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Carbon Management for the Agricultures in European Union

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Abstract: *This paper uses a nontraditional DEA approach to modeling carbon emissions from the agriculture in each one of European Union countries as an undesirable output. We proposed a zero sum gains DEA model with hybrid returns to scale to reallocate carbon emissions from the agriculture in each one of European Union countries using efficiency measures. Model results suggest that agriculture, which has already exceeded their limits, must reduce pollution or negotiate a quota with others. This reallocation strategy creates a carbon management,, without changing the total sum of carbon emissions from the agriculture in European Union countries.*

Keywords: *Zero Sum Gains DEA model, Hybrid returns to scale, Carbon management, Negotiation process*

1. Introduction

Human activities have altered the chemical composition of the atmosphere through the accumulation of greenhouse gases and have contributed to climate change that is one of the greatest challenges in our time. A long-term cooperative action among all countries is required to prevent that carbon dioxide, methane and nitrous oxide cause a climate change. The resulting climate changes may have profound impacts on biological and human activities that are sensitive to the climate (Nordhaus, 2008). Concentrations have more than doubled, and nitrous oxide concentrations have risen by 15% since the beginning of the industrial revolution (Gomes and Lins, 2008).

Agriculture is a source of emissions of greenhouse gases, accounting for 14% of global emissions (Smith et al. 2007, 2008; and, FAO, 2009). When combined with land use changes and deforestation, agriculture represents more than one third of total emissions of greenhouse gases. Reducing carbon emissions from agriculture to ensure food security and economic growth, will form part of an urgent and global effort to combat climate change (Brouer and McCarl, 2006; and, United Nations, 2009). Otherwise, climate change will cause shifts in the distribution of land areas and create problems for livestock sector.

The Kyoto Protocol was established in December 1997 in order to achieve the objective of the United Nations Framework Convention on Climate Change, which proposed the greenhouse gas emissions in the atmosphere to be set at concentrations that did not affect life on Earth. The 2009 Copenhagen Accord suggests the necessity for deep cuts in global emissions, according to the science and the IPCC Fourth Assessment Report to keep the increase in global temperature below 2ºC (United Nations, 2009; Meinshausen et al, 2009; Quiggin, 2010; and, Ramanathan and Xu, 2010). The trend of gradual decarbonization was reversed in 2010. This trend, instead of moving in the right direction, is now moving in the wrong direction. The goal of 2°C will require a reduction in carbon intensity of, at least, 4.8% per year until 2050. If we had started in 2000, the reduction would have been 2% per year in carbon intensity to achieve this goal.

The Durban conference in 2011 reinvigorated the idea of a "sustainable and green economy" that has a horizontal impact on society and affects various sectors, namely industry, agriculture, transports, buildings and consumers. The carbon emissions must be reduced so that the overall increases of temperature are limited to less than 2°C (and up to 1.5°C increase is considered).

These objectives will be accomplished, if the governments accept the decisions taken at COP17 in Durban, to have a second commitment period of Kyoto Protocol from January 2013 and to adopt a universal agreement on the climate changes law no later than 2015 which has to be implemented from

2020 (IISD, 2011).The new agreement will bring all countries under the same legal regime enforcing commitments to control green house gases, so far, under the1997Kyoto Protocol, only industrialized countries have legally binding mission targets. This means that all countries have started to look at the "big picture" and that the process for a new model has already started, going further than a climate change "just."

The problem of this study is the lack of a fair reallocation strategy of carbon emissions from the agriculture in each one of European Union countries, which contributes to achieve the rates of decarbonisation required to stay within 2°C target agreed by governments in the 2011 Durban conference. The aim of this study is to evaluate the performance of agriculture in each one of European Union countries in the presence of carbon emissions such as undesirable outputs and to develop a reallocation strategy on their carbon emissions using efficiency measurements that might create a carbon quota trade. This study develops a zero sum gains DEA model (ZSGDEA model) with hybrid returns to scale (Macedo, 2005; and, Macedo, Soares de Mello and Gomes, 2010) to reallocate carbon emissions from the agriculture in European Union countries.

The reallocation strategy, using efficiency measures, determines the agriculture in each one of European Union countries that can yield pollution or can trade carbon quotas with other countries, while those that have already exceeded their limits must reduce pollution or negotiate a carbon quota with others, which would require a carbon quota trade among themselves, without changing the total sum of carbon emissions from the agriculture in European Union countries.

This paper is organized as follows. Section 2 presents the methodology. The first part of this section describes approaches to modeling undesirable outputs in a DEA context. The second part of this section presents a ZSGDEA model with hybrid returns to scale, which treats the returns to scale differently along the efficient frontier. Section 3 presents the data collected for this study. Section 4 discusses model results. Finally, section 5 concludes.

2. METHODOLOGY

The performance of agriculture in each one of European Union countries in the presence of carbon emissions, such as undesirable outputs, is studied in this paper. The undesirable output is an undesirable result of a productive process, whose production must be minimized (Gomes and Lins, 2008). A nontraditional DEA model is also developed for modeling undesirable outputs.

2.1. Modeling Undesirable Outputs in a DEA Approach

The advantages and disadvantages of the three main approaches for modeling undesirable outputs in a DEA context were discussed by Dyckhoff and Allen in 2001. The first approach uses the reciprocal of the output producing undesirable as DEA output, in which the undesired production is modeled as being desirable. This approach is applied by Lovell, Pastor and Turner (1995) and called “reciprocal multiplicative” (Golany and Roll, 1989; Scheel, 2001; and Gomes and Lins, 2008). The second approach considers DEA model as a multi criteria, in which an undesirable output is modeled in DEA approach as input (Rheinhard, Lovell and Thijssen, 1999). This approach considers undesirable outputs as inputs which require to create the same production possibility set as if it is considered the undesirable output as desirable by using a reciprocal additive transformation (Scheel, 2001). The last approach is based on values translation by adding to the reciprocal additive transformation of the undesirable output *i* a positive scalar, big enough, so that the final values are positive for each one of the Decision Making Units (DMUs) (Ali and Seiford, 1990; and, Gomes and Lins, 2008). This is only valid for BCC model (Banker, Charnes and Cooper, 1984) and additive DEA models (Charnes et al, 1985), since CCR model (Charnes, Coopers and Rhodes, 1978) is not translation invariant (Cooper, Seiford and Tone, 2000). This approach must only be used when the decision maker is sure about the relations between undesirable outputs and other inputs and outputs (Dyckhoff and Allen, 2001).

DEA models consider that the undesirable outputs can be reduced in an independent manner, without integration or cooperation among the production units. This study uses an alternative approach to modeling undesirable outputs, based on the zero sum gains DEA models, which consider the production dependence among the DMUs (Gomes, 2003; Gomes, Soares de Mello and Lins, 2003, 2005; Lins et al, 2003; and, Gomes and Lins, 2008). The ZSG DEA model represents a situation similar to a zero sum game (Osborne and Rubinstein, 1999), where all that was gained (lost) by one of the players must be lost (gained) by others, in which the net gains sum must be equal to zero. In opposition to the traditional DEA models, the way one DMU reaches its target in the efficient frontier implies changing the frontier through the use of strategies in DEA targets searching in a smoothed frontier (Gomes and Lins, 2008). Gomes (2003) proposes strategies in DEA targets searching, with emphasis on the proportional reduction strategy. According to this strategy, the inefficient DMU searching for efficiency has to lose some quantity of input (or alternatively gain some quantity of output). In order to keep the total sum constant, other DMUs must gain the amount of input (lose the quantity of output) proportionally to their original values of the input (output) (Gomes and Lins, 2008).

The traditional DEA models (CCR, BCC and their variants) determine the set of DMUs that compose the efficient frontier, as well as the set of DMUs that it is outside of the efficient frontier, and they can determine the strategies that the inefficient DMU uses to reach the frontier and, finally, to become efficient. When limitless resources exist, the traditional DEA models seem to take care of them well beyond the expectations. However, there is a set of situations of decisions making in which limitation of resources exists. In this case, there exists a reallocation of resources that determine the DMU can reach the efficient frontier. For the case of limited resources, a ZSG DEA model is used because the total sum of gains and losses of all DMUs when reaching the efficient frontier must be zero (Gomes and Lins, 2008). This approach is an alternative to handle undesirable outputs, which can be seen in works by Färe, Pastor and Turner (1989, 2000), Yaisawarng and Klein (1994), Färe and Grosskp of (1995, 2003, 2004), Lovell, Pastor and Turner (1995), Thanassoulis (1995), Tyteca (1996), Rheinhard, Lovell and Thijssen (1999, 2000), Dyckhoff and Allen (2001), Hailu and Veeman (2001), Scheel (2001), Zofio and Prieto (2001), Kumar and Khanna (2002), Korhonnen and Luptacik (2003), Murtough et al (2002), Seiford and Zhu (2002), Sun (2002), Gomes (2003), and Gomes and Lins (2008), since the ZSG DEA model assumes that the DMUs can become efficient, guaranteeing that the total reallocation of the output (input) with constant sum.

The ZSG DEA models include an additional restriction to the traditional DEA models, which make the sum of net gain equal to zero. In contrast with the traditional DEA models, the way as a DMU reaches its target at the frontier may cause a change in the shape of the efficient frontier. We can find a variety of strategies to in efficient DMU to get its target. In search for targets, the proportional reduction strategy stands out (Gomes, 2003). In this case, the DMU that seeks efficiency needs to lose some units of input (orgain some units of output). The sum remains constant only if the gain (or loss in case of output) of other DMUs is proportional to their levels of input (output). The DMUs, which have lower levels of input (output), gain (lose) less and those units that have the highest level of input (output) gain (lose) more.

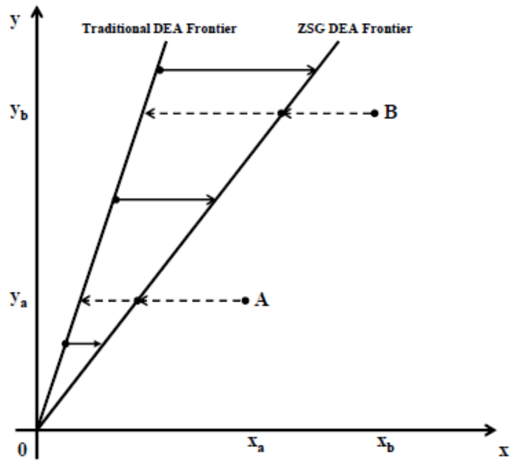

Figure1. *Search for efficiency applying ZSG DEA model*

Notes: Figure adapted from Gomes and Lins (2008)

y – output; x – input; and, A and B - DMUs

The possibility of more than one DMU to maximize efficiency can be made in competition or cooperation. The most interesting case is when the DMUs form a cooperative group. The search in cooperation means that the DMUs seek to allocate a quantity of input (or to withdraw a quantity of output) only to DMUs which do not belong to the group. When several DMUs cooperate, the ZSG DEA model is a multi objective nonlinear programming problem (Gomes, 2003). This problem leads to the use of metaheuristics due to the number of variables and DMUs. The Proportionality Theorem of the Efficiencies in Proportional Strategy proves that the model can be reduced to a nonlinear programming model (Gomes, 2003). This theorem states that in many DMU sin cooperation and, in the search for targets with proportional strategy, the efficiencies of DMU sin ZSG DEA model are directly proportional to their efficiency in the traditional DEA model.

When all in efficient DMUs form a cooperation group and seek efficiencies in traditional DEA efficiency frontier, the application of ZSGDEA model makes the total reallocation of the variables which occurs with constant sum. After this reallocation, all DMUs belong to the efficient frontier, that is, all DMUs will be100% efficient. This new frontier of the ZGS DEA model is called uniform frontier or maximum efficiency and is located below the frontier of the traditional DEA model since the efficient DMUs gain input units (or lose out put units) to compensate for loss (orgain) of the in efficient units to maintain the constant sum (Fonseca et al, 2010).The DMUs A and B belong to the “cooperation group” (Fig.1). These units try to take input amounts only from the DMUs that are not in the “cooperation group”. This maximum efficiency case might be seen as "ideal" for regulators since it will be presented to the decision maker a distribution of inputs (or outputs) that make with that all units are100% efficient. For the construction of uniform frontier directly in which the inefficient DMUs form a cooperation group X, Gomes (2003) proved that the Determination Theorem of the Target establishes that the target of the DMU under consideration by the ZSG DEA model of proportional strategy is equal to the target in the traditional case multiplied by the reduction coefficient (Gomes2003, p.28). This theorem, together with the Proportionality Theorem of Efficiencies in Proportional Strategy, reduces the solution for a nonlinear programming problem with a single equation. Thus, the DEA CCR and BCC models have the equation (1), where h_{Ri} and h_i are the efficiencies in the ZSG DEA and the traditional DEA models; X is the group of DMUs in cooperation; and, $r_{ij}=h_{i\text{-}I}/h_{j\text{-}I}$ is the proportionality factor resulting from the use of proportional strategy in input oriented. Equation (2) is only valid for output oriented model and $q_{ij}= hi_{\text{-}O}/h_{j\text{-}O}$ is the proportionality factor.

$$h_{Ri} = h_i\left(1 + \frac{\sum_{j\in X}\left[x_{j(1 - r_{ij}h_{Ri})}\right]}{\sum_{j\notin X} x_j}\right) \quad (1)$$

$$h_{Ri} = h_i\left(1 - \frac{\sum_{j\epsilon X}\left[y_j\left(q_{ij}h_{Ri} - 1\right)\right]}{\sum_{j\notin X} y_j}\right) \quad (2)$$

There are references to other models that use the constant sum constraint on DEA models. We highlight some of these works. Avellar, Millioni and Rabello (2005, 2007) and Avellar (2010) propose the DEA CCR models based on limited inputs and outputs where the distribution of resources /products may be influenced by both the inputs and the outputs involved. These models can be substituted by a hyperbolic, ellipsoidal, or spherical frontier. Their development is based on the geometric profile of the three-dimensional CCR frontier. These models postulate a function type for the frontier, unlike the traditional DEA model. Guedes (2007) calls this type of model "parametric DEA." Lozano & Villa (2004) propose a DEA BCC model in two phases, called constant sum of outputs (CSO). The first phase of this model solves the traditional DEA BCC model. The second phase calculates the radial contraction of outputs, the targets of constant sum and the targets of non constant sum.

2.2. The ZSG DEA Model with Hybrid Returns to Scale

This study uses an approach called ZSGDEA model with hybrid returns to scale. This approach has a configuration with respect to hybrids returns to scale which treats these returns differently in different parts of the efficient frontier (Macedo, 2005; and, Macedo, Soares de Mello & Gomes, 2010). These models with hybrid returns to scale have two operating regions: increasing returns-constant returns (VRS-CRS) or constant returns-decreasing returns (CRS-VCR). The VRS-CRS model will be used when you want to give increasing returns to scale to small values of input and proportional to large values. The CRS-VRS model corresponds to constant returns to scale for small values, and decreasing returns to scale for large values (Macedo, 2005; and, Macedo; Soares de Mello and Gomes, 2010).These models are particular cases of the traditional DEA CCR and BCC models. The difference between the models is in the convexity constraint. This constraint is absent in the DEA CCR model and, it is equal to $\sum_j \lambda_j = 1$ in the DEA BCC model. However, the convexity constraint is written as $\sum_j \lambda_j \geq 1$ for the DEA model with hybrid increasing returns of scale and, $\sum_j \lambda_j \leq 1$ for the DEA model with hybrid decreasing returns of scale (Cooper et al, 2000; Macedo, 2005; and, Macedo, Soares de Mello and Gomes, 2010).

The models with hybrid increasing returns to scale and hybrid decreasing returns to scale are specific cases of the traditional DEA models and, they also are particular cases of the ZSG DEA CCR and BCC models (Macedo, 2005). Thus, the theorems for the DEA CCR and BCC models remain valid for the DEA model with hybrid returns to scale. As a result, equations (1) and (2) are valid for the ZSG DEA models with hybrid returns of scale, with efficiency measures calculated according to the chosen models. After the reallocation, all the DMUs will belong to the efficient frontier, that is, all DMUs will be 100% efficient (Gomes and Lins, 2008). This study uses a ZSG DEA model with hybrid returns to scale because it assumes a different behavior in the various regions of operation (Macedo, 2005). It can behave initially as constant returns to scale (CRS) and for high values, as variable returns to scale (VRS), in harmony with the idea that agricultures with larger area are privileged and agricultures, which concentrate in small extensions their carbon emissions, are penalized.

In this context, we use this approach in two steps. The first step uses traditional DEA BCC models to calculate efficiency measures under constant returns to scale, and increasing returns to scale which allow to identify the hybrid returns to scale for each agriculture in European Union countries. The hybrid returns to scale show in which region each agriculture is operating. All efficiency measures are calculated based on agricultural characteristics of European Union countries. The second step uses a ZSG DEA model with hybrid returns to scale to calculate the reallocations of carbon emissions, without changing the total sum of carbon emissions from the agriculture in European Union countries.

The formulation (3) represents a ZSG DEA BCC model with hybrid returns to scale for CRS-VRS case and output oriented, from the case that just one DMU searches for the efficient frontier in which the output sum is constant (Macedo, 2005; and, Macedo, Soares de Mello and Gomes, 2010). The ZSG DEA BCC model with hybrid returns to scale for CRS-VRS case and output-oriented is as follows:

$$
\begin{aligned}
&Max \quad h_{Ro} \quad \text{Subject to} \\
&\sum_j \lambda_j \, x_j \leq x_0 \\
&h_{Ro} y_o \leq \sum_j \lambda_j x_j \left(1 - \frac{y_o (h_{Ro} - 1)}{\sum_{j \neq 0} y_j}\right) \qquad (3) \\
&\sum_j \lambda_j \leq 1 \\
&\lambda_j \geq 0 \quad , \forall_j
\end{aligned}
$$

Where h_{Ro} is the DMU_o efficiency under the restriction that the output sum must be constant; x_j and y_j are the original values of inputs and outputs, respectively; x_o and y_o are the inputs and outputs for the DMU_o; and, λ_j are DMU contributions to the efficient projections. This formulation includes the convexity restriction $\sum_j \lambda_j \leq 1$ for the ZSG DEA BCC model with hybrid returns to scale under CRS-VRS case and output oriented.

The model (3) represents the case in which a single DMU aims at the DEA uniform frontier or maximum efficiency frontier. There is the possibility that more than one DMU will search, at the same time, for the purpose of maximizing their efficiency, which can be made in competition or in cooperation. This study deals only with the cooperative case. This means all inefficient DMUs comprise a cooperation group and search for efficiency in the traditional DEA efficient frontier, the ZSG-DEA model with hybrid returns to scale will promote the total reallocation of the input (output) with constant sum of an input (output) (Macedo, Soares de Melo and Gomes, 2010).

The choice of the model is important to determine the efficiency of agriculture in each one of European Union countries. The DEA BCC model, theoretically more appropriate due to differences in scale among the agricultures, presents a serious distortion to make an effective agriculture that has the greatest value in any of the outputs, without taking into account the inputs (Macedo, Soares de Mello and Gomes, 2010). The DEA CCR model presents an inverse problem. It is extremely strict with the agricultures with small values of the variables. We chose a DEA model with hybrid variable returns to small DMUs and constant returns to large DMUs (Macedo, Soares de Mello and Gomes, 2010). This model eliminates the two problems mentioned above: it gives a chance for small agricultures to increase their carbon emissions and it does not allow that this situation occurs for big polluter agricultures.

The efficiency measures under hybrid returns to scale calculated by the DEA CCR and BCC models are now used to reallocate carbon emissions of agriculture of each one of European Union countries through a ZSG DEA model with hybrid non decreasing returns to scale. We adopted the proportional reduction strategy, with all inefficient agriculture of each one of European Union countries forming a cooperation group. This approach allows that the most efficient agriculture in each one of European Union countries could pollute more, and the inefficient agricultures have to be deprived to pollute without changing the total sum of carbon emissions. There is not software to use the DEA model with hybrid returns to scale. This approach is applied in two steps. In the first step, we run linear programming problems corresponding to the DEA CCR and BCC model for each DMU using the GAMS program to determine the efficiency measures under hybrid returns to scale. In the second step, we apply the proportionality regarding the ZSG DEA model with hybrid non decreasing returns to scale by inserting the corresponding equation into the GAMS program.

3. Data and Information

The choice of variables in DEA models must be done carefully because it determines what the model will measure (Macedo, Soares de Mello and Gomes, 2010). It is important to avoid the inclusion of some variables since they can cause in efficient DMUs reach the efficiency frontier due to these variables. In traditional DEA models, the inclusion of variables does not reduce the efficiency of any DMU, but they can increase the efficiency value of some DMUs. We must have the same care in choosing the variables in the ZGS DEA models.

Agricultural production not only uses environmental resources as inputs, but also puts pressure on the environment by emitting pollutants such as greenhouse gas emissions and, therefore, contributes to climate changes. The relationship between inputs and outputs is a key issue if the objective is to obtain a fair allocation of the carbon emissions (undesirable output) of agriculture in each one of European Union countries. Gomes and Lins (2008) consider that there exists a fair allocation of carbon emission when all DMUs become 100% DEA efficient that is, all of them lie on the uniform frontier.

The introduction of carbon emissions as undesirable output and other variables in the DEA approaches has been studied by various authors. Raman a than (2002, 2005, 2006) uses DEA approaches to study the relationship between gross domestic product, energy consumption and carbon emissions. Gomes (2003) and Gomes & Lins (2008) use the population, energy consumption and gross domestic product as output and carbon emissions output as undesirable output. However, there are several ways of modeling undesirable outputs (Scheel, 2001, Gomes (2003), Macedo, 2005; Macedo, Soares de Mello and Gomes, 2010). These authors modeled the carbon emissions as an input because they understood that the amount of carbon emissions should be minimized.

The variables used in this study are the livestock production (in LSU - livestock units in units), the utilized agricultural area (in hectares) and the greenhouse gas emissions (in tons of equivalent carbon and referred in this paper as carbon emissions) from agriculture in each one of European Union countries (Table 1). All European Union countries belong to Annex I of Kyoto Protocol. The livestock production includes various categories of livestock. The utilized agricultural area is the total arable land, permanent grassland and land used for permanent crops, excluding unutilized land, woodland and land occupied by buildings, farmyard, tracks and ponds, etc. This variable was included to inhibit the chimney effect that is, the effect of pollution concentration in a small land area of a country. The agricultural main source of greenhouse gas emissions is the enteric fermentation in ruminant animals (cattle, sheep and goats) that accounts for 72% of methane (CH_4) emissions from agriculture; soil denitrification that produces 88% of nitrous oxide (N_2O) emissions from agriculture; and, manure decomposition that is responsible for 27% of CH_4 and 12% of N_2O emissions from agriculture. Since these different green house gas emissions have different global warming potential, the data are expressed in terms of carbon-equivalent in order to make them comparable. The values of each variable for each agriculture in European Union countries were collected for the 2007 year from Agricultural Statistics – Main Results (European Union, 2009).

Table1. *Input and Output Data*

	Livestock Production	Utilized Agricultural Area	CO_2
Belgium*	3.788	1.374	9.719
Bulgaria*	1.246	3.051	4.996
Czech*	2.053	3.518	8.117
Denmark*	4.582	2.663	9.759
Germany*	17.985	16.932	63.763
Estonia*	0.313	0.907	1.350
Ireland*	5.918	4.139	17.744
Greece*	2.626	4.076	9.576
Spain*	14.381	24.893	42.347
France*	22.544	27.477	95.742
Italy*	9.901	12.744	37.222
Cyprus*	0.247	0.146	0.761
Latvia*	0.488	1.774	2.132
Lithuania*	1.031	2.649	5.225
Luxembourg*	0.161	0.131	0.656
Hungary*	2.409	4.229	8.906
Malta*	0.050	0.010	0.088
The Netherlands*	6.415	1.914	18.255
Austria*	2.473	3.189	7.497
Poland*	11.118	15.477	37.127
Portugal*	2.030	3.473	7.945
Romania*	6.042	13.754	19.701
Slovenia*	0.554	0.489	2.092
Slovakia*	0.747	1.937	3.233
Finland*	1.152	2.292	5.722
Sweden*	1.785	3.118	8.549
United Kingdom*	13.944	16.130	44.069

Notes: ** Countries belong to Annex I of the Kyoto Protocol*

Livestock production in Millions of LSU (livestock units); and,

Utilized agricultural area in Millions of hectares;

CO_2 – Millions of Tons ($Tons^3$) CO_2– equivalent

This study considers the livestock production and the utilized agricultural area modeled as output variables and the carbon emission variable as an undesirable output modeled here as an input variable. We assume that the maximum carbon emissions concentration is the sum of the 2007 carbon emissions from the agriculture of each one of European Union countries.

The DEA modeling requires a choice with respect to orientation and returns to scale (Gomes and Lins, 2008). The DEA BCC model is appropriate due to the wide disparities of each agriculture. Thus, agriculture that produces more livestock and has a large agricultural area and a high pollution to be efficient would have the right to emit more carbon, which makes no sense. The DEA CCR model is an inverse problem. This model is accurate with the agricultures in which the value of their variables is low. These agricultures would bevery inefficient, should require to reduce their carbon emissions and should limit their development. This research uses a DEA model with hybrid non decreasing returns to scale that behaves with variable returns to the small DMUs, and constant returns to the large DMUs. This approach eliminates the problems of the DEA CCR and BCC models because it allows the small agricultures to increase their carbon emissions and it does not allow this to happen to the big polluting agricultures.

4. Results and Discussion

Applying the DEA approaches, we get the results presented in table 2. This table shows the CRS, VRS and hybrid efficiencies. The last column of table 2 shows how the hybrid efficiency behaves in relation to variable returns of scale (VRS) or constant returns of scale (CRS) and where each one of DMUs is operating.

Model results show that the agricultures in Latvia, Malta and Romania are efficient in the traditional DEA approaches (Table 2). Latvia and Malta are 100% efficient due to low levels of livestock production and agricultural area, while Romania is 100% efficient because of a large agricultural area in comparison with the levels of carbon emissions.

Table2. *DEA CRS and VRS Efficiencies and DEA Hybrid Efficiency*

	CRS Efficiency	VRS Efficiency	Hybrid Efficiency	Prevailing
Belgium	0.732	0.830	0.732	CRS
Bulgaria	0.848	0.849	0.849	VRS
Czech	0.722	0.729	0.722	CRS
Denmark	0.956	1.000	0.956	CRS
Germany	0.648	1.000	0.648	CRS
Estonia	0.873	0.878	0.878	VRS
Ireland	0.707	0.800	0.707	CRS
Greece	0.751	0.761	0.751	CRS
Spain	0.973	1.000	0.973	CRS
France	0.588	1.000	0.588	CRS
Italy	0.677	0.737	0.677	CRS
Cyprus	0.663	0.686	0.663	CRS
Latvia	1.000	1.000	1.000	CRS
Lithuania	0.691	0.691	0.691	VRS
Luxembourg	0.541	0.552	0.541	CRS
Hungary	0.780	0.788	0.780	CRS
Malta	1.000	1.000	1.000	CRS
The Netherlands	0.643	0.869	0.643	CRS
Austria	0.840	0.858	0.840	CRS
Poland	0.785	0.848	0.785	CRS
Portugal	0.730	0.732	0.732	VRS
Romania	1.000	1.000	1.000	CRS
Slovenia	0.597	0.615	0.597	CRS
Slovakia	0.813	0.814	0.814	VRS
Finland	0.615	0.617	0.615	CRS
Sweden	0.601	0.607	0.601	CRS
UK	0.776	0.928	0.776	CRS

Source: *Model results*

After determining the CRS, VRS and Hybrid efficiencies with the traditional DEA model, this study uses the ZSG DEA model with hybrid returns to scale and its results are presented in table 3. Respecting the CO_2 variations imposed to each agriculture as well as the final levels of CO_2 emissions after reallocation, all the agricultures in each one of European Union countries will have to present the 100% efficiency. The 100% efficiency values are shown in the column called ‘Maximum Efficiency frontier’ in table 3.

The analysis of the column “CO_2 Variation in %” in table 3 shows that fourteen agricultures in European Union countries can increase their carbon emissions after the reallocation of carbon emissions. For the thirteen remaining agricultures in European Union, it is required that they decrease their carbon emissions and, the results show that they have a negative variation after the reallocation of carbon emissions. We can verify that the total sum of positive and negative variations of the carbon emissions for the agricultures in European Union countries is null. We can see that the total sum of the original carbon emissions (column 2) is equal to the total sum of carbon emissions after the reallocation (column 3) in table 3. The last column shows maximum efficiency frontier that is calculated after carbon reallocation using a ZSG DEA model with hybrid returns to scale where all the agricultures in the European Union are 100% efficient.

The identification of the “cutting efficiency” will determine if the agriculture must increase its carbon emissions or if it will have to reduce it. This point is different for each model if it is a CRS, a VRS and a hybrid case. In the hybrid case, the “cutting efficiency” is between two agricultures. Belgian agriculture has one of the lowest increases and can increase its carbon emission in 0.03 tons^3, while Portuguese agriculture has one of the lowest decreases and must decrease its carbon emission in 0.10 tons^3.The “cutting efficiency” occurs in approximately 73% of the efficiency. The agricultures that possess efficiency superior to that value can increase their carbon emissions, while the agricultures that possess efficiency inferior to that value must decrease their carbon emissions. Danish and Spanish agricultures might increase their carbon emissions. Spanish agriculture might increase its carbon emissions in 14tons^3, equivalent to33% of its total carbon emissions. This agriculture lies in the region of constant returns with efficiency of above the “cutting efficiency” (97%). Danish agriculture can increase its carbon emissions in 3tons[3], equivalent to31% of its total carbon emissions. This agriculture lies in the region of constant returns with efficiency above the “cutting efficiency” (96%). Among the biggest decreases in the agricultures, we have Luxemburg (54% of efficiency), France (59% of efficiency) and Slovenia (60% of efficiency). According to values presented in table 3, the agriculture in Luxemburg decreases more than in 0.17 tons[3] of its carbon emissions, what it corresponds 25% of the decrease of its total carbon emissions. This agriculture has low carbon emissions, and it is in the CRS region of the ZSG DEA model with hybrid returns to scale with efficiency below the “cutting efficiency” (54%). French agriculture reduces its carbon emissions in 18.59 ton[3], which corresponds 19.4% of the reduction of its total carbon emissions. The agriculture in Slovenia reduces its carbon emissions in 0.38 tons[3] corresponding to 18.2% of its total carbon emissions.

Table3. *VRS-CRS Hybrid Efficiency, CO2 before and after Reallocation, CO2 Variation and Maximum Efficiency Frontier*

	VRS-CRS Hybrid Efficiency (1)	Original CO_2 in Tons[3] (2)	CO_2 after Reallocation in Tons[3] (3)	CO_2 Variation in Tons[3] (4)	CO_2 Variation in % (5)	Maximum Efficiency Frontier (6)
Belgium	0.73	9.719	9.751	0.032	0.33	1.00
Bulgaria	0.85	4.996	5.810	0.814	16.29	1.00
Czech	0.72	8.117	8.033	-0.084	-1.04	1.00
Denmark	0.96	9.759	12.786	3.027	31.02	1.00
Germany	0.65	63.763	56.608	-7.155	-11.22	1.00
Estonia	0.88	1.35	1.625	0.275	20.34	1.00
Ireland	0.71	17.744	17.208	-0.536	-3.02	1.00
Greece	0.75	9.576	9.854	0.278	2.91	1.00
Spain	0.97	42.347	56.515	14.168	33.46	1.00
France	0.59	95.742	77.154	-18.588	-19.41	1.00
Italy	0.68	37.222	34.555	-2.667	-7.16	1.00
Cyprus	0.66	0.761	0.692	-0.069	-9.11	1.00
Latvia	1.00	2.132	2.923	0.791	37.10	1.00
Lithuania	0.69	5.225	4.951	-0.274	-5.24	1.00
Luxembourg	0.54	0.656	0.486	-0.170	-25.86	1.00
Hungary	0.78	8.906	9.525	0.619	6.96	1.00
Malta	1.00	0.088	0.121	0.033	37.10	1.00
Netherlands	0.64	18.255	16.104	-2.151	-11.78	1.00
Austria	0.84	7.497	8.637	1.140	15.20	1.00
Poland	0.79	37.127	39.958	2.831	7.63	1.00
Portugal	0.73	7.945	7.937	-0.008	-0.10	1.00
Romania	1.00	19.701	27.009	7.308	37.10	1.00
Slovenia	0.60	2.092	1.711	-0.381	-18.19	1.00
Slovakia	0.81	3.233	3.610	0.377	11.66	1.00
Finland	0.62	5.722	4.822	-0.900	-15.72	1.00
Sweden	0.60	8.549	7.043	-1.506	-17.62	1.00
UK	0.78	44.069	46.864	2.795	6.34	1.00
Total		472.293	472.293	0		

Source: *Model results*

Table4. *Stratification of the agricultures in European Union countries according to the percentage changes of carbon emissions (X)*

	Agricultures	Up to 10%	10% < X <20%	20% < X < 30%	X > 30%
Increases	14	5	3	1	5
Decreases	13	6	6	1	0

Source: *Model Results*

The table 4 shows the stratification of the agricultures in European Union that can increase or decrease carbon emissions. These model results show that fourteen agricultures in European Union can increase their carbon emissions according to the reallocation of carbon emissions, while thirteen agricultures in European Union have to decrease their carbon emissions and they are concentrated in groups of carbon emissions reduction up to 30%. Moreover, some agricultures in European Union can increase their carbon emissions more than 30%. No agriculture in European Union is asked for decreasing the carbon emission more than 30%, what it would be very difficult of being reached.

5. CONCLUSIONS

The purpose of this study is to evaluate the performance of agriculture in each one of European Union countries in the presence of carbon emissions and, to present a fair allocation of their carbon emissions using efficiency measures. This fair allocation of the carbon emissions might create a carbon management among the agricultures in European Union. This trade determines that the agricultures which are within the level of carbon emissions according to the Durban Conference in 2011can yield pollution or can trade carbon quotas with other agricultures, while those that have already exceeded their limits must reduce pollution or must negotiate a carbon quota with other agricultures, which would require a carbon quota trade among them, without changing the total sum of carbon emissions of agriculture in European Union countries.

This study applies a nontraditional DEA model for modeling carbon emissions of agriculture in each one of European Union countries. The carbon emissions are modeled as an undesirable output that is modeled here as an input variable in order to minimize it, using a ZSG DEA model. These models determine a maximum efficiency frontier based on the reallocation of carbon emissions. Advanced models can be used, and a ZSG DEA model with hybrid returns to scale is adequate for the reallocation of carbon emissions. This model allows that the big polluting agricultures like France must reduce its level of carbon emissions, while the small agricultures should not be penalized.

The ZSG DEA model with hybrid returns to scale benefits the agricultures in European Union that work at the optimal scale operation and punish the ones that are not operating on the optimal scale. French and German agricultures must decrease their carbon emissions or these agricultures should search for partners that want or can reduce their carbon emissions to keep their carbon emissions unchanged. Danish and Spanish agricultures, according to ZSG DEA model with hybrid returns to scale, might increase their carbon emissions, and still remain efficient or can trade their excess quota with other agricultures. So, it is possible to propose a carbon quota trade and the agricultures can increase their carbon emissions by buying carbon quotas from other agricultures or can reduce their carbon emissions by selling carbon quotas to other agricultures. These results agree with the "flexible mechanisms" provided for in the Kyoto Protocol, and they can help the agricultures to define a carbon management in order to set their levels of carbon emissions in European Union.

Model results encourage future research to improve a carbon quota trade. The introduction of other greenhouse gases might be a very interesting improvement because the ZSG DEA models should incorporate weight restrictions since each pollutant has a different importance for the greenhouse effect. The other improvement could be the restrictions of weight ranges assigned to output or input variables that might be helpful to define a "Common Carbon Management Policy".

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