquire absolute prevalence as a "producer" of these technologies.

The lack of a systematic technological policy on the government side has led to a situation in which the allocation of resources in the Instituto Nacional de Tecnología Agropecuaria was basically left to individual initiatives originated in the researchers and extensionists of INTA who were exposed to the influences of the farm environment in which they work, being this environment essentially biased in the direction of the dominant farm interests. The planning system was not based necessarily on a set of priorities

rationally established, but rather on a process of accumulation of initiatives and decisions about them.

In summary, this made the public research system flexible enough, as to allow the research funds to be channeled in the direction indicated by actual demand. In this sense, a wider representativeness of farm interests and a clear definition of government demand for technological change are essential to reach a socially optimum use of resources in agriculture.

Once the new technology has been made available, the response of the farmers in the adoption process is essentially determined by the economic conditions surrounding the new technique. The analysis of the case of hybrid corn in Argentina has shown that a substantial proportion of the variation in the rate of acceptance of this technology is explainable by differences in the profitability of the shift from open-pollinated to hybrid varieties in different regions of the country.

In the case of fertilizers, the available empirical evidence, based only on experimental data, supports the hypothesis that there exists a latent demand for this land-saving yield increasing technology in Argentina, even at the prevailing relative prices. Furthermore, the possibility of fertilizer application will increase if the alternative of international relative prices is considered.

However, in absence of economic stress, the actual demand for the generation of this type of innovation is weak or nonexistent. Big farmers, representatives of the dominant farm interest, in general, will operate an extensive type of production where some rotation pattern is feasible, as a method of fertility conservation. This method is, on the other hand, perfectly congruent with their land/other inputs factor ratios. In doing so, they place their lands out of the relevant range of fertilizer response. This explains the inexistence of actual demand for this technology derived from the dominant farm interest; and consequently, the existence of a gap between latent and actual demand for it.

In addition, a land induced technological treadmill is postulated to be acting as a dynamic mechanism of interaction which will bridge the gap between latent and actual demand. In other words, eventually this mechanism would lead the economy towards an optimal path of generation and use of technologies, through a dynamic interplay of coercive elements in interaction with the market mechanism and the behavior of profit seeker farmers. This process appears to be of extreme long-run nature, but can be accelerated by a land taxation scheme.

In Argentina, a country which is largely open to the world market of beef and cereals, where it faces a highly

elastic long-run demand schedules, at least for some of the exportable goods, the generation of highly profitable land saving technologies as a part of a more general economic policy framework, may generate diseconomies of large scale and force management dedication, thus acting in the direction of a land reform process that can be accelerated by a land taxation scheme. Among the ingredients of such economic policy framework, can be included:

- a) A definition of the government demand for technological change, in particular, the clear setting of the criteria for the allocation of resources in the public agricultural research network, according to the sectorial objectives of economic policy.
- b) A shift in the emphasis from the price policy on the final products, which has been widely used resulting in reallocation of land to alternative uses without changing the traditional form of production, to a systematic price policy on the inputs side which should be more effective in releasing the constraints in which the sector has moved for the last decades. Special consideration should be given to the inputs embodying land saving technologies.
- c) Finally, a land taxation scheme, which will not only accelerate the land induced technological

treadmill, but also will provide a transfer mechanism for the surplus generated by technological change, materializing the contribution of agriculture to the overall development of the country.

In summary, technology appears to be a powerful agent of structural and behavioral changes; the recognition and instrumentation of its potentialities is in the hands of those who have the responsibility for research planning and economic policy making in Argentina.

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APPENDIX
SURVEY QUESTIONNAIRE

**Encuesta Sobre Difusión de Semilla Híbrida de Maíz, Fertilizantes
y Herbicidas, en las Distintas Zonas Maiceras del País.
A Realizarse en las Estaciones Experimentales
y Agencias de Extensión del INTA**

Nombre del Extencionista

Ubicación de la Agencia de Extensión o Estación Experimental

Ciudad o Pueblo

Partido

Provincia

1) Qué partidos comprende la zona maicera en que Ud. trabaja ?

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2) En esta zona, cuál estima Ud. que ha sido en los últimos 5 años :

a) el porcentaje de hectáreas sembradas con maíz híbrido, sobre el total de hectáreas sembradas con maíz;

b) el porcentaje de productores que utilizaron maíz híbrido sobre el total de productores de maíz.

-*-

Campaña	Has. sembradas con maíz híbrido % <u>Has. totales sembra das con maíz en la zona</u>	Productores que utilizaron maíz híbrido % <u>Total de productores de maíz</u>
1966/67 % %
1967/68 % %
1968/69 % %
1969/70 % %
1970/71 % %

3) En qué año estima Ud. que el porcentaje de hectáreas sembradas con maíz híbrido sobre el total de hectáreas sembradas con maíz llegó en su zona:

- a 10% año (o campaña)
- a 50% año (o campaña)

4) Cuál es el porcentaje máximo de difusión de semilla híbrida (columna *- pregunta 2) que Ud. estima que puede alcanzarse en su zona.

porcentaje máximo%

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5) Si este porcentaje máximo indicado en la pregunta 4 no ha sido alcanzado aún, en qué año o campaña estima Ud. que será alcanzado ?

año o campaña

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6) Si el porcentaje máximo de difusión indicado en la pregunta 4 fuera inferior al 100%, o sea si no todas las hectáreas en maíz fueran sembradas con semilla híbrida, podría Ud. indicar cuales serían las razones que permitirían explicar porque no se llegará en su zona a una difusión completa (100%) de la semilla híbrida.

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7) Cuál estima Ud. que ha sido en los últimos cinco años:

- a) el porcentaje de hectáreas en maíz en las cuales se ha utilizado fertilizante:
- b) el porcentaje de productores que utilizaron fertilizantes en maíz sobre el total de productores de maíz.

Campaña	Has. en maíz en las que se aplica fertilizantes % <u>Total de has. sembradas con maíz</u>	Productores que utilizaron fertilizantes en maíz % <u>Total de productores de maíz</u>
1966/67
1967/68
1968/69
1969/70
1970/71

8) Cuál es el tipo de fertilizante más comúnmente utilizado y cuál es el promedio de aplicación por hectárea (kg/ha) ?

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9) Cuál estima Ud. que ha sido en los últimos cinco años:

- a) el porcentaje de hectáreas en maíz en las cuales se han utilizado herbicidas;
- b) el porcentaje de productores que utilizaron herbicidas en maíz sobre el total de productores de maíz.

Campaña	Has. en maíz en las cuales se han aplicado herbicidas % <u>Total de has. sembradas con maíz</u>	Productores que utilizaron herbicidas en maíz % <u>Total de productores de maíz</u>
1966/67
1967/68
1968/69
1969/70
1970/71

10) Cuál es el herbicida más comunmente utilizado y cuál es la cantidad, tiempo y método de aplicación ?

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11) Cuáles son las recomendaciones hechas a los productores con referencia a:

a) variedades híbridas específicas más adecuadas para su zona

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b) Uso de fertilizantes, cantidad, composición y método de aplicación

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c) Uso de herbicidas, cantidad, tiempo y método de aplicación

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12) Estima Ud. que los primeros que han adoptado semilla híbrida serían (o han sido) también los primeros en adoptar fertilizantes, herbicidas y otras prácticas avanzadas de producción maicera ?

SI

NO

Podría explicar porqué ?

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13) Cuáles son en su opinión los principales factores limitantes para un mayor uso en maíz de:

a) Híbridos
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b) Fertilizantes
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c) Herbicidas
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14) Qué proporción de su tiempo (sobre una base anual) dedica Ud. en el trabajo de extensión en prácticas de producción maicera ?

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15) Qué tipo de trabajo de extensión realiza fundamentalmente (por ejemplo, visitas individuales a los productores, reuniones de productores, etc.) ?

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