

**Assessment of Environment Impact of CAP Reforms on European
Agricultural Production Efficiency**

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Amílcar Serrão *

Abstract

The studies of performance and production efficiency have ignored additional products of most transformation processes classified as undesirable outputs. Without the inclusion of the undesirable outputs, the efficiency measurement is a purely technical measure, and it does not account for the interaction of the system with the environment and the impact of policy decisions on the system. Moreover, there are technological dependencies between the desirable and the undesirable outputs which have to be included in the analytical tools used to measure efficiency.

The relationships between the desirable and the undesirable outputs motivate the exploration of new areas of the measurement of efficiency to incorporate policy decisions and address new issues. This research develops a formulation that uses goal programming in conjunction with Data Envelopment analysis – known as GoDEA approach – to deal with the conflict between the desirable and the undesirable outputs. This approach is used to assess the environment impact of the Agenda 2000 and the 2003 Common Agricultural Policy reform on agricultural production in fifteen European countries.

Model results show that the 2003 CAP reform strengthens environmental policies and has a better performance than the Agenda 2000 for some European countries. The North and Central European countries have been dealing better with environmental issues than the Mediterranean countries.

Key Words: Data Envelopment Analysis, Performance Measurement, Undesirable Outputs, Technological Dependence, Goal Programming, Common Agricultural Policy

JEL classification: CO2, DO1, Q15, Q58

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1 - Introduction

There are many research studies addressing the impact of environmental policies on measurement of agricultural production efficiency in European Union. Most of these research studies only consider inputs used by agricultural production and the desirable outputs as the result of input utilization. However, agricultural production consumes resources as inputs and produces desirable outputs (agricultural products) and undesirable outputs (emissions and wastes). Without the inclusion of the undesirable outputs, their approaches ignore real world considerations. The nature of undesirable outputs is different from that of the desirable outputs and they demand a different set of assumptions related to the production possibility set and the modeling of the production process.

Agriculture is a major source of greenhouse gas emissions and has contributed 14% of global emissions (FAO, 2009). When combined with related land used changes, including deforestation, this share becomes more than one-third of the total greenhouse gas emissions. Reducing and removing emissions from agriculture, while ensuring food security and enabling economic growth will need to form part of an urgent global effort to combat climate change.

The Kyoto Protocol was established in December 1997 to achieve the objective of the United Nations Framework Convention on Climate Change, which proposes the greenhouse gas emissions in atmosphere must be set at concentrations that do not affect life on Earth. The 2009 Copenhagen Accord suggests the necessity of deep cuts in global emissions according to science, and as documented by IPCC Fourth Assessment Report to reduce global emissions so as to hold the increase in global temperature below 2 degrees Celsius (United Nations, 2009).

The problem of this research study is the influence of the conflicts between the desirable outputs and the undesirable outputs for measuring agricultural production efficiency of the CAP reforms in EU15 countries. The Agenda 2000 and the 2003 CAP reform have been presenting environmental policies to deal with the conflicts between undesirable outputs and desirable outputs in European countries.

The Agenda 2000 insisted that farmers who received support should at least meet the standards of good farming practices. Farmers should be eligible for additional levels of support where they were contributing to environmental standards above the baseline of good practices. The 2003 CAP reform sought to promote agricultural resources and natural and cultural heritage of the countryside. The environmental aid scheme encouraged farmers to introduce or continue to use farming practices compatible with environmental practices and natural resources conservation.

The last two CAP reforms were critically important because they implemented environmental policies which contributed to reduce environmental pressures. These policies had an effect on agricultural production in European Union. A considerable number of measures or indicators for agricultural production efficiency have been suggested. Most of these measures have ignored additional products of agricultural practices that can be classified as the undesirable outputs. These outputs include environmental variables such as pollutants, greenhouse gas emissions, acidification, eutrophication and wastes. Without the inclusion of the undesirable outputs, efficiency evaluation becomes a purely technical measure of the agricultural production alone, and does not account for the interaction of the agricultural production with the surrounding environment and the impact of environmental policies on the agricultural production. The environmental policies could limit the amount of the undesirable (bad) output produced even to the detriment of the desirable (good) output maximization goals.

For addressing this problem of conflicting between the desirable outputs and the undesirable outputs, this research defines two objectives. The first objective is to explore a new approach for including the undesirable outputs in Data Envelopment Analysis. The second objective is to explore the goal programming approach to address the issue of multiple-objective problems relating to inputs, desirable outputs and undesirable outputs. The main goal of this research is to find a suitable direction of taking the modeling the world closer to the real world.

2 – Methods

Analytical tools normally used in efficiency evaluation is the traditional Data Envelopment Analysis approach developed by Charnes et al (1978), Banker et al (1984) and Coelli et al, (1998), Cooper et al (1999). The differences between the undesirable outputs and the desirable outputs need to be analyzed and understood well before they can be expressed by mathematical expressions (Thanassoulis and Dyson, 1992). This motivates the explanation of new areas of measurement of efficiency to evaluate the impact of environmental policies on agricultural production efficiency and address technological relationships. This research study presents an alternative to the traditional Data Envelopment Analysis approach to give a more realistic and comprehensive score of agricultural production efficiency considering both, the desirable and the undesirable outputs (Färe et al. 2000). This approach addresses technological dependency between the desirable and the undesirable outputs and the conflicts among agricultural production goals through an alternative model that uses Goal Programming in conjunction with Data Envelopment Analysis approach, a concept known as GoDEA approach presented by Thanassoulis and Dyson (1992), Athanassopoulos (1995), Sheth,

(1999) and Hoopes (2000). The goal programming model solves problems with different goals which are conflicting such as the desirable output and the undesirable output and input. The model minimizes the slacks associated with the inputs, desirable and undesirable outputs. The mathematical formulation is provided below.

$$\begin{aligned}
\min \quad Z = & \sum_{n=1}^N (w_n^{p+} s_n^{p+} + w_n^{p-} s_n^{p-}) + \sum_{r=1}^R (w_r^{q+} s_r^{q+} + w_r^{q-} s_r^{q-}) + \sum_{m=1}^M (w_m^{x+} s_m^{x+} + w_m^{x-} s_m^{x-}) \\
\text{s.t.} \quad & \\
& \sum_{j=1}^J \alpha_j p_{nj} + s_n^{p+} - s_n^{p-} = p_{nj_0} \quad \forall n = 1, 2, \dots, N \\
& \sum_{j=1}^J \alpha_j q_{rj} + s_r^{q+} - s_r^{q-} = q_{rj_0} \quad \forall r = 1, 2, \dots, R \\
& \sum_{j=1}^J \alpha_j x_{mj} + s_m^{x+} - s_m^{x-} = q_{mj_0} \quad \forall m = 1, 2, \dots, M \\
& s_n^{p+} - s_n^{p-} \geq 0 \quad \forall n \\
& s_r^{q+} - s_r^{q-} \geq 0 \quad \forall r \\
& s_m^{x+} - s_m^{x-} \geq 0 \quad \forall m \\
& \alpha_j \geq 0 \quad \forall j = 1, 2, \dots, J
\end{aligned} \tag{2.1}$$

Where:

- Z – objective function value;
- p – desirable outputs;
- q – undesirable outputs;
- x – inputs;
- s – positive and negative deviational variables; and,
- w – weights associated with the deviational variables.

The GoDEA model has a Goal programming structure because of the structure of the objective function, where the overall target is to minimize any inefficient associated with any of the variables (Pasupathy, 2002). When the positive and negative deviational variables associated with the inputs, the desirable and the undesirable outputs, the model gets to the frontier. The values of the weights associated with the positive and negative variables are determined by repeated solving of the model and by experience.

The formulation of this model includes technological dependencies and looks for insights for the desirable outputs and undesirable outputs. This formulation does not give efficiencies scores but determines the shortfalls and the excesses of the variables. All the inefficiency associated to the variables is captured in the slacks.

3 – Data and Information

The data set contains two inputs, one desirable output and one undesirable output for fifteen European countries. The inputs are capital stock (millions of Euros) and labor (thousands). The outputs are the desirable output (agricultural production in millions of Euros) and the undesirable output (CO₂ in millions of tons). The values of each variable for each EU15 country were collected for the 2002 year for the Agenda 2000 and for the 2006 year for the 2003 CAP reform from Agricultural Statistics – Main Results (European Union, 2003,2004, 2006 and 2007).

4 – Results & Discussion

The GoDEA approach was applied to the data set for the 2000 Agenda and the 2003 CAP reform. The formulation incorporates the desirable and the undesirable outputs using goal programming. The results are presented in the tables below for the Agenda 2000 and the 2003 CAP Reform.

The results of the Agenda 2000 are as follows:

| DMU | Output Shortfall | CO ₂ Excess | Capital Excess | Labor Excess |
|------------|------------------|------------------------|----------------|--------------|
| France | 50981 | 18.663 | 21371 | 0 |
| UK | 37135 | 14.646 | 17608 | 0 |
| Germany | 54312 | 15.674 | 0 | 0 |
| Italy | 15564 | 13.546 | 24786 | 0 |
| Spain | 12675 | 12.692 | 0 | 0 |
| Ireland | 5638 | 2.778 | 0 | 0 |
| Holland | 0 | 0 | 0 | 0 |
| Denmark | 0 | 0 | 0 | 0 |
| Greece | 14267 | 4.887 | 5821 | 0 |
| Belgium | 21531 | 3.065 | 0 | 0 |
| Portugal | 7541 | 2.346 | 3649 | 0 |
| Luxembourg | 0 | 0 | 0 | 0 |
| Austria | 24638 | 6.332 | 0 | 0 |
| Finland | 0 | 0 | 0 | 0 |
| Sweden | 0 | 0 | 0 | 0 |

Table 4.1 – Results – The Agenda 2000

Source: Model results

The results of GoDEA approach in the 2000 Agenda show that the slacks of the desirable output (agricultural production) are increased for 10 DMUs while the slacks for CO₂ (undesirable output) in this approach are zero for 5 DMUs. The analysis on the input side shows that the slack of the capital stock are increased for 5 DMUs, while the slacks for labor are zero for all of the DMUs. These results are a consequence of the GoDEA approach which captures all of the inefficiencies in the slacks. The greatest output shortfall is in Germany, while the greatest CO₂ excess occurs in France.

The results of the 2003 CAP reform are as follows:

| DMU | Output Shortfall | CO ₂ Excess | Capital Excess | Labor Excess |
|------------|------------------|------------------------|----------------|--------------|
| France | 45753 | 12.334 | 25341 | 0 |
| UK | 31865 | 10.346 | 18429 | 0 |
| Germany | 52794 | 11.391 | 5256 | 0 |
| Italy | 16476 | 14.887 | 25467 | 0 |
| Spain | 14039 | 13.483 | 1090 | 0 |
| Ireland | 1462 | 0.996 | 0 | 0 |
| Holland | 0 | 0 | 0 | 0 |
| Denmark | 0 | 0 | 0 | 0 |
| Greece | 16114 | 6.774 | 6022 | 0 |
| Belgium | 17433 | 2.5576 | 0 | 0 |
| Portugal | 8044 | 3.113 | 4008 | 0 |
| Luxembourg | 0 | 0 | 0 | 0 |
| Austria | 21366 | 5.0451 | 0 | 0 |
| Finland | 1047 | 0 | 945 | 0 |
| Sweden | 0 | 0 | 0 | 0 |

Table 4.2 – Results – The 2003 CAP reform
Source: Model results

The results of GoDEA approach in the 2003 CAP reform show that the slacks of the desirable output (agricultural production) are increased for 11 DMUs while the slacks for CO₂ (undesirable output) in this approach are zero for 5 DMUs. Germany has the greatest output shortfall and France continues to have the greatest CO₂ excess. These results showed that the environmental policy of the 2003 CAP reform had influence on the reduction of CO₂ emissions in some countries.

Model results show that the 2003 CAP reform strengthened environmental policies and had a better performance than the Agenda 2000 for some European countries. The North and Central European countries have been dealing better with environmental issues than the Mediterranean countries. The approach applied in this research has a strong influence in the results because of the structure of the objective function, where the overall target is to minimize any inefficiency associated with any of the variables.

5 – Conclusions

The problem of this research study is the influence of the conflicts between the desirable outputs and the undesirable outputs for measuring agricultural production efficiency of the CAP reforms in EU15 countries. The Agenda 2000 and the 2003 CAP reform have been presenting environmental policies to deal with the conflicts between undesirable outputs and desirable outputs in European countries.

The present research study has two objectives. The first objective is to explore a new approach for including undesirable outputs in Data Envelopment Analysis. The second objective is to explore the goal programming approach to address the issue of multiple-objective problems relating to the inputs, the desirable outputs and the undesirable outputs. The undesirable outputs are an anomaly which demand a different set of assumptions related to the production possibility set and the modeling of the production process. The goal programming approach is here applied to minimize the slacks associated with the inputs, desirable and undesirable outputs. This model is different from the rest of models developed because, unlike other models, this model looks for improving the performance by considering the inefficiency with respect to all the three different types of variables. The formulation used in this research does not provide efficiency scores but identifies the shortfalls and the excesses of the corresponding variables.

Model results show the 2003 CAP reform compared with the 2000 Agenda perform well for the North and Central European countries than the Mediterranean countries. The analysis of the slacks help us to make this comparison, being easier on the input side, where some of the slacks are very close.

The Gödel approach needs further research not only to find the best way to apply it but also ways to communicate its results to the decision maker.

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