OECD DEVELOPMENT CENTRE

Working Paper No. 21
(Formerly Technical Paper No. 21)

INTERNATIONAL COMPARISONS OF EFFICIENCY IN AGRICULTURAL PRODUCTION

by

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Research programme on:
Changing Comparative Advantage in Food and Agriculture

July 1990

OECD OCDE

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RÉSUMÉ

La question de l'efficience de la production agricole - en termes de définition et de mesure - figure au coeur de cet ouvrage. A l'aide d'un modèle de simulation agronomique, il y est procédé à des comparaisons, dans diverses régions de France, d'Argentine et des Etats-Unis, sur le blé, le maïs, le tournesol et le soja.

L'aptitude d'un pays à défendre sa position d'exportateur d'un produit agricole ou à maintenir la production d'une culture en déficit malgré la concurrence des importations dépend de trois facteurs : 1) l'efficience de la production agricole ; 2) l'efficience, au plan national, des systèmes de commercialisation, de stockage et de transports ; 3) le niveau de protection de l'agriculture décidé par différentes politiques nationales. Les deux premiers facteurs correspondent à ce qu'il est généralement convenu d'appeler les "avantages comparatifs" d'un pays dans une production donnée.

Dans le contexte international actuel, de nombreux pays en développement ont intérêt à connaître leurs potentialités relatives d'efficience en agriculture, de même que l'importance, pour leur position sur le marché mondial, des facteurs naturels, techniques ou économiques. Cette étude contribue à une meilleure appréhension de la mesure des situations relatives et de l'importance des différents types de facteurs.

Ses estimations de rendements potentiels pour un grand nombre de techniques agricoles permettent des comparaisons à l'échelle internationale ; elle explore enfin, parallèlement, les conséquences possibles de changements dans la structure des prix des différents pays.

SUMMARY

This paper deals with the problem of definition and measurement of the efficiency of agricultural production. Using an agronomical simulation model, it makes comparisons of wheat, maize, sunflower and soybean production in different regions of France, Argentina and the United States.

The ability of a country to defend its position as an exporter of a specific agricultural product or to maintain local production of a product in deficit, facing the competition of imports, is shown to depend on three factors: 1) the efficiency of agricultural production; 2) the efficiency of an internal transportation, stockage and trading system; and 3) the level of protection for agriculture introduced by different national policies. The first two factors are usually considered as defining the comparative advantage of a country on the considered product.

In the international context of today, it is important for many developing countries to know their relative position in terms of potential efficiency in agricultural production and to know to what extent that position depends on natural, technical or economic factors. This paper provides insights into the measurement of these relative positions and the importance of the different types of factors.

By estimating potential yields for a wide number of agricultural techniques, it provides international comparisons and simultaneously explores the possible effects of changes in the price structures in different countries.

PREFACE

The Development Centre's 1987-89 programme on "Changing Comparative Advantage in Food and Agriculture" brought together analyses of the policies influencing international interactions with those affecting agricultural development on the national level. An important element in that programme was the investigation of factors affecting changing competitiveness and efficiency.

Guillermo Flichman's analysis of efficiency in agricultural production breaks new ground in our understanding of the factors determining international comparative advantage. The methodological innovation of adapting agronomic models to economic analysis is of great interest. These models allow the decomposition of the different elements determining plant growth in a manner which allows the detailed international comparison of the factors affecting agricultural growth and efficiency.

The analysis presented advances the discussion on the measurement of comparative advantage, pushing it beyond the doldrums in which it has drifted in recent years. Whereas the empirical results presented are restricted to a comparison of French, US and Argentinian efficiency in wheat, maize, soybean and sunflower production, it is clear that the theoretical and methodological framework has a wider applicability. The considerations involved in the extension of the approach to a multiproduct analysis are taken up in the concluding section.

A focus of recent development thinking has been the relationship between growth and efficiency. The study shows that, in certain areas, Argentina is competitive with France or the United States. The result poses questions regarding the role of subsidies and the implications of trade liberalisation which go beyond the immediate concerns of the study. They emphasize, however, the need for careful scientific analysis. The methodological framework and empirical results presented are of significance to policy makers interested in growth and development.

Louis Emmerij
President
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I. INTRODUCTION

In this paper, we deal with the definition and measurement of the efficiency of agricultural production. Using an agronomical simulation model, we make comparisons of wheat, maize, sunflower and soybean production in different regions of France, Argentina and the United States.

A country's ability to defend its position as an exporter of specific agricultural products or to maintain local production of a product in deficit in the face of competition from imports, depends on three essential factors: 1) the efficiency of agricultural production; 2) the efficiency of an internal transportation, stockage and trading system; and 3) the level of protection supplied to agriculture by different national policies. Usually, the first two factors decide a country's comparative advantage concerning the specified product.

A country with low comparative efficiency of agricultural production may, however, become a net exporter if its internal policies compensate that inefficiency with export subsidies and/or import tariffs. Problems related to the distortions created by these practices have been largely discussed and analysed. A consensus exists (to some extent) on the methods needed to quantify the level of protection to agriculture (PSEs' and CSEs').[1]

In today's international context it seems important for many developing countries to know their relative position in terms of potential efficiency in agricultural production, and to what extent that position depends on natural, technical or economic factors.[2] Comparative advantages that depend on economic factors may change along with economic policies in the short term. Technical factors that determine competitiveness may change in the long term. These are essential principles of a dynamic comparative advantage approach.[3] Advantages related to natural resources usually do not change, though in a very long period they might because they also depend to some extent on the price system. For practical reasons we may assume that they do not change. The methods usually used to compare production efficiency between countries do not distinguish among these three factors. It seems important to do so, however, for defining patterns of agricultural development.

The simplest approach to international measures of efficiency involves existing production costs of agricultural products in different countries.[4] Comparing a representative commodity's production costs at a given exchange rate (we will not consider the exchange rate problem right now) while allowing for its relative costs in separate countries can give a fair idea of each country's position.

Any shift in relative prices of inputs or outputs may induce changes in the techniques used in each country altering the level and structure of production costs. Even considering a set of possible techniques in each country as given, this type of comparison allows only limited conclusions. This approach can not explain what part of the differences found in the comparisons originate from natural, technical or strictly economic reasons.

Measures related to agricultural production efficiency can be calculated on the basis of production and cost functions estimated by econometric methods.

The theoretical definition of comparative advantages, after the Heckscher-Ohlin version and the further developments by Stopler and Samuelson, is based on one essential assumption: the production functions of similar goods are the same in all countries. This implies that the difference of techniques of production that exists among countries is a consequence of the heterogeneity of production factors among countries.

One of the principal problems of econometric methods of estimation of production functions is the specification of production factors. What can be defined as "capital" in a certain country may be something different somewhere else. The same problem appears with "labour" or with "land". We can assume that if the production factors are properly specified, the production functions of a given good are the same all over the world. Of course, the level of disaggregation of the data should be considerable, as well as the representation of the alternative techniques. The usual econometric methods can not do this. If cross-section data are used, the individual techniques that proportionate the basic data for the estimates of the production functions are influenced by the present structure of relative prices. Usually, the variation in the proportions of factors used is quite low. If time series are used, the problem of measurement of technological progress appears. Even the most elegant methods that try to deal with this question are not always very convincing.[5]

The method closer to the original notion of production functions as a "blueprint of possible techniques" is the one that tries to build "engineering" production functions, obtaining the technical coefficients of production from agronomists. The problem is that it is not easy to obtain the necessary information. Usually, agronomic research is not done to obtain appropriate data for economists. It is difficult to separate the influence on production of the level of fertilization, the weather, different technical schedules, differing varieties and the quality of the soil with existing information. This is the case even in countries in which very old experimental agricultural stations exist.

We have been able to partially solve these problems using a plant growth simulation model called Erosion Productivity Impact Calculator (EPIC)[6]. The use of this type of model allows new ways of implementing the engineering production function approach. It is possible to use EPIC to simulate production outcomes of almost any type of agricultural technique. We can represent the effects on yields of changes in the quantities of fertilizer, the levels of irrigation, the types of equipment, the characteristics of alternative varieties and rotation schemes. The model also simulates weather conditions. EPIC can be seen as a kind of very sophisticated comprehensive agricultural production function. With it we are able not only to make international comparisons of efficiency and measure the relative importance of natural, technical and economic factors, but we can also simulate the possible effects of changes in price structures in different countries.[7,8]

In the following section of this paper we will present a very simple model that gives us the theoretical and methodological framework for the empirical research. In the third section there is a synthesis of the initial results, comparing French, American and Argentinian efficiency in wheat, maize, soybean and sunflower production. In the last section, propositions to enlarge the comparisons to a multiproduct analysis are presented.

II. INTENSIFICATION AND EFFICIENCY IN AGRICULTURE

Intensification is defined here as the increase of any of the production factors except land. Since land is usually a fixed element, different levels of intensification at certain moments correspond to alternative techniques. If we figure all the costs of the economy, excluding the price of land, we can aggregate into monetary terms all the production factors other than land and consider them a single factor, that is, the total monetary cost of production. The opportunity cost of capital used in agricultural production is incorporated in this cost. The level of intensification will then be given by the ratio C/T, T being the land, measured in physical units.

In the case of an increase in agricultural yields, we will consider it a product of intensification only if C/T increases. If there is an increase of yields without an increase of the ratio C/T, as is the case when ameliorated agronomical procedures are followed, for example, without any improvement in the quantity of inputs, it is not a case of intensification, but one of simple technical progress. This definition allows one to differentiate, in the case of yield increase, between causes related to technical progress and those related to a change in the level of intensification.

It is possible to present two situations in which there is intensification. The first occurs in the case of only one commodity. The second occurs when we take into account several commodities simultaneously. In the first case, intensification takes place when C/T increases because there is a change in the technique used to produce the commodity considered. In the second case, intensification may occur because the proportion of commodities using more intensive techniques increases, even if the technique used in each case remains the same. Of course, it is also possible to have a combination of both types of situations. Initially, we are going to deal only with the first type of intensification. In other words, the analysis concerns only one agricultural product.[9]

In this monoproduct model, we initially define our production and cost functions in monetary units, accounting for the set of prices of the economy as given, except for land rents. Only the land rents and the level of intensification are determined in an endogenous way. This assumption works well with a situation in which agricultural prices are administered prices and the agricultural sector does not have a significant influence on the prices of inputs and capital goods it uses.[10] The production function for each crop is expressed as one variable function for simplification purposes. Behind that monetary function, there is a detailed physical production function and a given set of prices. Rent, including "remuneration of land" and management, is defined as the difference between the total value of production and total monetary costs. Under this assumption farmers should maximize rent.

We suppose that the production per unit of land is a function of C/T, homogeneous and of degree 1, as is usually admitted.

It is quite simple to demonstrate[11] that if the prices of inputs, capital goods and wages are given, there exists only one level of intensification (that may represent more than one technique) for which the unit cost of production is minimized. We consider that, for a given set of prices and a given set of techniques, maximum efficiency is obtained when the unit cost of production is minimized. This minimization does not depend on the price of the agricultural product.

The level of intensification that is optimal for the agricultural firm under the already described assumptions, given the price of the agricultural product and the opportunity cost of capital (or the alternative rate of profit for investments made in the non-agricultural sector), is the level of intensification that maximizes the level of land rent. Land rent is the residual revenue after deducting production costs and the opportunity cost of capital from gross revenue.[12]

If agricultural prices are administered prices (and we suppose that is the case) the level of intensification that gives the minimal unit cost of production does not necessarily coincide with the level of intensification that gives the maximum land rent. There is, under our assumptions, only one agricultural product price that allows a coincidence between maximum rent and minimum cost. The amount of the difference between the level of intensification that produces the cost minimization and the one that permits the rent maximization depends on the level of agricultural prices.

The price of the agricultural product determines the level of intensification that maximizes land rent, but has no influence on cost function.

If we are able to build strictly physical production functions, we can analyse separately natural, technical and economic factors that influence real and potential efficiency. Real efficiency is shown by the unitary cost corresponding to the intensification level induced by rent maximization and potential efficiency is the minimum production cost.

Let us first consider natural and technical factors. It is difficult to separate them, especially when an antiquated national genetic research system exists. Plant varieties have been adapted not only to natural but also to economic conditions in each country. In Argentina, for example, wheat has been selectively bred more for disease resistance than (as in France) a high response to fertilization. If we now obtain a lower response to fertilization in Argentina, the technical factors are "mixed" with the natural ones (more severe climatic restrictions, richer soil). We may say that "pure" natural factors do not exist, but always depend on the state of development of technology.[13] Development of technology, as the theory of induced innovation shows, is not unaffected by economic factors. All this interaction allows us to make strict distinctions in a static analysis. Making these distinctions is necessary for analysing possible dynamic modifications of comparative advantages.

Using the plant growth simulation model, we are able to obtain yields corresponding to a wide range of alternative techniques in a particular region.

The estimation of a large set of potential techniques with this methodology allows us to make the following calculations:

a) We compare potential minimum production costs in each country, respecting the national price structures. We can estimate the change necessary in the agricultural product's price to produce a switch to the most efficient technique. This is done by means of a large number of simulations that represent different possible techniques.

b) If we apply the same price structure of inputs to both countries, we are able to analyse the influence of natural-technical factors separately from that of strictly economic factors. As this analysis is based on the knowledge of implicit physical production functions, all factor substitution effects eventually induced by the change of the price structure may be properly studied.

The problem of the exchange rate in the comparison is solved if we make comparisons with a given national price structure applied to all countries. These comparisons are independent of the exchange rate.

To distinguish between natural and technical factors, it is possible to "invent", for example, "French style" wheat varieties adapted to Argentinian conditions, and "experiment" with them through EPIC. With this information, we can quite accurately pinpoint the weight of natural, technical and economic factors in determining comparative agricultural production efficiency.

III. COMPARISONS OF EFFICIENCY IN WHEAT, MAIZE, SOYBEAN AND SUNFLOWER PRODUCTION IN DIFFERENT REGIONS OF ARGENTINA, FRANCE AND THE UNITED STATES

3.1 General Aspects of the Comparisons

3.1.1 The Regions

The regions considered in this study are represented by a set of soil and weather data used for the simulations in the EPIC model. In each case, we have chosen the data upon technical advice from national agronomical research institutions (Institut National de la Recherche Agronomique in France, US Department of Agriculture in the United States, Instituto Nacional de Tecnologia Agropecuaria in Argentina). The climatic and soil information used for the simulation model had to be representative of the agricultural region.

The Argentinian regions are Pergamino and Tres Arroyos. In France, the regions are La Beauce and Toulouse. The regions in the United States are Kansas and Marshall, Indiana.

Wheat production efficiency was analysed in each region. Tres Arroyos, La Beauce and Kansas are quite representative of the most significative wheat-producing regions of the three countries (the Southeast Pampean Region of Argentina, the Paris Basin in France and the Great Plains in the United States). Pergamino, Toulouse and Marshall, Indiana, are traditional maize-producing regions, but wheat has some importance, especially in rotation with soybeans.

Maize and soybeans were studied in Pergamino, Marshall and Toulouse. These locations are representative of the most important producing regions of both crops in the three countries. In the case of sunflowers we considered only one Argentinian and one French region, Tres Arroyos and La Beauce.

3.1.2 The Validation of the Epic Model in the Different Regions

To validate the simulation model in the different regions for the four crops, we simulate the results in terms of yield of the dominant techniques actually used in each region. This means that we take into account the rotation of the crop, the tillage system, the fertilization level and irrigation (when used). We consider the whole set of parameters employed to be adequate if the simulation results are close enough to the real yields obtained in the simulated conditions. As EPIC always optimizes from the agronomical point of view, in the regions where farmers are technically more efficient the simulations give yields close to the regional average. In other cases, the simulated results are higher than the average, but they are close to the results obtained by the "good" farmers. A specific limitation of EPIC is that it does not simulate pest and disease control. We always assume a good phytosanitary control in the simulations. As all the regions considered have good weather and soil conditions, the results obtained with the simulation model are quite close to reality. The EPIC model works better when climatic conditions do not cause severe stress to plant growth and that is the case in all the regions we studied.

For wheat, the results of the simulations are almost equal to the average regional values for La Beauce, Kansas and Toulouse. They are higher (approximately 15 per cent) for Marshall, Pergamino and Tres Arroyos.

These differences may originate not only in differences in technical efficiency of farmers but also heterogeneity of the natural conditions in the regions. The essential results of the study are not changed, even if we correct the whole set of data by lowering the yields of Marshall, Pergamino and Tres Arroyos.

In the cases of maize, sunflowers and soybeans, the validation was good in all the regions. The simulated yields are slightly higher than the average ones.

3.1.3. The Techniques Simulated: Rotations, Fertilization, Irrigation, Type of Equipment

After the validation, we assume EPIC works correctly, and we simulate a large number of techniques that cannot be validated because of lack of data. As a matter of fact, the interest of using EPIC resides principally in creating this "pseudo-data". For example, in Pergamino there are some experimental results of maize irrigation. They show very high yields with lower levels of fertilization than in Marshall or Toulouse. A two- or three-year simulation gives about the same results, but if we do a long-term simulation (20 years or more), higher levels of fertilization appear necessary after a long period of high yields that exhaust soil fertility. EPIC allows us to measure this, ameliorating the evaluation of the long-term, real costs of this technique. A similar problem appears in the case of wheat production in La Beauce. If we simulate extensive rotations with leguminous pastures, we obtain yield estimates that are impossible to get from experimental data, because they do not exist. Considering the set-aside programme of the European Community, the practical interest of analysing the feasibility of these extensive techniques appears evident[14].

Simulation of a large number of techniques allows us to analyse changes that should occur under different price structures, as we explained in the second part of this paper.

3.1.4. The Definition of Efficient Techniques

All the simulated techniques are technically efficient since with the combination of inputs used, production is maximized. That is the job of EPIC. Still, we need to define efficient techniques with an economic criterion. Our definition depends on the price structure. For each national price structure there will be a set of efficient techniques that may change when a different set of input prices is applied.

The technique T_1 with a total production cost per hectare of $(C/T)_1$ produces a yield Y_1. It is an efficient technique only if all the techniques $T_1 \ldots T_{i-1}$, with $(C/T)_1 \ldots (C/T)_{i-1} < (/T)_1$ produces yields $Y_1 \ldots Y_{i-1} < Y_1$.

In other words, we consider efficient techniques those that, for a given set of input prices, produce a higher yield than all other possible techniques, with a lower total production cost per unit of land.

We defined different sets of efficient techniques for each crop, region and price structure. The results, including the principal characteristics of these techniques, are presented in the Appendix. Between 50 and 90 simulated techniques, the set of efficient ones vary from 25 in the case of wheat in La Beauce (with all price structures) to a minimum of eight for maize in Marshall with the French price structure.

Generally we can say that the technique producing the highest level of rent, as we have defined it, does not always correspond with the technique producing the lowest unit production cost. Differences between the levels of costs and rent change substantially when we switch price structures.

3.2 The Case of Wheat

3.2.1. The Yields

It is possible that there exists a natural base for the yield differences between the six regions. The highest yields without fertilization are in Tres Arroyos, but with fertilization and both with and without irrigation, the highest production per hectare is in La Beauce.

These differences are based essentially on different soil and weather conditions, and on the characteristics of the varieties. This "natural" base has been partially influenced by the characteristics of the farming systems. The extensive nature of Argentinian agriculture allowed a higher quantity of organic materials to remain in the soil. In Kansas, however, the agriculture is also extensive and the yields are nevertheless lower than in Tres Arroyos. Also the genetic parameters of the varieties influence the level of response to intensive techniques. We simulated, for the case of Tres Arroyos, a "French style variety" and we obtained a relatively modest increase in yield. It seems that the soil and weather conditions are the principal determinants of differences in yields. This idea has been confirmed by agronomists and can be thoroughly examined by looking at the detailed results of EPIC simulations. To some extent, these results confirm that enormous errors can be made when land is considered the unique factor in production, and similar in all countries and regions. Even the introduction of a "quality index" lacks the complexity of all the interactions that simultaneously play a role in the determination of yield levels. These natural differences, as we will see, greatly influence the choice of techniques in the different regions.

3.2.2 Comparisons with the National Price Structure

We considered the set of prices of 1987 for the three countries, as well as inputs, capital goods and products. The price of the products is necessary for calculating the level of rent of each estimated technique. Comparing the minimum possible unitary production cost of each region gives the differences in efficiency, both for natural-technical reasons and for economic reasons (with heterogeneity in the price structure). It has been shown that the techniques corresponding to the lowest unitary costs are not always those that produce higher rents.

In some cases, the technique corresponding to the minimum production costs is the dominant one. This is the case when the technique also produces maximum rent, or when farmers do not maximize the rent because other factors, essentially risk, push them to choose cost-minimizing techniques.

In the case of Kansas and Pergamino there is concurrence between minimum cost techniques and those that produce maximum rent. For all other regions the maximum rent techniques imply a higher level of inputs than the lowest cost techniques. In La Beauce, irrigation is not a dominant technique for wheat production, partly because water is not always available.

Variations in levels of minimum costs are considerable when the national price structures are used. Tres Arroyos seems to be the region with the lowest production costs for wheat, followed by the other Argentinian region, Pergamino. The two American regions and La Beauce have a unitary minimum cost of production that is roughly two times that of Tres Arroyos, and the production cost of Toulouse is four times higher than that of Tres Arroyos. When using the national price structures, it is impossible to know which part of the differences is due to natural and technical reasons and which part is just a consequence of the different price structures. This comparison is also limited by its dependence on the exchange rate. If it changes from 6.07 FF per US$ to 7.00 FF per US$, for example, Marshall's costs become higher than those of La Beauce. The comparison using the same price structure allows us to eliminate this problem. Of course, as we will see, the cost margins widen when we apply each of the national price structures because natural conditions are different, and even with the same price structure the proportions of production factors are not the same in all regions.

3.2.3 Comparisons with the Argentinian Price Structure

Variations in production costs of the different regions are smaller than in the comparison using national price structures. The variation coefficient of minimum production costs changes from 0.48 to 0.40. The most dramatic differences, however, appear in the level of rents. If Argentinian prices are applied, rent becomes negative for all possible techniques in Toulouse. In the case of La Beauce, only two techniques (out of 25 efficient techniques) obtain positive levels of rent and three (out of ten) in Kansas. The situation is better in Marshall. The reason is clear: in Argentina the relation between input prices and wheat price is weaker than in France and the United States. The techniques that produce maximum rents (or the least negative, in the case of Toulouse), as well as those that produce the minimum cost are more extensive, except in the case of Marshall, where the technique producing maximum rent is the same under the American and under the Argentinian price structure. It is interesting to see that in La Beauce, the agriculture is not very extensive. If we consider the techniques producing the lowest production cost, the yield changes from 75 q/ha to 73 q/ha when we apply the Argentinian price structure.

3.2.4 Comparisons with the French Price Structure

The relative prices of wheat and inputs are better in France than in Argentina. This fact creates higher rents for all the regions when the French price structure is applied. Also some input prices (especially wages and gas-oil) are higher than in Argentina. This is why unit production costs are also higher. The most important result of the comparison is the narrowing of differences between minimum unit costs of production. The coefficient of variation that was 0.48 and 0.40 under national and Argentinian price structures is only 0.29 when the French price structure is used. The differences between maximum potential rents are also reduced.

In this case, the minimum cost of production is still obtained at Tres Arroyos, but the difference with La Beauce is insignificant. For the French region the minimum production cost was more than two times the cost of Tres Arroyos, respecting the national price structures. The difference now is less than 5 per cent. The Argentinian technique becomes more intensive: the amount of fertilizer is 120 kg instead of 30 kg, but the yield increase is relatively modest, rising from 46 q/ha to 56 q/ha. In this case, the simulated technique implies the use of a "French style" variety, simulated with EPIC. The same level of fertilization, with the same type of variety, produces 69 q/ha in La Beauce. The techniques of the American regions are the same as those that minimize the cost within the national price structure.

Techniques maximizing rent are more intensive and they imply irrigation in the cases of Toulouse, La Beauce and Pergamino. In Marshall, Kansas and Tres Arroyos, the same techniques that minimize costs maximize rent.

3.2.5 Comparisons with the American Price Structure

The results obtained with the American price structure are similar to those obtained with the French prices. The only important difference concerns irrigation. The cost of irrigation is much lower in the United States, and this influences the results to some extent. The relative order of the different regions in respect to the minimum potential cost of production, though, does not change.

3.3 **The Case of Maize**

3.3.1 The Yields

In the case of maize the yield differences between the regions are very small for the maximum potential yield: with irrigation and a high level of fertilization, it is around 100 q/ha in the three countries. On the other hand, without fertilization and irrigation, the differences are quite large because of different soil characteristics.

One possible explanation for the similar maximum potential yields is the more homogeneous character of dominant maize varieties in the three countries. As maize varieties are hybrids, commercialised by private firms all over the world, their differences are less marked than those found in wheat.

3.3.2 Comparisons with the National Price Structures

In Toulouse and in Marshall, the two more intensive techniques are the least costly ones, using the national price structures. In Pergamino, on the other hand, the minimum production cost is obtained with a rather extensive technique. If we look at the techniques producing the highest rents, we find they are the same in French and American regions. In the case of Pergamino the use of an intensive technique, implying a high level of fertilization and irrigation, would maximize rent, but the rent potential increase is quite low (10 per cent). Actually, irrigation is not used in Pergamino, but it is widely employed in Toulouse and in Marshall.

The differences in minimum production costs between regions are very important when we apply the national price structures. Pergamino is the region with the lowest cost.

3.3.3 Comparisons with the Argentinian Price Structure

In this case, the techniques that minimize costs are more extensive both in Toulouse and in Marshall. The same techniques maximize rent in Toulouse. In Marshall, on the contrary, maximum rents continue to be obtained with the more intensive technique.

As ever, the differences are smaller when we use the same price structure for all the regions. Nevertheless, the order of the regions in relation to their minimum potential production cost does not change. The technique that produces maximum rent in Marshall implies a slightly higher production cost, with almost twice the level of rent.

3.3.4 *Comparisons with the French Price Structure*

In the case of maize (as with wheat) the use of French prices increases the levels of rents and costs in the other countries. Differences between minimum potential production costs, however, are less affected.

The Argentinian technique producing the lowest production cost with the French price structure uses more fertilizer than in the former case, with lower yields. The reason for this is that the rotation is dissimilar, and the cost of pasture rotation with the French structure is higher. When we analyse what happens with the maximum level of rents, the differences become more striking.

To maximize rent, irrigation techniques should be used in the three regions. This implies an important increase in yields in Pergamino and in Marshall. In the American case, the technique that maximizes rent and minimizes cost is the same as that within the national price structure.

The techniques that maximize rent are quite similar in the three regions and so are the economic results, both in terms of costs and rent. Pergamino appears to produce the highest rent and the lowest cost.

3.3.5 *Comparisons with the American Price Structure*

The principal difference introduced by the American price structure is the lower cost of irrigation techniques. This is why the lowest cost techniques are, simultaneously, the ones producing the highest rents.

Techniques minimizing costs and maximizing rents are the same as those that maximize rent under the French price structure. As with the other price structures, Pergamino is the region with the lowest cost and the highest rent.

3.4 **The Case of Soybeans**

3.4.1 *The Yields*

In this case, the range of yield variation is very similar in the three regions. This crop is not responsive to nitrogen fertilization but only to phosporus. Irrigation also produces increases in yield, especially in Toulouse.

3.4.2 *Comparisons with the National Price Structures*

The minimum cost techniques are those that maximize rent. The differences in yields are not very important, but costs are quite different in the three regions.

The reason for the cost differences is this: in Marshall and Pergamino it is possible to obtain approximately the same yields as in Toulouse, without fertilization or irrigation.

3.4.3 *Comparisons with the Argentinian Price Structure*

Using the Argentinian price structure, the cost-minimizing techniques continue to maximize rents. In the case of Marshall, this technique is the same as the one used in the structure of the national prices. On the other hand, in Toulouse, all techniques give negative rents except the most extensive one, which also minimizes the cost of production.

The cost differences are considerably reduced, and in the case of Marshall they are almost the same as in Pergamino, while rent levels are higher.

3.4.4 Comparisons with the French Price Structure

Optimal techniques are those that appear in the national price structure. As in the case of the Argentinian price structure, the difference between Marshall and Pergamino is very small.

3.4.5. Comparisons with the American Price Structure

The introduction of the American price structure does not change the minimizing cost-maximizing rent techniques in Toulouse. In the Argentinian region, the most intensive technique with fertilization and irrigation becomes the one with the highest rent. The minimizing cost technique is always the same. The reason for this change is the low cost of irrigation in the American price structure.

3.5 **The Case of Sunflowers**

3.5.1 The Yields

For this crop we have studied two regions: La Beauce and Tres Arroyos. The yields are not too different. As in the other cases, the same production is obtained with smaller amounts of fertilizer in the Argentinian region.

3.5.2. Comparisons with the National Price Structures

The techniques maximizing rent are approximately the same as those minimizing costs.[15]

It is interesting to note that in La Beauce a very strong increase in fertilizer, coupled with irrigation, produces a relatively modest augmentation of yields. A completely different situation appeared in the case of wheat in the same region, where the response to fertilization was the highest among the six studied sites. The level of rent produced by sunflower production in La Beauce is similar to that produced by wheat, because of sunflowers' higher price.

3.5.3. Comparisons with the Argentinian Price Structure

When we apply the Argentinian price structure, all the techniques produce negative rents in La Beauce. The minimum cost technique is an extensive one, producing also the "highest rent" (that is, in this case, the less negative one).

3.5.4. Comparisons with the French Price Structure

The French price structure produces a noteworthy gap between the technique resulting in minimum cost of production and the one maximizing rent in Tres Arroyos. The high cost of pasture rotation when we apply the French price structure makes a very extensive technique the less costly. Nevertheless maximum rent is obtained with an intensive technique.

IV. COMMENTS ON THE RESULTS

The results show the importance of technical-natural factors in the determination of relative production efficiency. The Argentinian regions have the minimum potential production costs for the four products within the three different price structures. Still, the differences between those costs vary considerably. In the case of wheat, for example, the ratio of the Argentinian cost (Tres Arroyos) to the French cost (La Beauce) is 0.43 using the national price structures. This ratio becomes 0.56 with the Argentinian structure, 0.96 with the French structure and 0.67 with the American price structure. The order of minimum potential costs of the different regions changes only in the case of wheat. For soybeans and maize, Pergamino has the lowest costs, Toulouse the highest. In the case of sunflowers, Tres Arroyos always has lower costs than La Beauce. The differences are smaller when the same structure of prices is applied, but never so reduced as in the case of wheat.

Three results give some hints of the supply response to price changes. If we assume that the producers are rent maximizers, we can predict the change of techniques brought about by a change in prices. Of course, this does not give a good prediction of the effects of wheat production on the supply response of any particular country, for example, because we are observing only one or two regions. Taking into account, though, that a very significative part of French wheat production is achieved in regions with characteristics similar to those of La Beauce, it is possible to say that a dramatic price reduction would not reduce production very much, because the techniques that maximize rent continue to be quite intensive when we apply the Argentinian price structure. On the other hand, when we see what happens in Toulouse, we can predict that wheat production would be abandoned under that hypothesis of prices, because all techniques produce negative rents.

It is clear from these results that more intensive techniques do not always imply higher unit production costs. Decreasing returns to land exist, naturally, but only after a certain level of intensification. That level of intensification depends on technical-natural factors and, of course, on each price structure. Our methodology permits this type of analysis because it gives good technical information on alternative techniques, independent of the price structure.

We believe that these results show the magnitude of the errors that can occur when making predictions on supply responses that depend upon estimates of production functions obtained by the usual procedures. Yet no alternative methodology for supply estimations is currently available. The principal limitations are twofold: 1) Decisions, at the farm level, are done at a multiproduct level, and 2) It is necessary to consider different production regions of a particular country simultaneously if we want to estimate the effects of price changes on supply. This is why we intend to continue this line of research building farm models and sector models that use "pseudo-data" created by agronomic simulation models.

V. A MULTIPRODUCT ANALYSIS TOWARDS REGIONAL AND SECTORIAL MODELS

Further developments may arise from this line of research. The monoproduct approach has very strict limits. It is not possible to adequately reproduce the farmers' optimization decisions or to take risk into account. The technique that maximizes rent to land in a monoproduct situation may not be the optimal one if different products are competing for the use of production factors. We have already built representative farm models, defining activities by means of the growth plant simulation model.[16] Another step will be the development of Agriculture Sector Models whose activities will also be defined with this type of methodology.

The primary objective is to develop Agricultural Sector Models able to perform counterfactual experiments that examine alternative policies under different international scenarios and consider the potential technological changes that may intervene in the medium term (5-10 years). The natural resources of each region and their interactions with a large number of alternative techniques have to be carefully taken into account. Detailed micro-economic characteristics of different types of farms should be considered in the model. Restrictions concerning the long-term conservation of natural resources (e.g. soil erosion) should also be taken into account. The model should incorporate agronomic and economic specifications in a unified manner.

Traditionally, two alternative approaches to policy evaluation have been used. Either large agricultural sector models based on linear programming representations of typical farms or econometric models of supply-demand equilibrium simulate different possible scenarios. Each approach has inherent advantages and disadvantages. One objective of future work would be to overcome their disadvantages, some of which we have indicated below.

5.1 Sector Models Based on Large LP Matrices

These models can quite accurately determine known alternative techniques, as well as farm heterogeneity and risk. Their drawbacks are their cumbersome size, their slowness in solving alternative policy scenarios and the difficulty of updating them. The representation of new technical alternatives is accomplished by drawing on the knowledge of agronomists and the results of experimentation.[17] Variation of existing techniques, in most cases based on farm surveys, is usually limited and underestimates the possible technical changes that can be effected by different policies.

5.2 Econometric Models

These models have limitations arising from the type of data they must use. The technologies they are able to represent are always tied up with the real set of prices that exist at a precise moment, when the estimates are based on cross-sectional data. When time series data are used, problems occur with the consideration of technical progress as a residual. This limits these models' capacity to do prospective analysis. Also the variation of relative prices captured by the data of time series models is in many cases insufficient for analysing eventual changes induced by policy measures.

5.3 Future Research Directions

A mathematical programming model that emerges from a series of representative farm linear programming models would considerably enhance our existing analytical capabilities. These linear programming models are characterized by the creation of activities through the use of a plant growth simulation model, EPIC.[18] This allows us to obtain probable yields under different soil and weather conditions for a wide range of techniques, including those not widely practised in the region. It is also possible to evaluate risk related to weather conditions in the LP model, because weather conditions are "controlled" in the EPIC model so that distribution as well as the mean of yields is found.

5.4 Farm Models

Farm models give the essential micro-economic information necessary to build agricultural supply behaviour in the sector model.[19] The principal characteristics of these models are:

- Activities generated using EPIC make it possible to use "pseudo-data" that will allow a richer representation of the potential technical universe in continuous functional forms.

- The objective function maximizes return to land and entrepreneurial revenue. The land price is therefore a result of the optimization process. The objective function is also influenced by cash-flow and credit restrictions.

- Adaptations to risk are represented, creating the possibility of obtaining a model of farmers' behaviour close to reality. These models also permit analysis of possible effects of price stabilization policies on supply.

- It is possible to simulate effects of credit rationing at different subsidized interest rates for specific types of equipment.

- All input and output prices are exogenous. That is, a competitive environment at the farm level is assumed. They can be parametrized in order to simulate the effects of different policies.

- Effects of fiscal policies, including different kinds of land taxes, can also be analysed.

Farm models allow us to simulate the effects of alternative policies at a micro-economic level. Ideally, there should be one farm model for each type of representative farm and zone.

5.5 **The Sector Model**

Agriculture sector models are partial equilibrium models, representing the behaviour of the entire agricultural sector. The supply side is built through the aggregation of the representative farm models. Demand is introduced by exogenously generated demand functions. This implies that it is possible to endogenize the price formation of agricultural products. If supply of production factors is not completely elastic, factors prices may also be endogenized in a similar manner.

A wide body of experience exists on the construction and use of these types of models.[20] A big problem that usually appears with this methodology is that if the heterogeneity of techniques, natural resource endowments and types of farms is to be respected, the model becomes oversized. This presents difficulties in its use as a tool in counterfactual policy experiments. Another problem is the limited representation these models afford of the technical universe, in spite of their size. Usually, for each activity, no more than two techniques are considered, a "traditional" technique and an "improved" one.

The line of research proposed allows us to overcome these two handicaps of sector models:

- Activities are replaced by yield functions (possibly non-linear) for each product, offering a wide range of technical alternatives. These functions will be estimated from "pseudo-data" created by means of a large number of EPIC simulations. This procedure permits us, for a similar representation of reality, to reduce the size of the model. If we consider, for example, six products, four zones, three types of farms and ten techniques using the LP aggregation method, we would need to define 720 activities. Using the yield functions, this number shrinks to 72.

- With the EPIC model as "data generator", the representation of alternative techniques is more complete. This procedure is already used in the American National Policy Sector Model developed by the Center for Agricultural and Rural Development (CARD), Iowa State University, which is based on the procedure of aggregation of LP representative farm models. The use of EPIC also permits the consideration of long term environmental effects of different agricultural practices, especially on soil erosion.[21]

- The objective function is based, as usual in sector models, on the addition of producers' and consumers' surplus. Institutional restrictions such as incorporation of transaction costs and credit rationing, however, prevent the existence of all the conditions that would define perfect competition.

- The constraints of the sector model are coherent with those defined in the farm models.

- Risk is introduced as a function of prices and yield variability, with a negative sign in the objective function. This risk function is estimated with information produced by the farm models.

- The resulting models of farm behaviour are non-linear programmes which can be readily solved on a personal computer.

The advantage of this type of model, compared to the direct use of the farm LP models for policy analysis, is that it gives a global representation of the agricultural sector. This allows endogenous product and factor prices if necessary, and this is not possible with the representative farm models. It permits global forecasts of supply and exports under different policy scenarios.

NOTES AND REFERENCES

1. The concept of Producer Subsidy Equivalent and Consumer Subsidy Equivalent was originally elaborated by T. JOSLING and widely used by OECD, FAO and the USDA. There exists an agreement to employ it in the current round of GATT negotiations.

2. When we say "economic factors" we mean factors strictly related to the internal price structure.

3. ABBOT, P.C. and R.L. THOMPSON, "Changing Agricultural Comparative Advantage", *Agricultural Economics*, 1, 97-112, 1987. Besides these theoretical problems, it is necessary to say that data used by economists usually have a level of aggregation that does not allow deep analysis of technological change.

4. STANTON, B. F., "Coûts de production et compétitivité sur les marchés mondiaux de céréales", *Economie Rurale* No 176, November-December 1986. This article is a good example of this type of approach.

5. BOUSSARD, J. M., "On Agricultural Production Functions", Paper presented for the European Association of Agricultural Economists Meeting, Bonn, 13-14 April, 1988.

6. At the beginning of 1988 we began a Research Project at the IAMM on International Comparisons of Efficiency in Agriculture. J. M. BOUSSARD of INRA is associated with this project. Two IAMM graduate students, C. VICIÉN and D. DEYBE prepared their Master Thesis on related subjects. The case studies are Argentina, France, Italy and the United States. The plant growth simulation model we are using is EPIC, Erosion Productivity Impact Calculator, developed by the United States Department of Agriculture, Agricultural Research Service and the Texas A and M University at Temple, Texas, by J. WILLIAMS, A. JONES and P. DYKE.

7. JACQUET, F. and G. FLICHMAN, "Intensification et efficacité en agriculture", *Economie Rurale*, Paris, January-February 1988.

8. FLICHMAN, G. and C. VICIÉN, "Comparaisons internationales d'efficacité dans la production de grains. Le cas de l'Argentine et la France"; Paper presented at a meeting of the French Society of Agricultural Economics, October 1988.

9. In the last section we propose some methods that allow a multiproduct approach to this problem.

10. As is true for the case studies examined: France, Argentina and the United States.

11. JACQUET, F. and G. FLICHMAN (1988).

12. The concept of rent we are using is the Ricardian one: "The price of corn is not high because farmers pay a high rent . . . rents are high when the price of corn is high . . .".

13. Marx realized this with great lucidity; when making a critical reference to Ricardo he argues that the quality of different types of land is not independent of the historical state of development of techniques.

14. This subject was particularly developed in our paper, prepared in collaboration with D. DEYBE and C. VICIÉN, "Is Extensive Cereal Production Possible?", presented at the Seminar on Land Use and Management organized by the European Commission at Brussels, 8-9 March 1989.

15. There is a small difference that does not justify a separate presentation. All the techniques are presented in the Appendix.

16. See Note 14. D. DEYBE has already built an LP model of a representative farm of the Pergamino region, defining the production activities by means of EPIC. See DEYBE, D., "Politiques agricoles et érosion", Master Thesis, Institut Agronomique Méditerranéen de Montpellier, April 1989.

17. An exception is the American CARD model that is now using the same growth plant simulation model we use to create alternative techniques, but only for measuring erosion associated with different techniques.

18. See Note 6.

19. These models have some common features with models developed for two zones of the Argentinian Pampean Region. See FLICHMAN, G., "Alternativas Tecnológicas y Politica Agropecuaria. La Producción de Granos en la Region Pampeana", Proyecto de Cooperación para la Modernización del Sector Agropecuario Argentino, Secretaria de Agricultura, Ganadería y Pesca, Instituto Interamericano de Cooperación para la Agricultura, Buenos Aires, 1987. See also DEYBE, D., *Politiques agricoles et érosion des sols en Argentine ; une méthodologie pour leur analyse*, Master Thesis, Institut Agronomique Méditerranéen de Montpellier, April 1989.

20. An important new innovative feature of these models is the introduction of institutional constraints related to market interaction (credit policies, marketing institutions, land market structure). See ROTH, M., and ABBOT, P.C., "Evaluating Agricultural Price Policy under Dual Market Regimes and Institutional Constraints", submitted to the *Journal of Development Economics*, April 1989.

21. Relations between agricultural policies and soil erosion have already been studied, using a representative farm LP model with activities defined using EPIC (DEYBE, D., 1989).