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Sustainable or not sustainable, that's the question: ranking European regional agricultural systems using Data Envelopment Analysis

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1. Introduction

Sustainability is a complex and sophisticated concept. Measuring to what extent a complex regional agricultural system is sustainable is difficult and challenging. For example, in different decision-making contexts stakeholders can use different criteria and methodologies, thus arriving at different (and contrasting) judgments about the sustainability of the same agricultural practice (e.g. a certain amount of soil erosion per hectare could be judged as sustainable in the EU and not in the US, in China, or in Australia). Therefore in this paper we first discuss the concept of sustainability and then the way to operationalize it and to make it useful for assessment procedures using Data Envelopment Analysis (DEA) as methodological approach. The use of DEA for assessing sustainability is not new. Cherchye and Kuosmanen (2002; 2006), for example, discussed different applications of DEA for the assessment of sustainable development at country level. Other papers addressed this issue at firm and sector level and mainly focused on the concept of eco-efficiency (Zaim 2004; Kuosmanen and Kortelainen 2005; 2007). Lu and Lo (2007) used a DEA approach to rank 31 Chinese regions in terms of their sustainability taking into account economic and environmental indicators. In this paper we focus on a broader conceptualization of sustainability and we apply a DEA approach to assess European agricultural performances on a regional level. To our knowledge this is the first time a regional level dataset and DEA have been used in a paper to provide such an assessment. This level of analysis will become increasingly important in following years in order to support European decision making processes related to rural development policy. Our perspective is to consider the "mosaic approach" of sustainability and its three dimensions (Smith and McDonald, 1998; OECD, 2008): economic, social, and environmental. The mosaic approach of sustainability is related to the capacity of human activity (e.g. land management) (1) to be feasible (*economic dimension*), and (2) to be acceptable by society (*social dimension*), and (3) to maintain ecological processes (*environmental dimension*) (Tisdell 1997; Perman et al. 2003, p. 93). In this sense sustainable agriculture can be considered as a process in which demand for its products, such as food, raw materials and rural amenities, is met from farming practices that are economically efficient, socially acceptable, and environmentally friendly.

This paper is organized as follows: in Section 2 we present the indicators used to address the issue of measuring sustainability at regional level. In Section 3 we present the basic DEA models. In Section 4 we present the scenarios we implemented in order to address the different dimensions of sustainable development. In Section 5 we present the computational results. Finally in Section 6 concluding remarks are presented as well as directions for further research.

2. Indicators of sustainability

The main problem when dealing with the assessment of sustainability is that this concept often appears as a "black box" in terms of usage. This is due to the fact that the concept of sustainability carries a variety of meanings, exemplified by the very different interpretations given to it by social and natural scientists (i.e. economists, sociologists, and ecologists). Hence for answering the question whether a given system (i.e. a region) is sustainable we often need reference levels, indicators, and benchmarking methods (Cherchye and Kuosmanen 2002; 2006). As highlighted by Oskam and Feng (2008) almost all definitions of sustainability make its identification and measurement problematic, because they are related to dynamicity and uncertainty. This means that the judgment on sustainability is often scale, time and socially (institutionally) dependent, and assessment of sustainability is complex. For example, it is highly unclear what will be the future needs of society, and what will be the scale of values that will be adopted. This explains why it is “easier” to express an evaluation on what is *un*sustainable (now) rather than on what is sustainable (now and tomorrow) (Oskam and Feng 2008). Therefore even though the theoretical definition of sustainability is clear, it is less clear how to make it operational in an empirical analysis. We use the mosaic approach to assess the sustainability of the agricultural systems in the European regions. As stated in Section 1 the mosaic approach states that the *economic dimension* requires feasibility, the *social dimension* requires acceptability, and the *environmental dimension* requires carrying capacity (Spangenberg 2002; Schleyer *et al*. 2007). Usually at country (national) level this is addressed by using indices of sustainable development linked to data collected by International Institutes. These data often are not available at regional (sub-national) level. Examples are the Environmental Sustainability Index of the World Economic Forum (WEF 2002), the Human Development Index of the United Nations Development Program (UNDP 2001) or the Ecological Footprint (Wackernagel *et al*. 2002). OECD has recently provided useful national and regional-based indicators specifically oriented to measure the sustainability of agriculture using the mosaic approach conceptualization background (OECD 2008). At regional level also the European Union has recently proposed suitable indicators of agricultural sustainability. Among others the EU proposes economic indicators related to productivity and investments, social indicators linked to the take-over ratio and the level of education in agriculture, and environmental indicators related to soil erosion and water use[1].

In Table 1 we present the indicators we selected from this dataset in order to assess sustainability of agricultural systems at the level of European regions. We selected these indicators in order to fulfill two basic concepts: closeness to the theoretical definitions and availability of information for all the units of analysis we are considering in this research. For addressing the economic dimension we selected two indicators: productivity of labor and the gross fixed capital formation in agriculture. They are linked to the idea of increasing the competitiveness and efficiency of the European agriculture. Both are of the type more is better. For addressing the social dimension we selected two indicators: ratio of farmers under 35 years of age to farmers over 55 years of age, and the level of training and education in agriculture. They indicate the capacity of agriculture to provide acceptable living conditions such that a good standard of education can be achieved and future generations of land managers can procure an acceptable standard of living. Both indicators give insights related to the capacity of agriculture to promote social cohesion and equity. They are of the type more is better. For addressing the environmental dimension we selected four indicators: the risk of soil erosion, the intensity of plant production and animal grazing and the relevance of irrigated areas. They are linked to the objective of reducing the consumption of important natural resources such as soil and water, and to enhancing resilience of agro-ecosystems. They are all of the type less is better.

[1] http://ec.europa.eu/agriculture/agrista/rurdev2008/index_en.htm

Table 1 – Indicators of sustainability of agriculture in European regions

Indicators	Type
Economic dimension (feasibility)	
Productivity of labor	
1. Value added per AWU[a]	More is better
Investment level	
2. Gross Fixed Capital Formation in agriculture (euro/farm)	
Social dimension (acceptability)	
Inter-generational equity	
3. Ratio of farmers < 35 years / farmers ≥ 55 years	More is better
Education level	
4. Training and education in agriculture (% land managers with high education)	
Environmental dimension (carrying capacity)	
Land management	
5. Risk of soil erosion (t/(year·ha))	
6. Intensity of land use for plant production (%UAA)[b]	Less is better
7. Intensity of land use for animal production (%UAA)[b]	
Water management	
8. Relevance of irrigated areas (%UAA)[b]	

Source: Our elaboration on European Commission – Agriculture and Rural Development Dataset[1]
[a] where AWU means Annual Work Unit; [b] where UAA means Utilized Agricultural Area

A dataset for 252 regions in the European Regions (NUTS2) is established from the European Commission – Agriculture and Rural Development Dataset for the year 2004/5[2]. In Table 2 we present the summary statistics of the indicators of sustainability for the regions.

Table 2 – Summary statistics of the indicators of sustainability

Indicators	Statistics			
	Mean	Max	Min	S.D.
Economic indicators				
1. Gross value added per AWU (10^3 euro/AWU)	23.53	77.22	1.09	14.93
2. Gross Fixed Capital Formation in agriculture (10^3 euro/farm)	12.06	63.8	0.00	12.36
Social indicators				
3. Ratio: farmers < 35 years / farmers ≥ 55 years	0.17	0.60	0.00	0.13
4. Training and education in agriculture (%)	35.91	89.70	0.40	24.05
Environmental indicators				
5. Risk of soil erosion (t/(year·ha))	1.55	31.79	0.00	3.27
6. Intensity of land use for plant production (%UAA)	79.94	100.00	0.51	28.05
7. Intensity of land use for animal production (%UAA)	92.09	100.00	0.00	20.81
8. Relevance of irrigated areas (%UAA)	5.59	60.43	0.00	10.11

Source: our elaboration on European Commission – Agriculture and Rural Development Dataset[1]

Economic indicator 1 is the gross value added at basic price per annual working unit in agriculture. Gross value added is defined as the value of output less the value of intermediate consumption. Output is valued at basic prices and intermediate consumption is valued at purchasers' prices. As indicated by the European Commission the gross value added per Annual Work Unit (AWU) provides comparable data on labor productivity and allows for comparison over sub-sectors and regions. An Annual Working Unit corresponds to 2,200 working hour per year which is the amount of hours an employee is willing to provide when fully employed in the agricultural business. Economic indicator 2 is the gross fixed capital formation in agriculture per farm. It refers to the investments in assets that are used repeatedly or continuously over a number of years to produce goods in agriculture. Social indicator 3 refers to the ratio of young and old farmers in a given region. It provides the measurement of the take-over in agriculture. A

[2] This year will be used by the EU Commission as the reference point (baseline) from which starting to assess the effect of Rural Development Strategy in the EU in the period 2007-2013.

ratio close to zero indicates an extremely low take-over (therefore an unattractive agricultural sector) while a value close to one indicates a high take-over (and therefore a very attractive agricultural sector). Social indicator 4 refers to the percentage of farmers who received a full agricultural training. This indicator is calculated as any training course continuing for the equivalent of at least two years full time training after the end of compulsory education and completed at an agricultural college, university or other institute of higher education in agriculture, horticulture, viticulture, sylviculture, pisciculture, veterinary science, agricultural technology or an associated subject. Environmental indicator 5 refers to the risk of soil erosion which is estimated on the base of the Pan-European Soil Erosion Risk Assessment model – Pesera project (JRC-Ispra). This indicator expresses the potentiality of soil loss in terms of ton per hectare and per year. Environmental indicators 6 and 7 indicate the percentage of hectares under intensive agriculture. Indicator 6 is the area under arable crops production (except forage crops), when the regional yield for cereals (excluding rice) is more than 60% of the EU-27 average. Cereal yield is a 3 years average. Indicator 7 is the area for grazing livestock production (cattle, sheep, and goats), when the stocking density exceeds 1 Livestock Unit per hectare of forage area (forage crops, permanent pastures and meadows). Environmental indicator 8 refers to the relevance of irrigated areas calculated as the percentage of hectares in which irrigation is used. An irrigated area is defined as the area of irrigated crops, i.e. the area of crops that have actually been irrigated at least once during the 12 months prior to the survey date. Crops under glass and kitchen gardens, which are almost always irrigated, are not included.

3. Basic models, Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) was developed in 1978 by Charnes, Cooper and Rhodes (Cooper *et al*. 1978) as a mathematical programming technique for evaluating and comparing the performance of a set of decision making units (DMU's) with common inputs and outputs. No a priori weights are needed. DEA indicates a set of best performers, i.e. the most efficient units from the total set, having an efficiency level of 1. DEA also calculates the efficiency levels of the remaining DMU's, which are values between 0 and 1. In the domain of sustainable development assessment DEA approaches have been developed by several authors, for example to address differences among countries in terms of sustainable development (Cherchye and Kuosmanen 2002; 2006), or to measure the eco-efficiency of private firms (Zaim 2004; Kuosmanen and Kortelainen 2005; 2007). An application of DEA at regional level could be found in Lu and Lo (2007) referring to the assessment of sustainable development of 31 Chinese regions. In the context of this paper our DMU is a European region and the type of performance we are looking for is the sustainability of the regional agricultural system. To use a region as DMU is consistent to the type of decision making process we are experiencing in the European Union in relation to the organization and the implementation of the rural development policies. This level of decision making will become even more and more important in the near future in order to address the linkages between sustainability and rural development in the European Union (Buckwell 2010).

Within the DEA framework a DMU is defined as an entity that converts inputs into outputs. It is assumed that the set under investigation consists of R units (DMU_1, DMU_2, …, DMU_R). Each unit consumes I inputs to produce J outputs. A certain unit DMU_r consumes input i in a quantity of x_{ir} and produces output j in a quantity of y_{jr} ($x_{ir} \geq 0$ and $y_{jr} \geq 0$ for all i, j, r). Efficiency is defined as ratio of the weighted sum of the outputs and the weighted sum of the inputs, under the restriction that efficiency can never exceed the value of 1. The efficiency of a DMU increases as its outputs increase and/or its inputs decrease (and vice versa). In this study 252 European regions are modeled as the DMU's, the indicators of the type "less is better" are modeled as the inputs (environmental indicators), and the indicators of the type "more is better" are modeled as the outputs (economic and social indicators). One by one each region is chosen as the reference region. A model is formulated in which the weights that the reference region assigns to the various inputs and outputs are the decision variables. These weights are chosen in such a way that the efficiency of the reference region is maximized:

$$\max \sum_{j=1}^{J} y_{j0} U_j \tag{1}$$

s.t.

$$\sum_{i=1}^{I} x_{i0} V_i = 1 \tag{2}$$

$$\sum_{i=1}^{I} x_{ir} V_i \geq \sum_{j=1}^{J} y_{jr} U_j \quad \text{for } r = 1...R \tag{3}$$

$$V_i \geq 0 \text{ for } i = 1\ldots I \tag{4}$$

$$U_j \geq 0 \text{ for } j = 1\ldots J \tag{5}$$

with $r = 0$ the reference region, U_j the non-negative weight that the reference region assigns to output j, V_i the non-negative weight that the reference region assigns to input i. Objective function (1) maximizes the weighted sum of the outputs of the reference region. Restriction (2) states that the weighted sum of the inputs of the reference region should equal 1. As the efficiency of the reference region is defined as the ratio of the weighted sum of its outputs and the weighted sum of its inputs the objective function (1) equals the efficiency of the reference region. Restriction (3) assures that the efficiency of each of the regions is no more than 1. In order to measure the efficiency of R different regions the model has to be run R times.

According to model (1)-(5) each region will set the weights in such a way that its own efficiency is maximized, which implies that (a) the weights assigned to the inputs and outputs can differ greatly from one region to another, (b) every region has the opportunity to "ignore" (i.e. assign zero weight to) inputs and outputs for which its indicators are relatively bad. Following Pedraja-Chaparro *et al*. (1997) we formulated restrictions that put lower bounds (6,8) and upper bounds (7,9) on the relative weight that the reference region can assign to inputs and outputs:

$$y_{j0} U_j \geq u\_low \sum_{k=1}^{K} y_{k0} U_k \quad \text{for } j = 1\ldots J \tag{6}$$

$$y_{j0} U_j \leq u\_up \sum_{k=1}^{K} y_{k0} U_k \quad \text{for } j = 1\ldots J \tag{7}$$

$$x_{i0} V_i \geq v\_low \quad \text{for } i = 1\ldots I \tag{8}$$

$$x_{i0} V_i \leq v\_up \quad \text{for } i = 1\ldots I \tag{9}$$

with *u_low* (*v_low*) the lower bound of the relative weight of each output (input), and *u_up* (*v_up*) the upper bound of the relative weight of each output (input).

4. Scenarios

By using the model set-up we presented in the previous section we are able to transfer the conceptual background of the mosaic approach of regional agricultural sustainability into an appropriate operational decision making framework. Regions with the best performance in (at least) one of the dimensions of sustainability will have high efficiencies.

Scenarios

The model set-up allows us to experiment with various preferences for the importance of each of the three dimensions in assessing the sustainability of the regions. Accordingly five scenarios were used for ranking the regions based on the efficiency that results from their indicators of sustainability:

A. *Basic scenario* – Standard DEA model.
B. *Balanced scenario* – Lower bounds and upper bounds on the relative weights of all inputs and outputs.
C. *Economic scenario* – A lower bound is put on the relative weights of the economic indicators.
D. *Social scenario* – A lower bound is put on the relative weights of the social indicators.
E. *Environmental scenario* – The ranking is based solely on the values of the environmental indicators.

The properties and characteristics of each scenario can be summarized as follows:

A. Basic scenario: This scenario models an assessment procedure where regions are ranked without assuming any preferences with respect to the dimensions of sustainability. The efficiencies of all regions were calculated by running basic DEA-model (1)-(5) for every region. Then the European regions were ranked according to their efficiencies.

B. Balanced scenario: This scenario models an assessment procedure where all three dimensions of sustainability are taken into account. Regions should use all outputs and inputs when they optimize their efficiency, and they should not assign more than 50% relative weight to one input or one output. Therefore restrictions (6B), (7B), (8B), and (9B) were added to model (1)-(5):

$$y_{j0}U_j \geq \tfrac{1}{10}\sum_{k=1}^{K} y_{k0}U_k \qquad \text{for } j = 1 \ldots J \qquad (6B)$$

$$y_{j0}U_j \leq \tfrac{1}{2}\sum_{k=1}^{K} y_{k0}U_k \qquad \text{for } j = 1 \ldots J \qquad (7B)$$

$$x_{i0}V_i \geq \tfrac{1}{10} \qquad \text{for } i = 1 \ldots I \qquad (8B)$$

$$x_{i0}V_i \leq \tfrac{1}{2} \qquad \text{for } i = 1 \ldots I \qquad (9B)$$

C. Economic scenario: This scenario models an assessment procedure where the economic dimension is regarded as the most important one. The relative weight that the reference region assigns to the economic indicators 1 (labour productivity) and 2 (fixed capital formation in agriculture) should be at least three times higher than the relative weight assigned to the social indicators. This was modelled by adding restriction (6C) to model (1)-(5):

$$y_{10}U_1 + y_{20}U_2 \geq \tfrac{3}{4}\sum_{k=1}^{K} y_{k0}U_k \qquad (6C)$$

D. Social scenario: This scenario models an assessment procedure where the social dimension is regarded as the most important one. The relative weight that the reference region assigns to the social indicators 3 (ratio farmers < 35 years / farmers ≥ 55 years) and 4 (training and education in agriculture) should be at least three times higher than the relative weight assigned to the economic indicators. This was modelled by adding restriction (6D) to model (1)-(5):

$$y_{30}U_3 + y_{40}U_4 \geq \tfrac{3}{4}\sum_{k=1}^{K} y_{k0}U_k \qquad (6D)$$

E. Environmental scenario: This scenario models an assessment procedure where only the environmental dimension is considered. Therefore it was assumed that all regions have only 1 output, for which they all have the same value. So economic and social indicators 1-4 were removed from the model, and replaced with (artificial) indicator 9, for which all regions have value 1. Regions should use all inputs while optimizing their efficiency. Model (1)-(5) is changed accordingly:

$$\max \quad U_9 \qquad (1E)$$

$$\text{s.t.} \quad \sum_{i=1}^{I} x_{i0} V_i = 1 \qquad (2)$$

$$\sum_{i=1}^{I} x_{ir} V_i \quad \geq \quad U_9 \qquad (3E)$$

$$V_i \geq 0 \qquad \text{for } i = 1 \ldots I \qquad (4)$$

$$U_9 \geq 0 \qquad (5E)$$

$$x_{i0}V_i \geq \tfrac{1}{10} \qquad \text{for } i = 1 \ldots I \qquad (8E)$$

$$x_{i0}V_i \leq \tfrac{1}{2} \qquad \text{for } i = 1 \ldots I \qquad (9E)$$

5. Computational results

In Appendix 1 we present the efficiencies of 252 European agricultural regions as calculated under the five different scenarios[3]. Given the size of the sample we comment these efficiencies (i) first sketching the information about the most efficient regions in basic scenario A, and (ii) secondly synthesizing results per scenario and per country.

(i) In basic scenario A, where we run a free optimization model, 35 European regions have efficiency 1. As the models of scenarios B, C, and D are defined by adding extra restrictions to the model of scenario A no region can have a higher efficiency under scenario B, C, or D than under scenario A. So all regions that are efficient under scenario B, C, or D are also efficient under basic scenario A. Environmental scenario E uses a different set of outputs than scenario A. Therefore a region can have a higher efficiency in scenario E than in scenario A.

Adding balancing constraints (6B), (7B), (8B), (9B) in scenario B has quite an impact on the number of efficient regions: only 11 regions are efficient in balanced scenario B. It turns out that 23 regions are efficient in economic scenario C, and that 27 regions are efficient in social scenario D, and that 7 regions are efficient in environmental scenario E. In Table 3 we present the efficiencies of the 35 regions that are efficient in basic scenario A, given per country and per scenario. The efficient Spanish, Italian and Swedish regions owe their efficiency to the economic dimension while German, Dutch, and British regions owe their efficiency mainly to both the social and the economic dimension. The efficient Austrian and Finnish regions present more balanced performances while the efficient Polish regions owe their efficiency mainly to the values of their social

3 Appendix 1 couldn't be included in this version of the paper due to the limited number of pages available. The interested reader is welcome to request it to the authors.

indicators. There are 6 regions that show maximum efficiency in all five scenarios: the Austrian Salzburg, Tirol and Vorarlberg, Hamburg in Germany, Åland in Finland and the UK Highlands & Islands. They seem to show the "perfect" combination of low natural resource use (i.e. land and water) and high socio-economic performance. Hamburg and Salzburg are prevailing urban regions while all the others are intermediate (Vorarlberg) or prevailing rural regions[4]. (ii) A second approach we use to analyse results is to organize information of the overall regional performances per country such that variability within and between countries can be detected. Appendix 2 shows the main descriptive statistics for each EU State Member in each scenario[5]. In basic scenario A the best performers are Finland, Germany, and The Netherlands (0.930, 0.910, and 0.890 respectively) while the poorest performers are Slovakia (0.123), Cyprus (0.146), Greece (0.179), Bulgaria (0.182), Malta (0.186), Hungary (0.196), and Romania (0.197). The best performers in the balanced scenario B are again Finland, Germany, and The Netherlands (0.881, 0.735, and 0.690 respectively), while poorest performers are again Malta (0.013), Bulgaria (0.031), Romania (0.044), Slovakia (0.045). In economic scenario C The Netherlands and Finland present high scores again (0.857 and 0.819 respectively) while Bulgaria (0.044), Lithuania (0.058), Slovakia (0.079), Hungary (0.090), and Romania (0.098) have the lowest scores. In social scenario D besides Finland (0.930), Germany (0.910), and The Netherlands (0.855) also Czech Republic presents a relatively high score (0.829). Poorest performers in this case are Slovakia (0.122), Cyprus (0.129), Portugal(0.138), Greece (0.165), Spain (0.169), Italy (0.177), Malta (0.178), and Bulgaria (0.182). A different ranking is found in environmental scenario E. Estonia (1.000), Latvia (0.973), and Finland (0.870) have the highest efficiencies while Denmark (0.290), Malta (0.300), Cyprus (0.306), and Greece (0.307) have relatively low efficiencies.

In general the Central and Northern European regions show higher efficiencies than both the Southern (Mediterranean) and the "new Member State" (i.e. former communist countries) regions. Only in social scenario D former communist countries perform relatively well, while Mediterranean regions still show poor performances. These results are in line with the main observations of the current researches on development divergences of the European regions (Crescenzi, 2009). Besides evaluating the European countries in terms of their average efficiencies in the different scenarios it is also interesting to look at the variability in different countries. For comparing the variabilities we use the standard deviations as presented in Appendix 2. Poland, Sweden, and Austria have the highest standard deviations in basic scenario A. Under balanced scenario B Austria, UK, and Czech Republic have the highest standard deviations. In economic scenario C again Austria has the highest standard deviation, followed

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[4] The EU Commission classified the European regions accordingly to the OECD methodology. This methodology is based on population density (OECD, Creating rural indicators for shaping territorial policy, Paris, 1994). It is based on a two-step approach: First, the OECD identifies local areas (municipalities) as rural if the population density is below 150 inhabitants per square kilometer. Then, at regional level (NUTS 3 or NUTS 2), the OECD distinguishes:

- Predominantly Rural regions (PR) : more than 50% of the population is living in rural communes (with less than 150 inhabitants / km^2)
- Intermediate Regions (IR) : 15% to 50% of the population of the region is living in rural local units
- Predominantly Urban regions (PU) : less than 15% of the population of the region is living in rural local units.

As a result, the regions (NUTS 3 or NUTS 2) can be 'flagged' with their category: Predominantly Rural, Intermediate, Predominantly Urban. Characterization of the rural character at regional level, where most of the statistics are available, allows drawing easily a picture of the different types of areas at national level.

[5] Appendix 2 couldn't be included in this version of the paper due to the limited number of pages available. The interested reader is welcome to request it to the authors.

by Sweden and Czech Republic. Poland, Austria, and Czech Republic have the highest standard deviations in social scenario D. Austria is also the country with the highest standard deviation in environmental scenario E. Appendix 2 also shows the minimum and the maximum efficiency per country. It can be seen that in most countries the difference between the most efficient region and the least efficient region is considerable.

Table 3 – Efficiency scores of the 35 European regions (in scenario A).

Country	Region code and name		Scenario				
			A Free	B Balanced	C Economic	D Social	E Environmental
Austria	AT32	Salzburg	1	1	1	1	1
	AT33	Tirol	1	1	1	1	1
	AT34	Vorarlberg	1	1	1	1	1
Germany	DE13	Freiburg	1	0.720	0.438	1	0.740
	DE23	Oberpfalz	1	0.679	0.382	1	0.676
	DE41	Brandenburg-NO	1	1	1	1	0.720
	DE42	Brandenburg-SW	1	0.914	0.898	1	0.723
	DE60	Hamburg	1	1	1	1	1
	DE80	Mecklenburg	1	1	1	1	0.680
	DE94	Weser-Ems	1	0.991	0.838	1	0.699
	DEA1	Düsseldorf	1	0.715	0.665	1	0.669
	DEC0	Saarland	1	0.801	0.553	1	0.751
	DED3	Leipzig	1	0.916	0.864	1	0.661
	DEE1	Dessau	1	0.983	1	1	0.685
	DEE2	Halle	1	1	1	1	0.668
	DEE3	Magdeburg	1	0.938	0.932	1	0.677
Spain	ES13	Cantabria	1	0.258	1	0.361	0.709
Finland	FI13	Itä-Suomi	1	0.883	0.717	1	0.929
	FI1A	Pohjois-Suomi	1	1	1	1	0.830
	FI20	Åland	1	1	1	1	1
Italy	ITD1	Provincia Bolzano	1	0.617	1	0.695	0.532
	ITD2	Provincia Trento	1	0.264	1	0.317	0.518
The Netherlands	NL12	Friesland	1	0.752	1	1	0.520
	NL23	Flevoland	1	0.964	1	1	0.504
	NL33	Zuid-Holland	1	0.838	1	0.901	0.506
	NL41	Noord-Brabant	1	0.779	1	1	0.509
Poland	PL11	Lodzkie	1	0.090	0.069	1	0.360
	PL12	Mazowieckie	1	0.126	0.082	1	0.420
	PL34	Podlaskie	1	0.134	0.068	1	0.401
Sweden	SE01	Stockholm	1	0.303	1	0.613	0.540
	SE07	Mellersta Norland	1	0.512	1	0.485	0.622
	SE08	Övre Norrland	1	0.627	1	0.385	0.685
United Kingdom	UKM2	Eastern Scotland	1	1	1	1	0.800
	UKM3	S-W Scotland	1	0.895	1	0.621	0.812
	UKM4	Highlands & Islands	1	1	1	1	1

Source: Our elaboration on European Commission – Agriculture and Rural Development Dataset

6. Conclusions

In this paper we used Data Envelopment Analysis (DEA) to address the issue of ranking sustainability of agricultural systems of European regions. Inputs and outputs were defined based on the mosaic approach of sustainability and its three dimensions. We constructed 5 scenarios (i.e. points of view with respect to the importance of the three dimensions of sustainability) by adding various constraints to our basic DEA model. The results indicate that this approach can be considered as highly promising to address the issue of agricultural sustainability.

The combination of mosaic approach and DEA allowed us to operationalize the very complex and sophisticated concept of sustainability. In literature we can find alternative approaches, but we think the results of this paper highlight that DEA has several useful and interesting features. The flexibility of DEA and its relatively high accessibility are such that by adding relatively simple constraints significantly different scenarios can be provided without losing too much in terms of complexity and sophistication on the conceptual side. Thus DEA can be used as a tool for sustainability assessment at the level of desk analysis in situations where extracting sustainability assessment directly from the policy-makers would be too complex. A procedure for assessment of sustainability has to take into account how sensitive the results are to changes in the (underlying) assumptions within the adopted methodological approach. We have shown the impact of changing the optimization procedure (for example by introducing balancing constraints) on the efficiency values of the regions. This issue is extremely important in order to provide reliable information to the stakeholders and in order to take correctly into account their needs and preferences. Applying DEA at the EU regional level allowed us to expose the heterogeneity of conditions and performances within each EU Member State and also among them. To our knowledge this is the first paper that explicitly addressed this issue at this level in the EU context. We believe that using regional level data and DEA to take into account this heterogeneity will become increasingly important in following years in order to support European decision making processes related to rural development policy. The results related to variability highlighted the added value of our regional approach in addressing country-comparison analyses. Thus our approach can help to facilitate national-based policy to promote more sustainable regional development. Recent debate about the effectiveness of the EU regional funds allocation reveals that this is an area of research that will require increasing attention in the near future (Crescenzi, 2009). This paper provides clear indications for future research and extensions in this domain, for example in the direction of linking the performances under the different scenarios' assumptions to a set of explanatory variables in order to understand what are the driving factors in the analyzed phenomena. This is an important step in the context of policy-making related to sustainable development of agriculture and rural areas in the EU and a promising area of research for the upcoming years.

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