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Eco-efficiency versus eco-effectiveness in the sustainable development of agriculture: a comparative analysis in EU regions[1]

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Abstract: The main goal of the article was to present the environmental sustainable value (ESV) generated by farms in EU regions. We can consider two points of view on this issue, either an eco-efficiency or eco-effectiveness approach. The fundamental problem, namely the environmental sustainability of farms is different depending on the criterion we apply. When we assume the eco-efficiency criterion and use total output as an effect indicator, producers maximise it by adopted input (polluting capital), but when it comes to the eco-effectiveness criterion, there is a different priority – not production, but the lowest possible strain on the natural environment (environmental subsidies). 125 European regions (excluding the Canaries, Cyprus, Malta and Luxembourg – outliers) were analysed in 2015, as the last available year in FADN. Estimating Environmental Sustainable Value with frontier benchmarking was carried out.

Keywords: eco-efficiency, eco-effectiveness, sustainable development, agriculture, EU regions

JEL: Q01, Q56, J43, O13

Introduction

Discussions on the sustainable development of agriculture, the methods and measurement indicators, evaluation and indicative values, etc. are nothing new [Zegar 2012, Kates et al 2005]. In the literature, the issue is most often analysed in its economic, social and environmental aspects. While the first two are not difficult to measure and evaluate (mostly from the perspective of income, employment, education), some dilemmas arise in the context of environmental sustainability. One of the major dilemmas, if not the most important,

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is whether to generate the highest production effect on a farm, taking into consideration the means used (e.g. fertilisers, plant protection products) and gases emitted (e.g. greenhouse gases) during production, or to adopt a consensus consisting in the fact that the products used in agricultural production are unfavourable for the natural environment, but simultaneously that such actions are somehow rationalised through agri-environmental activities, and therefore the creation of environmental public goods. Unfortunately, there is no universally accepted research methodology and, interestingly, the eco-efficiency approach is dominant in the literature.

Eco-efficiency versus eco-effectiveness – literature review

The term "eco-efficiency" appeared in the 1990s as a practical tool to measure sustainability. It was introduced by the World Business Council for Sustainable Development [WBCSD, 2000] to identify a management philosophy aimed at encouraging businesses to search for environmental improvements that yield parallel economic benefits. In other words, companies are asked to be more environmentally responsible and more profitable. The OECD [1998] refers to eco-efficiency as the efficiency with which ecological resources are used to meet human needs, which can be measured as the ratio of an output divided by an input, where the output is expressed by the value of products and services produced by a firm, sector or economy as a whole, and the input is the sum of environmental pressures generated by the firm, the sector or the economy. Therefore, an output increase, for a given level of inputs, or an input decrease, for a given level of outputs, leads to an improvement in eco-efficiency. However, a change in eco-efficiency does not necessarily reflect a corresponding change in terms of overall sustainability, since what this ratio measures is only the relative level of environmental pressure in relation to the volume of economic activity, while sustainability is more related to absolute levels of environmental pressure [Bonfiglio et al. 2017].

Thus, the above approach is somewhat contradictory to the idea of environmental sustainability, which should take into consideration the actual environmental effect (*eco-effectiveness*) in farms. In addition, the common agricultural policy is evolving and, next to its original assumptions related to the assurance of quantitative and qualitative food safety, support for agricultural incomes etc., sets goals related to respect for the environment or the creation of public goods, in particular environmental ones. Therefore, it is interesting to what degree the support for agriculture, from various CAP programmes, national and regional policies, affects the increase in eco-efficiency of farms, and to what extent it affects their eco-effectiveness. At this point a certain conflict between eco-effectiveness and eco-efficiency might be expected, as the programmes supporting agriculture surely include such that have a strong impact on eco-efficiency issues, but also such wherein eco-effectiveness will be dominant. This conflict impedes the sustainable development of agriculture. The results of the planned research, then, will contribute significantly to the discussion regarding the future of the EU's common agricultural policy after 2020, but also the national and regional agricultural and environmental policies in the context of its evolution. It is not certain to what extent the hitherto funding of agriculture facilitates the implementation of goals regarding its sustainable development, and to what extent it consolidates an industrial model of production where issues of efficiency will be of key importance.

Methodology for measuring eco-efficiency and eco-effectiveness

Estimating Environmental Sustainable Value with frontier benchmarking (ESV, authors' original methodology) was carried out using two approaches: 1) eco-efficiency as a trade-off of productivity versus environment, and 2) eco-effectiveness as an ecological approach to environmental public goods versus polluting capital.

Environmental Sustainable Value (ESV) is a value-oriented method, developed as a means of measuring agricultural eco-efficiency at microeconomic level (e.g an agricultural farm). This enables a synthetic assessment of a farm's contribution to farming sustainability, taking into account the efficiency resulting from using economic, social and environmental resources in comparison to the opportunity cost [Figge and Hahn 2005, Illge et al., 2008, Van Passel et al., 2007].

The calculation formula for determining the ESV of farms in the regions needs to indicate a benchmark farm. The author's proposal is to calculate benchmark indicators *yb, rb* using a frontier approach, according to the DEA method. In the literature, the use of DEA techniques to measure eco-efficiency in different sectors, as well as for the assessment of the environmental performance of farms and the agricultural sector, is widely known [Gadanakis et al., 2015]. Conversely, there are only a few studies which estimate eco-efficiency at farm level using the DEA approach [Picazo-Tadeo et al. 2011; Gómez-Limón et al., 2012; Picazo-Tadeo et al., 2012; Berre et al. 2015; Gadanakis et al. 2015; Pérez Urdiales et al., 2016]. DEA is a linear-programming (LP) methodology that, starting from data on inputs and outputs of a sample of decision-making units (DMUs), allows the construction of a piece-wise linear surface over the data points. This frontier surface is constructed through the solution of a sequence of LP problems, one for each DMU. The distance between the observed data point and the frontier measures the relative inefficiency or ineffectiveness of each DMU. Within the DEA approach, several models have been developed since the pioneer work of Charnes et al. [1978]. First of all, DEA can be either input- or output-oriented. In the first case, the DEA method defines a frontier by searching for the maximum possible reduction in input usage, with output held constant. While, in the second case, the DEA method seeks the maximum proportional increase in output production, with input levels held fixed. Moreover, in relation to returns to scale, two approaches can be adopted: either constant or variable. The latter encompasses both increasing and decreasing returns to scale.

The calculation formula advocated also in the studies of Burja C. & Burja V. (2016), Illge et al., (2008) was used to determine the environmental sustainable value ESV of the farms in regions:

$$ESV_i = \frac{1}{m}\sum_{j=1}^{m} r_{ij}\left(\frac{y_{ij}}{r_{ij}} - \frac{yb_{ij}}{rb_{ij}}\right)$$

ESV_i is the sustainable value afferent to a farm from region *i*; r_{ij} and rb_{ij} represent the resource value (polluting capital as input indicator) of type *j* and region *I* of the analysed farm, i.e. of the farm considered as reference system; y_{ij} and yb_{ij} are the return of resources (effects indicators) of the analysed and benchmark farm; *i*= 1..n is the region and *j*=1...m is the type of analysed resource.

The advantage associated with the use of DEA in measuring eco-efficiency or eco-effectiveness for ESV indicator is the identification of a set of optimal weights for inputs (r) determined at farm level which maximise the eco-efficiency or eco-effectiveness score relative to the other farms in the sample. The optimising formula used to identify benchmark units is orientated as follows, for eco-efficiency:

$$\max_{r} OUT = \frac{\sum_{k=1}^{n} y_{ij}}{\sum_{j=1}^{m} r_{ij}}$$

and for eco-effectiveness (due to constant resources of public goods):

$$\min_{y} INP = \frac{\sum_{k=1}^{n} y_{ij}}{\sum_{j=1}^{m} r_{ij}}$$

where *OUT* means output indicator, INP input indicator, y_{ij} indicates, as above, output *j* of a farm *i*, r_{ij} the value of polluting capital as input indicator, and *k*=1...*n* is the type of analysed output.

In the first approach (eco-efficiency as a trade-off: productivity versus environment) we use the following variables: the input indicator will be polluting capitals (crop protection, fertilisers, energy, non-wood area, stocking density) and as an effect indicator – total output, total output crops and total output livestocks (three separate models). In the second ecological approach (environmental public goods versus polluting capital) we will use the subsequent variables: the input indicator will be polluting capitals (as above) and as the effect indicator – environmental subsidies. 125 European regions (excluding the Canaries, Cyprus, Malta and Luxembourg – outliers) were analysed in 2015, as the last available year in FADN, because we are treating this as a pilot study, focusing first of all on the methodology.

Results

Based on the analyses carried out, two rankings of EU regions were made, classifying them according to the eco-efficiency and eco-effectiveness of the agricultural activity conducted there. It was observed that the most intensive European agriculture (Dutch, Danish, German, French) enjoys the highest degree of environmental sustainability according to the eco-efficiency approach, where the effect is the total output value. A high position in this ranking means that agricultural producers from these regions achieve relatively the best ratio of the above-mentioned total output to the polluting capital input used. To put it differently, the productivity of the polluting capital (fertilisers, plant protection products, energy, etc.) is relatively the highest in the case of farms from this group of EU regions (cf. Table 1, 3). At the bottom of the ranking, there is the agriculture of certain German regions, Slovakia, Czech Republic, Estonia, Scotland, and individual Romanian or Bulgarian regions, which are the least efficient in terms of eco-productivity. Table 1 also shows ESV, expressed in euros, brought in by farms from individual EU regions – for instance, the best (Dutch) farms make as much as ca. EUR 173,000 of environmental sustainable value considered from the point of view of eco-efficiency. On the other hand, in the case of farms which are the weakest according to this criterion (e.g. Comunidad Valenciana), the value remains at a relatively high, negative level (ca. EUR -248,000). It can therefore be assumed that the value reflects the level of inefficiency in the use of the polluting capital input relative to the total output achieved. At the same time, the amount can determine the value of environmental public goods which these farms should deliver in order to compensate for the negative effects of their activity.

Table 3, illustrating the average values of the analysed variables for the best and worst ten EU regions according to this ranking, indicates that the average value of animal output in both groups is comparable, however, regions with the highest environmental sustainable value (ESV) are characterised by a relatively high index of stock density (twice as high as in the regions with the lowest ESV). This is a curious phenomenon, which may prove that greater intensification of production does not necessarily go hand in hand with higher profitability. We are touching upon the issue of the technological treadmill here, the essence of which is a phenomenon consisting in agricultural income not growing proportionally to increases in agricultural productivity. In order to increase agricultural productivity, farmers have to keep investing in new technologies and increase the scale of production. This is more an affliction of the agriculture of highly developed countries, where subsidies are largely used to support production [Czyżewski, Staniszewski 2016]. Crop production is half as large in the regions with the lowest ESV. This results in a higher use of plant protection products and fertilisers, disproportionately to the production value, as the value of their use is about three times higher than in the case of farms from the regions with the highest ESV. The situation is similar in terms of the energy intensity of production – in the case of the latter, it is twice as low. There are four times fewer non-wooded areas here as well.

Yet the highest environmental sustainability according to the idea of eco-effectiveness, where the result is the amount of environmental subsidies obtained, can be observed in the case of agriculture which can be considered as extensive. It can be found in the Finnish, Swedish, and Austrian regions. On the opposite side, we find farms from regions which clearly show less respect for the environment, farming relatively more intensively, i.e. German, French, and Slovak farms (cf. Table 2). An analysis of the average amounts of the variables under study on ten farms with the highest and lowest ESV indicates that in the former, the sum of environmental subsidies obtained is slightly higher. However, farms with a positive, relatively high ESV according to the eco-effectiveness criterion are characterised by clearly lower use of fertilisers (eight times lower), plant protection products (more than twenty times lower), and energy (four times lower). Stock density seems not to be of much significance, yet it should be noted that in the case of these farms, there are five times fewer non-wooded areas.

It can be said that the philosophy of the operation of farms achieving a high ESV level according to the eco-effectiveness criterion lies in the lowest possible strain on the natural environment, which clearly does not go hand in hand with the highest production results, and which can be observed in the group of farms with the highest ESV according to the eco-efficiency criterion. Thus, we should ask ourselves the question of what level of environmental sustainability we are striving for within the framework of CAP principles. From which farms should we expect an increased supply of public environmental goods?

Table 1. Top and bottom ten environmentally sustainable regions of the EU according to eco-efficiency (benchmark – the best unit, DEA) (125 EU regions, 2015, in €)

Top ten		**Bottom ten**	
Region	**ESV**	**Region**	**ESV**
The Netherlands (NED)*	172937,5	Saarland (DEU)	-28357,7
Denmark (DEN)	91343,5	Estonia (EST)	-33807,5
Provence-Alpes-CĂ’te d’Azur (FRA)	79004,8	Severozapaden (BGR)	-36472,3
Bretagne (FRA)	77347,2	Centre (ROU)	-40995,6
Vlaanderen (BEL)	75854,8	Sachsen-Anhalt (DEU)	-47630,7
Champagne-Ardenne (FRA)	56123,9	Czech Republic (CZE)	-87518,2
Pays de la Loire (FRA)	52674,9	Mecklenburg-Vorpommern (DEU)	-88651,4
Aquitaine (FRA)	47821,1	Scotland (UKI)	-97614,7
Lombardia (ITA)	47336,4	Slovakia (SVK)	-193744,0
Languedoc-Roussillon (FRA)	42297,3	ComunidadValenciana (ESP)**	-248037,0

*best region, ** worst region

Source: own calculation based on FADN.

Table 2. Top and bottom ten environmentally sustainable regions of the EU according to eco-effectiveness (benchmark – the best unit, DEA) (125 EU regions, 2015, in €)

Top ten		**Bottom ten**	
Region	**ESV**	**Region**	**ESV**
Pohjois-Suomi (FIN)*	6221,5	Centre (FRA)	-15814,8
Aosta (ITA)	4100,2	Haute-Normandie (FRA)	-16262,4
Etela-Suomi (FIN)	3808,4	ĂŽle-de-France (FRA)	-18241,9
Pohjanmaa (FIN)	2959,1	Sachsen (DEU)	-18470,0
Sisa-Suomi (FIN)	2809,8	Thueringen (DEU)	-18755,2
Lan inorra (SVE)	1739,6	Picardie (FRA)	-18779,4
Skogs-ochmellanbygdslan (SVE)	1694,7	Sachsen-Anhalt (DEU)	-27081,6
Austria (OST)	1522,2	Slovakia (SVK)	-28116,1
Cantabria (ESP)	1245,1	Mecklenburg-Vorpommern (DEU)	-42516,3
Alentejo e do Algarve (POR)	202,7	ComunidadValenciana (ESP)**	-76782,4

*best region, ** worst region

Source: own calculation based on FADN.

Table 3. Average values of the analysed variables in agriculture of the ten best and worst regions of the EU (benchmark – the best unit, DEA)

Variable	Eco-efficiency		Eco-effectiveness	
	Top 10	Last 10	Top 10	Last 10
Total crop output €	136193,8	206087,4	-	-
Total animal output €	115403,7	113793,2	-	-
Environmental subsidies €	-	-	8509.2	7011,1
Fertilisers €	9740,0	32734,3	5191,5	43809,2
Crop protection €	8614,8	23907,1	1686,5	34811,6
Energy €	12783,1	30304,9	9864,0	40786,5
Non-wooded areas ha	61,0	257,4	62,4	305,7
Stock density LU/ha	1,84	0,93	1,1	1,2
Environmental Sustainable Value €	74274,2	-89856,3	3040,7	-21916,3

Source: own calculation based on FADN.

Conclusions

The aim of the article was to present the environmental sustainable value generated by farms in EU regions. The approach to this issue differed, depending on whether it was based on eco-efficiency or eco-effectiveness. The study results indicate a fundamental problem, namely, the environmental sustainability of farms is different depending on the criterion we apply. If we assume the eco-efficiency criterion, it is the highest where the adopted input (polluting capital) produces relatively the highest effect in the form of the total output. When it comes to the eco-effectiveness criterion, however, there is a different priority – not production, but the lowest possible strain on the natural environment, which results from the fact that the highest ESV is achieved in regions where the ratio of environmental subsidies (output) to the polluting capital (input) is the best. This results from a certain rationalisation of agricultural producers' behaviours – on the one hand, they use much less of the above-mentioned input, yet at the same time, they obtain slightly more environmental subsidies. As observed above, this does not go hand in hand with the highest production results, which also indicates a certain contradiction in achieving environmental and economic sustainability. This recognition is important for policy makers on the future of CAP after 2020, and it is important to review the objectives of CAP in the context of understanding environmental sustainability and to consider which pathway – eco-effectiveness or eco-efficiency –

is appropriate for providing society with environmental public goods. This recognition is important for EU policy makers in the light of the future of CAP after 2020: the objectives of CAP should be reviewed in the light of an understanding of environmental sustainability and which pathway – eco-effectiveness or eco-efficiency – is appropriate for the delivery of environmental public goods to society.

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