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Building Agro-Environmental Indicators by the Integration of Biophysical and Economic models for Assessing Sustainability of Agricultural Trade Liberalisation

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BUILDING AGRO-ENVIRONMENTAL INDICATORS BY THE INTEGRATION OF BIOPHYSICAL AND ECONOMIC MODELS FOR ASSESSING SUSTAINABILITY OF AGRICULTURAL TRADE LIBERALISATION

Guillermo Flichman[1]

Introduction

In our days, it is increasingly relevant to introduce the environmental dimension in economic modelling. Making prospective analysis concerning impacts of changes in trade policies requires assessment about environmental effects of those changes. In this field, very important progress took place in the last decades, especially by the use of what is usually called "environmental indicators". Different type of models, in particular CGE models dealing with international trade make use of this type of indicators. In this paper, we deal with the specific problem of creating indicators concerning environmental and natural resources affected by agricultural activities in the context of trade liberalisation

In the first section, we develop a general view on environmental indicators and agriculture. In most cases these indicators are technical coefficients of emissions related to levels of production or consumption. For analysing agriculture environmental impacts, there are specific problems that have to be taken into account if we want to provide assessment about sustainability on a sound basis. Agriculture activities have very complex relations with the environment and the natural resources (or natural capital). In this section, some specific considerations will be developed about the differences and conflicts between spatial negative externalities (principally diffuse pollution) and temporal externalities, related with the deterioration of natural capital, what creates negative transfers to future generations (sustainability issue).

We develop in the second section some theoretical elements and empirical evidence of specific difficulties related with agricultural externalities, concerning the fact that these externalities have frequently discontinuous and non-convex relations with levels of production and/or inputs used. This characteristics make particularly difficult to apply some of the usual environmental policies used when externalities (industrial pollution i.e.) are related with production levels through linear or at least continuous, and monotone functions. This fact creates some complications concerning the type of indicators that can be really useful.

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In the third section, we present the type of information ideally required to produce indicators concerning agro-environmental impacts of policy changes. What type of information is needed and what tools are available for producing it; in other words, the *state of the art*. For this, we will make a synthetic description of the existing biophysical models that can be used to provide this information, as well as the particular problems of integrating that information in economic models.

The fourth section will deal with a specific proposal of what can be done in Europe in order to develop this field of applied research.

1 - Agricultural environmental indicators

The global relations between trade liberalisation, environment and agriculture have been frequently discussed. From a pure conceptual, theoretical point of view there is only one conclusion that seems solid: there is no possible generalisation about the environmental impacts of trade liberalisation. Even if the general impact is theoretically increasing income, it is not clear what will be the impact of this increase on environment. The existence of market failures concerning environmental goods avoids the existence of a general positive impact of liberalisation on environment and natural resources. All the literature on Trade and Environment shows contradictory examples, according to specific situations. That is why it is important to incorporate environmental indicators in trade liberalisation models.

In most cases these indicators are technical coefficients of pollution emissions related to levels of production or consumption. These indicators are usually presented as a matrix giving what amount a specific pollutant emission is produced per unit of production. There are different sources where economists modelling the impacts of changes in trade regulations can obtain these coefficients. They have been produced by national and international organisations for several countries. The World Bank and OECD provide an important amount of this type of information.

In some cases, modellers implement a desegregation of activities by type of technique, including two different sets of coefficients, one for the "conventional" technique and another one for the "environmentally friendly" technique. If there exist information about the different cost of these alternative techniques it becomes possible to analyse the trade-offs between the diminution of pollution levels and the increase of costs associated to it.

The improvements done in the last decade, concern essentially the consideration the relations between environmental quality of goods and demand and the differentiation of techniques from the supply side. The first point is related with what is called the "Kuznets function", that argues the existence of a non-monotony relation between the level of damage to environment and the level of revenue: in a first stage of growth, damages increase, but after some threshold (difficult to determinate) they diminish (Runge, 1998). But even if an important improvement in the way of dealing with the relations between trade and environment took place, there are some common features in the way agro-environmental indicators are produced and used that show important limitations. These limitations are related with the type of information that is used and the implicit assumptions concerning technology.

An indirect representation of technology (dual approach) through production costs, as is the case in almost all models dealing with trade, is not adequate to represent the complex relations between agriculture, environment and natural resources. A primal approach of technology, using

what is called "engineering production functions" (Chenery, 1949) appears as more adequate to deal with that complexity. We need to explicitly use the technical information concerning physical quantities of inputs and outputs, taking account the production of externalities as part of the output.

It is necessary to recall the fact that there are two problems inside the sustainability issue: One is related strictly within the field of conventional environmental economics, in other words, the existence of negative externalities related to economic activities. Most environmental indicators deal with this dimension of the problem, as long as they relate activity levels with pollution emissions. The other one deals with long term impacts of economic activities on the natural resources, as soil degradation (erosion, salinity, acidity) and depletion of water resources. Build indicators for this second type of problem is even more complex, because it is required to take into account impacts occurring in a long period of time. We will differentiate between these two problems.

1.1 - Agro-environmental indicators related with negative spatial externalities

This is typically the case of emissions related with agricultural production: different type of gases with "greenhouse effect", nitrate lixiviation in the water (rivers and aquifers), chemical pollution related with pesticide and herbicide applications.

The usual way of dealing with this issue is to use emission coefficients per unit of production. For example, one unit of wheat in a specific region of the world is associated with a certain amount of nitrates emission, etc. Two types of problems appear dealing with this approach. If there is a change in the market situation created by a trade liberalisation policy, let as assume an increase of prices, production will also increase. But one characteristic of agriculture production is that there is always one fixed production factor: land of a certain quality. In most cases, an increase in production implies a change in the techniques used, what means a change in the technical coefficients, including those concerning nitrate pollution. If in the situation before the increase in international prices the technique applied used a certain amount of fertiliser, associated with a quantity of nitrate emission, the increase on production - in the simpler case - will imply a more than proportional increase in the level of pollution. The technical coefficient of nitrate pollution, even in this extremely simple case, is not linear. And the parameters of the functions relating the increase of production to the increase of pollution are specific to one agricultural region. This means that when we apply the same coefficient of nitrate pollution for one ton of wheat, we are for sure making an enormous error.

A second problem is related with the fact that in agriculture there is usually a situation of multiple production. That means that in the same land, different crops are produced following a certain rotation. Changes in the combination of crops imply changes in the quality and quantity of inputs

used in a specific crop that takes part in the rotation (agricultural rotations frequently create scope economies).

One example can be the situation that may occur in some European Regions with the reform of the Common Agricultural Policy. If the system of subsidies changes and all crops receive the same level of support, distortions will be reduced and economic efficiency will increase. At a regional level, this means that the level of specialisation of agriculture will increase. Taking the specific example of South-West of France, the area used for oilseeds will be less and the area used for cereals will increase. The use of pesticides and herbicides is completely different according to the rotation system. This means that specialisation in cereals will increase economic efficiency but will also increase negative environmental externalities as a consequence of permanent cereal production. Monoculture needs a higher amount of pesticides and herbicides than a rotational scheme.

Considering the case of animal production, we find also very complex situations. Emission coefficients per unit of production do not correspond to reality. Pollutant emissions are different according to the type of techniques used. The feed component is essential to define these emissions. That is the reason why it is impossible to obtain good indicators if the technology is described only by the cost, without an explicit specification of the physical inputs used in production.

These considerations correspond to the simplest situation of negative spatial externalities. In the second section of this paper we will deal with more complicated situations, when the functions relating production and negative externalities are non monotone or even non convex.

1.2 - Agro-environmental indicators related with negative temporal externalities

In this sub-section we deal with problems related to the effect of agricultural production activities over time. The typical cases of these externalities are land degradation and resource depletion.

What type of indicator can be used for these cases? A physical indicator, measuring the level of deterioration of the resource seems to be an adequate choice. If this is the case, it may be possible to indicate directly the tons of land eroded, the cubic meters of water exhausted or the increase in the level of salinity of the soil. As it was the situation in the previous case, these indicators will not give a direct economic measure of the sustainability impact. For obtaining such a measure, it is necessary to make assumptions concerning technological change and use a dynamic inter-temporal model incorporating the change in the resources related with agricultural production and the impact of that change on future production.

The information required for building these indicators is even more difficult to obtain than the one needed for the indicators related to spatial negative externalities. In the former case, there exists some available information, even if its rapid use may deal to wrong results. In this case,

information is not only site specific, but it needs a specification related with a certain time horizon. We can see an example of this problem in the case of the impact of the amelioration of international cereal prices in Argentinean agriculture (Runge, 1998). The maize production in the pampas region was developed on rain fed conditions since the end of the nineteenth century. A dramatic increase of production took place in the last years, related with the amelioration of international prices that allowed the introduction of irrigation. Water comes from an aquifer that is not very well studied, but it is already verified that three sustainability problems are arising: the quality of the water of the aquifer is being deteriorated by salinity as well as by nitrates lixiviation. On the other side, erosion problems diminish, because the higher use of herbicides reduced tillage, but increased chemical pollution. Two negative consequences appear as well as a positive one. What simple indicator can be used to deal with this complex situation? It is clear that there is no single answer, but a wide field of research that needs interdisciplinary efforts. If we consider that the incorporation of irrigation was a consequence of change in trade conditions, what is for sure not the only reason, we can obtain not one, but several environmental and resource indicators that may be in contradiction.

Working with these problems requires specific tools. It seems extremely difficult to incorporate everything in a trade model. But it is possible to produce with a trade model the indicators that can provide information to be included in specific regional dynamic models designed to deal with long term economic effects of changes in resource use. We will develop the type of specific method that could be used for doing this in the last section of this paper.

2 - Agricultural externalities and environmental policies

The definition of environmental policies is based upon the assumptions that are developed in the theoretical approach of environmental economics. One basic assumption concerns the type of function that characterises the production of negative externalities. In almost all the literature on environmental economics, external costs are supposed to be continuous and monotonous functions.

In order to show the differences between the conventional approach and what can be found in reality concerning many agricultural externalities, we will develop briefly the classical example of a firm (A) localised near a river, where it rejects pollutants that create a cost to another firm (B) down the river (Bonnieux and Desaigues, 1998)

Firm A produces Y at P price using a unique production factor X (used as numeraire). Profit, for firm A is

$$\Pi = PY - X$$

and the private cost function is defined as

$$X = Y^2 \qquad (1)$$

In order to maximise private utility, we should obtain

$$PY - Y^2 \quad MAX \qquad (2)$$

The optimale private level of production is then

$$d\Pi/dY = \Pi_m = P - 2Y = 0 \qquad (3)$$

Π_m = marginal profit

Optimal private level of production is in this case,

$$Y^0 = P/2 \qquad (4)$$

Taking into account that we have pollutant emissions related with the production level, we define the pollution function as

$$L = aY^2 \qquad a > 0 \qquad (5)$$

Defining a as a technical parameter.

These emissions affect firm B with a unit cost C, total external cost is then

$EC = CL$ (6)

This external cost is a positive function that increases with the pollution level and with the level of production of firm A. This means that the marginal external cost increases for each unit of increase in production and tends to zero when production tends to zero.

In order to calculate the social optimum Π S, we have to introduce the external cost in the calculation.

$\Pi S = PY - X - EC$ (7)

Social maximum utility will be

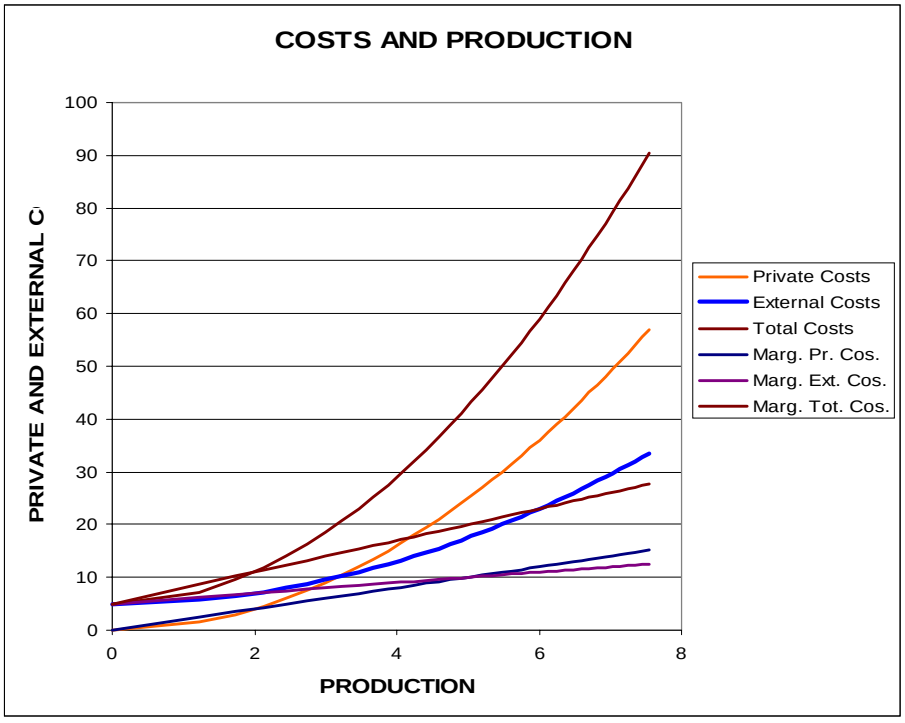
$PY - Y^2 - Ca\,Y^2 \quad MAX$ (8)

$d\Pi S/dY = \Pi S_m = P-2(1+aC)Y = 0$ (9)

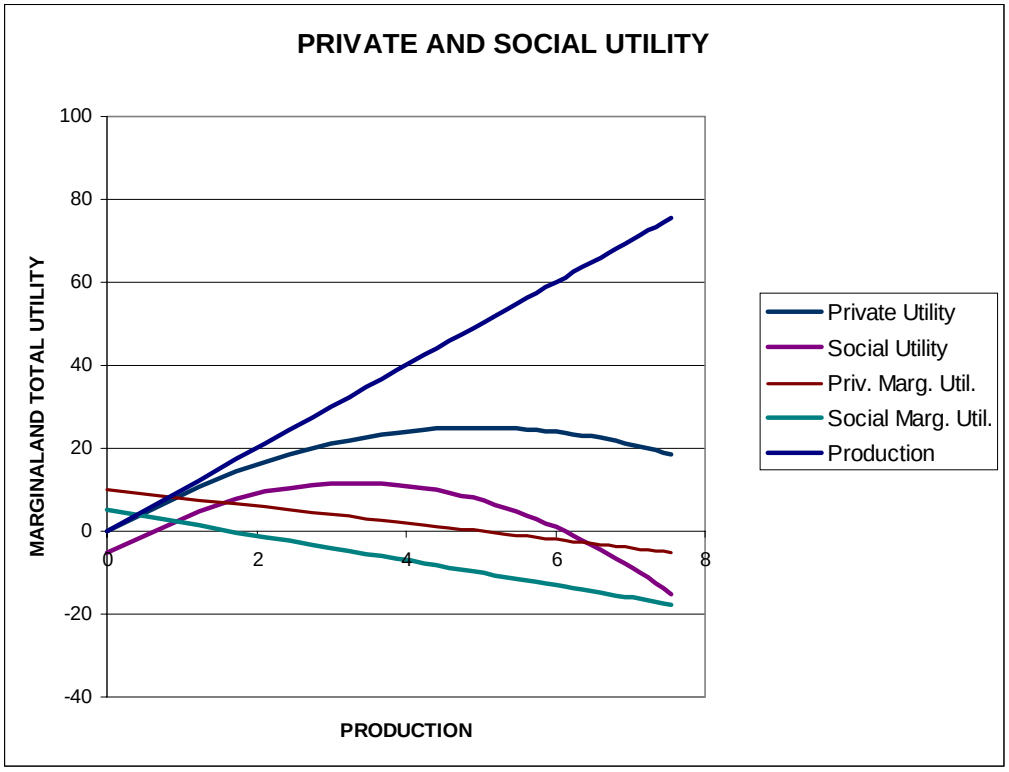
$Y^* = P/2(1+aC) < Y^0$ (10)

This example shows the type of externality function that is currently accepted: when we include the social cost to obtain the social utility, and we maximise this social utility, we always obtain an optimum that corresponds to a reduction of the production level.

Graph 1



Graph 2



This kind of example can be found in almost all text books on environmental economics and shows how standard approach of environmental economics considers how functions of externalities behave. Environmental economists have however considered the possibility of non convex cost functions of externalities, but only in the cases when the cost is so high that the production of the victim disappears, and so the marginal cost becomes zero (Starret, 1972, Boisson, 1970, Burrows, 1995 Hanley et al, 1995)

The different problem that appears concerning relations between agricultural production and negative externalities concerns the particular form that functions of **physical** externalities may have. It is a completely different thing. What we mean is that some externalities may increase with production up to a certain level and afterwards decrease. Or vice-versa, decrease first and increase afterwards. In some cases, a decrease can be followed by an increase and then a new decrease may appear. And all this is expressed in strictly physical terms.

Let us give some examples:

- **Nitrate Pollution.**

In this case, it may occur that increase in production originated by an increase in nitrogen fertilisation produces more pollution. But if at a certain moment irrigation is introduced, combined with nitrogen fertilisation, an increase in production and in the quantities of nitrogen applied may be associated to a decrease in the pollution levels. This is a strictly agronomic problem, related with the Von Liebig hypothesis (Paris, 1992, Chambers et al, 1996, Berck et al, 2000) concerning the very low substitutability of some agricultural inputs. If one applies more and more nitrogen, production per unit of land will increase up to a point when another input becomes the limiting factor. At a certain level of production, an increase in nitrogen fertilisation produces a very low increase in production and a high pollution. Applying water and more nitrogen, production will strongly increase, the plants will use the new nitrogen added and a part of the one that was lost as pollution using lower quantities of nitrogen. If we continue to apply more and more fertilizer and water, production will continue to increase and pollution will increase also. We are facing a non-convex function of the physical externality. In this case, we are dealing with the production of one good. If we consider a farm, a region or the whole agricultural sector as a production unit, there is always a mix of production, and this type of non convexities may arise even more easily (Flichman et al, 2002)

- **Soil erosion.**

A typical situation may appear in which within a certain range of increase of production, the level of soil erosion decreases, and after a certain threshold it begins to increase. This is the case of a typical wheat-fallow rotation. As the soil remains without vegetation one year out of two, the level of soil erosion is high. If we increase the production changing to a technique of permanent wheat, the level of erosion will decrease, because the soil is covered by vegetation all the years. But if we increase production by a more intensive tillage, erosion and production will increase. Further on, if there is more fertiliser incorporated associated with irrigation, production will increase again and erosion will decrease (Plevne, 1999, Louhichi, 2001).

We need to introduce these technical characteristics of agricultural production in order to explain that the problem of defining the functional form of the physical externalities is not capricious, but related with basic characteristics of agricultural production.

This question of the form of the function of agricultural externalities has important consequences in terms of policy implications and makes more difficult building agro-environmental indicators. We can see the problem with a simple example in which the function of the externality is a non-monotone one, as in the case in which pollution increases up to a certain level of production and then decreases.

Let us assume that the cost function is the same we used in the previous example, but the function of the externality is different,

$L = aY^2 + bY + c$ (11)

where:

$a < 0$

$b > 0$

$c > 0$

These emissions affect firm B with a unit cost C, total external cost is then

$CL = C(aY^2 + bY + c)$

In this case, this cost is a function that increases with the pollution level. But the relation with the production is more complicated. The external cost increases up to a certain level of production and afterwards it decreases. The marginal external cost decreases when production increases and after a certain point it has negative values.

In this case, social maximum utility will be

$PY - X - C(aY^2+bY+c)$ MAX (12)

$\Pi S_m = P - 2Y - 2aCY - bC = P - 2(1+ aC)Y - bC = 0$

$\Rightarrow \quad Y^* = (P-bC)/2(1+ aC) \quad \Rightarrow \quad Y^* - Y_0 = -C(b+Pa)$

We can deduce that the level of production maximizing social utility may be higher, lower or equal to the one maximizing private utility. The solution depends on the level of the price.

Case 1 : $P < -b/a \quad \Rightarrow \quad Y^* < Y_0$

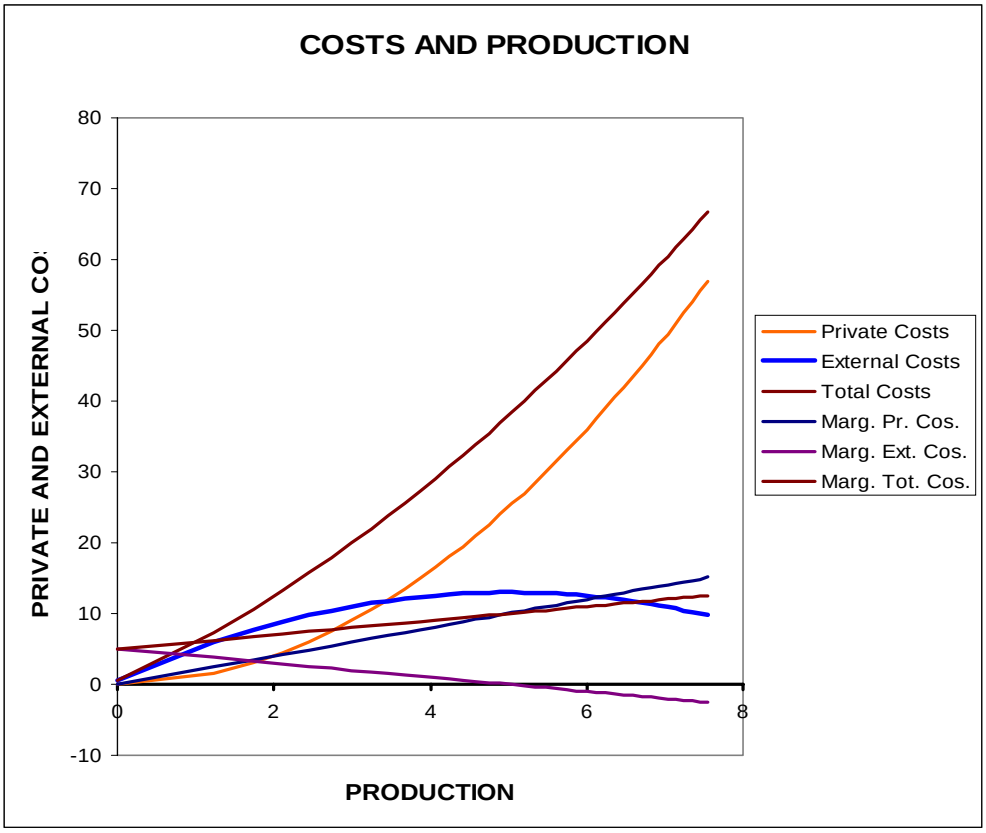
Case 2 : $P > -b/a \quad \Rightarrow \quad Y^* > Y_0$

Case 3 : $P = b/a \quad \Rightarrow \quad Y^* = Y_0$

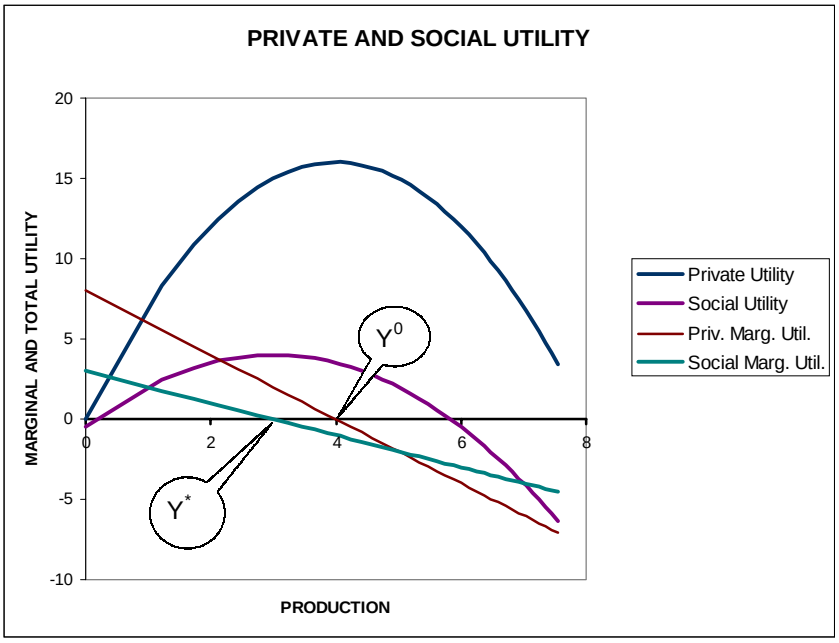
The policy implications of these results are relevant. In the first case, if we want to reduce the negative externality we should increase production and in the second case we should try to decrease it.

In Graphs 3, 4 and 5 this situation can be easily appreciated.

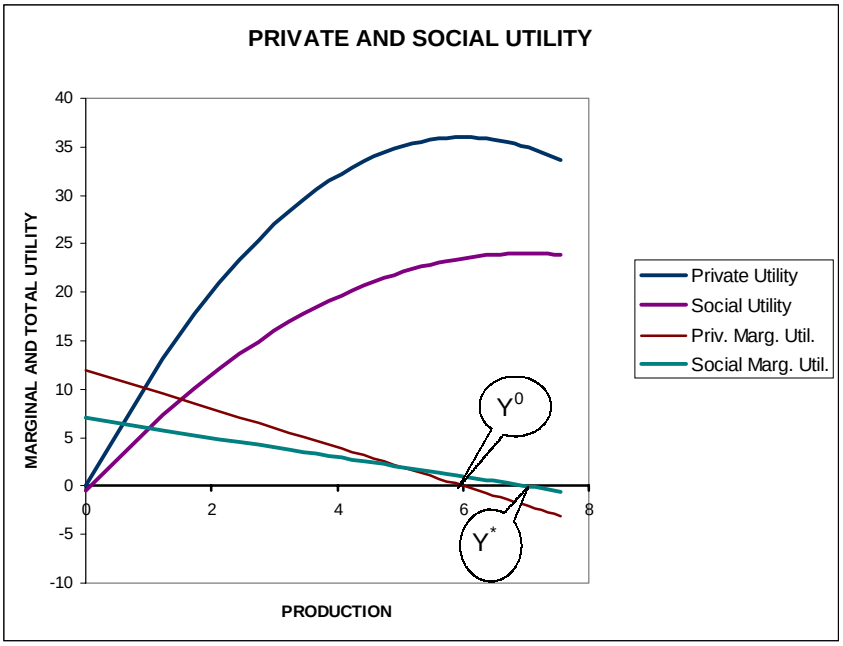
Graph 3



Graph 4 (case 1)



Graph 5 (case 2)



In Graph 3 it is possible to see the form of the external cost. This example is a stylised representation of empirical research work concerning the economic analysis soil of erosion in Turkey and in Tunisia (Plevne, 1999 and Louhichi, 2001).

Graph 4 shows the situation when the optimum social level of production is lower than the private optimum, and Graph 5 the opposite situation. It is clear that if we are in an initial situation as the one represented by Graph 4, a policy targeting a diminution of the externality should be oriented towards a lower production level. But in a situation as the one represented by Graph 5, it is exactly the opposite. In that case, if trade liberalisation implies an increase in prices, we could face a situation in which production growth can lower the negative externality. This is a particular result in specific conditions, not a general argument. In other cases it could be exactly the opposite (as in the case of irrigated corn in Argentina, mentioned before).

This example may be seen as just an amusing curiosity, but we believe it allows realising how complex are the links relating agriculture and environment. It is very clear that these links cannot be thoroughly represented through a straightforward relation between levels of production and levels of environmental damage. The question that appears immediately is: What kind of information is required to deal with this problem? What are the tools that are available? In other words what is the *state of the art*?

But that is the subject of the following section.

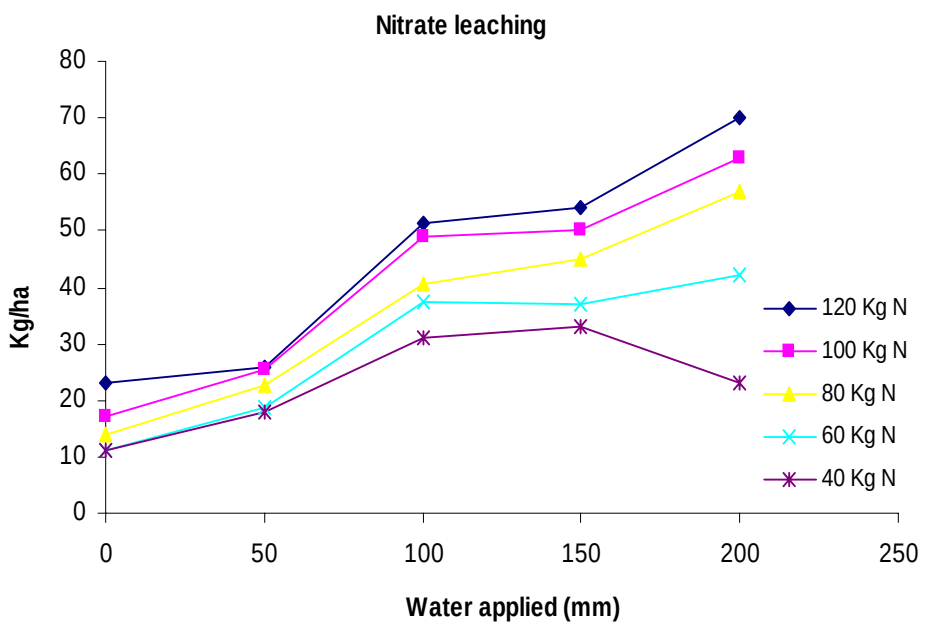
3 - Building physical agricultural production functions using bio-physical models

The information required to produce physical functions of agricultural externalities seems very difficult to obtain at a first view. But as we will see, with the tools available in our days it is not really as difficult as it seems to be.

The primal approach to the representation of technology needs an engineering production function approach. Bio-physical models can be considered by the economist as a very detailed engineering production function. They allow for the representation of the relationships between inputs and outputs, including externalities such as soil erosion, nitrate and chemical pollution, salinity, among the possible outputs.

In Graph 5 we show, just to give an example, the level of nitrate leaching corresponding to different amount of water and nitrogen applied. This example was obtained out of a simulation of wheat production in the Italian Puglia Region using CropSyst model.

Graph 5

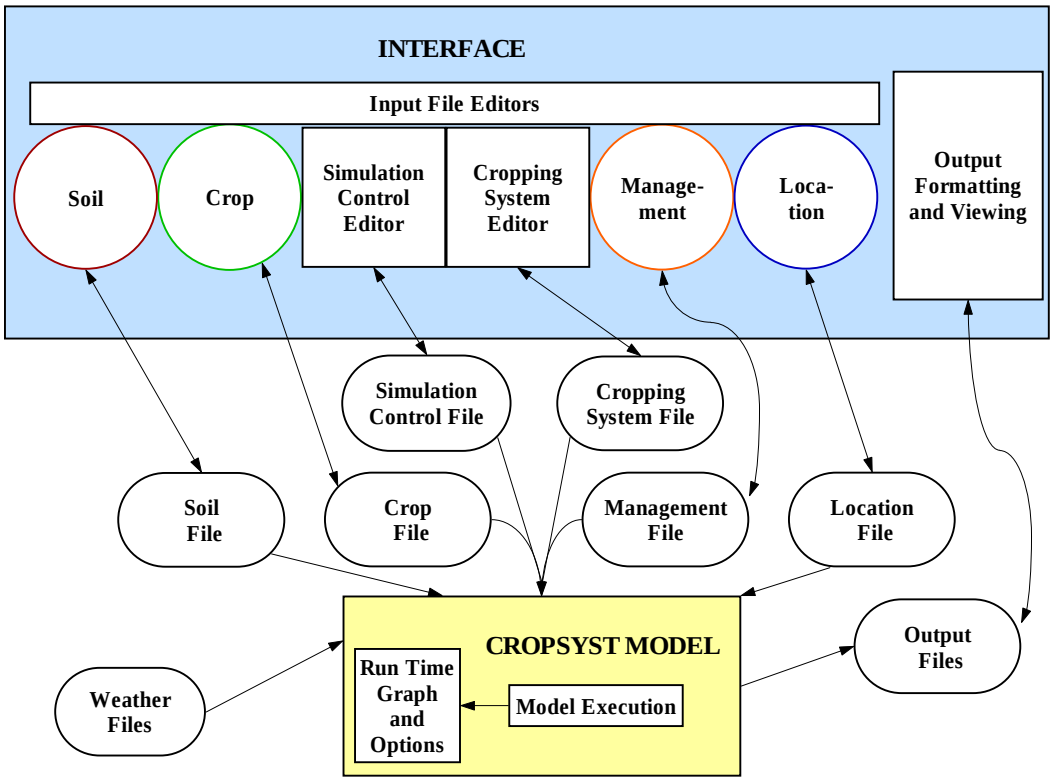


Agronomic bio-physical models began to be developed in the 70'. If we just consider pure biological phenomena, or input-output relations generated by nature, the engineering production

function is just the mathematical expression of those relations. That is the case for bio-chemical relations transforming energy in biomass, which are the basis of bio-physical models. But agronomic bio-physical models simulate not only that type of process, but also the effects of technical activities typical of agricultural activities: type of tillage, level of fertilisation, irrigation, etc. The whole modelling of the technical, biological and physical process, with their inter-relations allows the development of these types of bio-physical models. These models are partially mechanistic, partially empirical. The mechanistic component is dominant in the more complex models. This means that the relation between the quantity of fertiliser used and the yields obtained, is explained by a series of cause-effect mechanisms, where the soil, the climate, the characteristics of the plant and the variety are taken into account. It is far from being just a statistical regression out of experiments. The result is that these models are really a physical detailed production function. The exogenous parameters are essentially those of the soil, the climate and the characteristics of the plant. Of course, the management (periods of seeding, periods and level of fertilisation and irrigation, etc) are also part of the exogenous parameters. But the basic mechanisms that define the relation fertiliser-yield are the same in any part of the world.

The first models of this type have been developed to simulate the growth of a single crop in a certain environment. The family of models CERES (Jones et al, 1986) is the best known example. In the 80', a new category of models appears, allowing the simulation of crop rotations in a recursive way, incorporating the cumulative effects of agricultural activity on the soil conditions (erosion, fertility, water reserve in the soil, etc.) The most well known of these models are EPIC (Williams et al, 1984, Cabelguenne et al, 1986); CropSyst (Stockle et al, 1996) and recently STICS (Brisson et al, 1998)

The following scheme gives an idea of the structure of a bio-physical model. We take the example of CropSyst, but other models are structured in a similar way.



We can easily appreciate that the amount of data required for running these models is quite important: weather information (on daily basis), detailed soil data, crop parameters. But this information is usually available for any part of the world. The problem is the lack of homogeneous information. Even for the case of the European Union, it is extremely difficult to obtain these data at a NUTS 2 level for all the regions. Anyway, the administrative regionalisation is never representative of a soil-climate unit.

The integration of bio-physical and economic models for agricultural analysis began when the first agronomic bio-physical models where available. Before, what we can call the "first generation" of bio-economic models incorporated biological information (essentially related with population growth of fish and trees) in normative economic models, with the objective of optimising the use of a natural resource in time. These models use optimal control techniques to be solved and have a normative approach.

Some economists began to use these models as engineering production functions. The most usual technique applied to integrate the information provided by bio-physical models is to use the output of bio-physical models as input in mathematical programming models. This can be done as well as technical coefficients of linear activities or as functions that have to be previously estimated (Vicien C, 1990). These functions obtained out of simulated "data" are usually called "meta-models" (Bouzaher et al 1993).

The first research work integrating bio-physical and economic models began in the USA, with an important support from the Department of Agriculture. This work was related with the analysis of economic impacts of soil erosion on long term agricultural activities. The results of this research were helpful to obtain the approval of the soil conservation regulations. Later on, the focus was shifted to analyse diffuse pollution generated by agriculture (Mapp et al 1994, Bouzaher et al 1993 and 1995).

In Europe, the idea of integrating bio-physical and economic models was proposed by Flichman (1986) and the first application was a research on international comparisons of efficiency in agriculture (Flichman 1990). A big amount of research has been done in the last decade in this field in Europe and in other parts of the world. A bibliography on this specific field is incorporated as an appendix to this paper.

Most of the research work developed in this field in Europe is done at the farm level or at a regional level. In the United States, there exists at least one project developed at a national level (Atwood et al 2000). An Agricultural Sector Model for the USA is being coupled with the bio-physical model SWAT, in order to integrate issues as water pollution and erosion in the Sector Model.

The agricultural sector model in development for the European Union, CAPRI model and its continuation, CAP-STRAT[2] integrates some environmental indicators produced by rough bio-physical models. Indicators of different pollutant emissions (greenhouse effect gases, nitrate emissions) are estimated according not only to the level of the activities but also to the type of animal feed that is used. An indicator of water balances allows giving indications on the pressure on the resource in the regions where there are deficits as well as a weight to the nitrate emissions indicator. When we observe simultaneously surplus in nitrates and in water, the pollution risk is more important.

But there are important limitations due to the lack of basic homogeneous information on essential items such as soil and climate.

Integrating information from bio-physical models could substantially improve the quality of important environmental indicators related with agricultural production: nitrate pollution, chemical pollution, gases emissions, degradation of natural resources (soil, water), depletion of water resources, etc. But for the moment it is extremely difficult to go beyond regional case studies for using the most performing bio-physical models.

We can observe that there are two ways for assessing trade impacts on sustainability using bio-physical models:

([2]) http://www.agp.uni-bonn.de/agpo/rsrch/capstr/capstr_e.htm

- To produce indicators that can be directly included in trade models. In some cases, as we established in the previous section, these indicators should be more complex than just a matrix of data relating directly levels of activities to levels of emissions.
- To interact with bio-economic models at a regional scale integrating information obtained with the bio-physical models. These models should use as exogenous parameters the results of trade models. If a trade model produces certain results in terms of price modifications, a regional model can use these price results as information and simulate impacts on environment and natural resources.

These two ways of dealing with the problem should be considered as complementary. The first approach has the advantage of giving comparable information for all the regions considered in the trade model, but it has the disadvantage of using rather rough indicators. The second approach is better in terms of refined information, but it is impossible to use it for all regions in an acceptable manner.

4 - Some ideas on how to develop this type of research in Europe

We will start this section showing the difficulties of the exercise, in order to propose some actions. These difficulties are at least of three different types: data availability, aggregation level of analysis and disciplines/specialities involved.

4.1. Data availability

Basic information required for bio-physical modelling is not easily available at the EU level for all regions. Major projects on climate and soil information systems have been produced, but when the moment arrives to obtain the required information, even for a Research Project funded by the European Commission, the "institutionalized systemic" difficulties are sometimes hard to overcome. Use of agro-chemicals is a field on which information is almost inexistent at a regionalized EU level. And chemical pollution generated by agriculture is for sure a serious issue.

4.2. Aggregation level of analysis

The appropriate level for studying the environmental impacts of changes in agricultural activities is the farm or the regional level, defining the region by its soil-climate characteristics. Dealing with trade, the level of analysis corresponds to countries or groups of countries. This difference of scale creates difficult methodological problems that should be solved. Of course, if we are obliged to deal with administrative regions, the degree of precision of environmental assessment will decrease with the natural heterogeneity of the region and administrative accounting practices. Nevertheless, it may be useful to establish some rough indicators while being cautious by their inherent limitations. The only way to overcome this obstacle in a more rigorous way is to design in a coherent way regional case-studies that may allow an assessment of environmental impacts in specific situations. But this requires in terms of research organisation a unified framework.

4.3. Multidisciplinary approach

Using bio-physical models requires a well functioning cooperation with soil scientists, climatologists and agronomists. This type of cooperation is extremely difficult to establish and to maintain as institutional rigidities increase the difficulties. From an academic point of view, to cooperate with scientists of other disciplines usually does not pay off. Even from the point of view of research funding, the obstacles are quite important.

Available bio-physical models are not well adapted to be integrated with economic models. Some of them are too simple, as those elaborated by FAO for irrigations; others do not simulate the dynamic effects of rotations, being specific to one crop. The most complex, sometimes are very well designed for research in soil science, or hydrology, or plant physiology, but they are not

robust enough, what makes their application quite difficult. A good collaboration between economists and bio-physical modellers would ameliorate rapidly the capacity of bio-physical models to be integrated in economic analysis. The type of bio-physical model required by the economists is not the most advanced from the point of view of agronomic sciences. But for the members of the agronomic disciplines, to adapt a model following the requirement of economists has no advantage in academic terms. This problem will remain an obstacle without creating specific incentive to solve it.

4.4 - What can be done?

A possible action is to develop an institutional framework to help the development of this type of multi-disciplinary activity. This framework could be a Research Project specifically designed to involve the different type of specialists that are required: International Trade Economists, Agricultural Economists and Bio-Physical scientists.

The difficult aspect is that multidisciplinary research of this type should be "dominated" by the economic dimension in order to be really productive. Dominated in the sense that bio-physical modelling should be adapted to the requirement of the economic modelling. And this is a very difficult task to realise without a specific incentive to do it. If not, each scientist will gain remaining in his specific discipline. Experience in the past showed several times how scientific evaluations penalised those who contributed to this type of multidisciplinary research.

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BUILDING AGRO-ENVIRONMENTAL INDICATORS BY THE INTEGRATION OF BIOPHYSICAL AND ECONOMIC MODELS FOR ASSESSING SUSTAINABILITY OF AGRICULTURAL TRADE LIBERALISATION 1

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