Assessing programmes for the provision of agri-environmental services
– An efficiency analysis realized in Southern Germany –

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Abstract

Agricultural land use does not only concern farmers, but is of high relevance for the environment. Agri-environmental programmes aim to foster the environmental soundness of agricultural production. The aim of this study is to analyse the impact of agri-environmental programmes on the economic and the environmental performance of farms. Using the nonparametric method of Data Envelopment Analysis (DEA), we calculated the economic as well as the environmental efficiencies of farms and examined whether farms are able to succeed in combining environmental and economic efficiency. As study object serves a South German agri-environmental programme, the Bavarian KULAP. A farm survey was conducted covering a total of 102 farmers. The results show that farmers who participate in agri-environmental measures with tight requirements succeed in combining environmental and economic efficiency. We conclude that DEA is a suitable instrument for assessing agri-environmental programmes.

Key words

Agri-environmental programme, data envelopment analysis, environmental efficiency, economic efficiency

1. Introduction

From a social point of view the importance of agriculture goes far beyond the production of food and raw materials. Due to its extensive land-use, agriculture fundamentally shapes the landscape and its functions. It has significant influence on the quality of biotic and abiotic resources and determines biodiversity and the quality of water and soil resources (c.f. HEIßENHUBER et al. 2003). Farmers who attach great importance to agri-environmentally sound production cannot use their financial and labour resources exclusively for conventional production but also have to use them for the provision of agri-environmental services. For instance, in order to maintain landscape elements, farmers have to take on an increased workload, as well as face economic disadvantages because of not being able to use the most modern technology (c.f. KAPFER et al. 2002).

Agri-environmental programmes aim to foster the environmental soundness of agricultural production. Their goal is either to maintain existing environment-friendly production processes or even increase their importance by compensating farmers' loss of income. The question arises whether such programmes succeed in promoting environmental performance of farms without threatening economic performance. A suitable method allowing the economic and environmental performance of farms to be assessed is the Data Envelopment Analysis (DEA, cf. CHARNES et al. 1978). This technique integrates economic as well as environmental aspects and helps to distinguish between efficient and less efficient farms. A notable strength of DEA is that it allows for the consideration of multiple inputs and outputs while not requiring identical units. Consequently, even factors which cannot (or only at great expense) be expressed in monetary units can be included in the assessment. Furthermore, DEA can be applied to identify model farms which may be useful in understanding how environmentally sound land-cultivation can be promoted.

There are a number of studies which analyse farm performance with the help of DEA. For instance, BALMANN and CZASCH (2001) calculated and compared the economic efficiencies of East German farms. REIG-MARTINEZ and PICAZO-TADEA (2004) estimated the economic efficiencies of Spanish citrus farms in order to identify best-practice farms. Numerous studies also consider agri-environmental aspects. For instance, REINHARD et al. (2000) calculated the environmental efficiency of Dutch dairy farms and DE KOEIJER et al. (2002) measured the sustainability effects of Dutch sugar-beet growers by taking into account ecological efficiency. LATACZ-LOHMANN (2004) complements conventional efficiency calculations with environmental indicators.

In this paper we apply a DEA model in order to assess the impact of agri-environmental programmes on the economic and environmental performance of farms. In the following chapter the DEA model is presented and the efficiency measures are defined. In the next chapter the case study is introduced and case-sensitive input and output factors are determined. Afterwards the results of the model calculations are presented and finally results and methodical approach are discussed and conclusions are drawn.

2. Methodical approach

DEA is a non-parametric mathematical programming approach which enables the comparison of production performances of so-called Decision-making Units (DMU). In our case these DMUs are farms deciding on the use of productions factors in order to maximise farm output. The performance of each farm is rated by calculating the output-to-input ratio of the respective production processes; the less input a farm requires for producing a given output or the more output it produces with a given input, the higher the efficiency of the farm. The final efficiency score is derived within Data Envelopment Analysis by benchmarking the output-to-input ratio of an individual farm against the output-to-input ratio of all best-practice farms. These farms are part of an envelope forming a reference frontier for the benchmark process (cf. COOPER et al. 2007). Doing this the relevance of input (X) und output factors (Y) are expressed by weights (η in the input case, μ in the output case), which are determined in a way that the assessed DMU achieves as high a level of efficiency as possible.

A fundamental requirement regarding the set of input and output variables is that they have to cover the full range of resources used. Moreover, all relevant activity levels and performance measures should be captured (DYSON et al. 2001). However, the number of input and output variables is to be kept at a distinctly smaller level than the number of DMUs (or farms, respectively). Otherwise, too many DMUs will appear efficient and no relevant conclusions are possible. To minimize the number of variables to a suitable ratio with respect to the number of DMUs, the variables have to be aggregated. DYSON et al. (2001) suggest in this context that the number of DMUs should be at least twice the product of the number of input variables and the number of output variables.

Using DEA for the assessment of farms and agri-environmental programmes, we can define a standard efficiency measure for both economic and ecological farm performance. The ***standard environmental efficiency*** ($EnvE_{Stan}$) expresses how many environmental services a farm renders (per ha UAA) to society. Thus, the environmental efficiency indicates the societal relevance of the farm. The second indicator, the ***standard economic efficiency*** ($EconE_{Stan}$), considers the land input and economic inputs and relates it to economic output. It expresses the economic success of the farm and therefore represents the perspective of farmers.

From the technical point of view both standard efficiency measures are calculated with the Charnes-Cooper-Rhodes model (cf. COOPER et al. 2007, p. 42). Since the main (economic) goal in agriculture is to maximize output rather than to minimize input, we apply the outputorientated version (cf. COELLI and RAO, 2003). However, it should be emphasized that with either output or input orientation the technical efficiency scores will be the same unless a variable returns to scale model is applied. The linear programming problem to be solved for each farm is as follows:

$$\max_{\phi,\lambda} \phi \tag{1}$$

$$\text{s. t.} \quad -\phi y_i + Y\lambda \geq 0$$

$$x_i - X\lambda \geq 0$$

$$\lambda \geq 0 \ ,$$

where ϕ is a scalar, λ is a Nx1 vector of weights, X is a NxK matrix of input quantities for all N farms, Y is a NxM matrix of output quantities for all N farms, x_i is a Kx1 vector of input quantities for the i-th farm and y_i is a Mx1 vector of output quantities for the i-th farm. In order to derive the technical efficiency θ, expressing the performance of the studied farms, the reciprocal of ϕ has to be calculated. In order to derive input weights η and output weights μ, additional to the above described envelopment model the multiplier model has to be solved (cf. COOPER et al. 2007, p. 42).

The calculation of a variety of alternative efficiency measures provides a deeper insight into farmers' behaviour. With respect to economic efficiency, the question arises whether efficiency results depend on farms size. Small farms seem to achieve lower efficiency results due to economy of scale effects. In order to consider potential scale effects an ***increasing-returns-to-scale economic efficiency*** ($EconE_{IRS}$) model is applied. It is based on the increasing-returns-to-scale version of the Banker-Charnes-Cooper (BCC) model; mathematically it is achieved by adding the following constraint to formula (1):

$$e\lambda \geq 1, \tag{2}$$

where e is a row vector with all elements unity (cf. COOPER et al. 2007, p. 87 and 138). It is to note, that increasing size effects are exclusively calculated with regard to economic efficiency, since such effects are not assumed to be of major relevance within the provision of agri-environmental services such as the provision of low-intensity use areas or landscape elements.

In order to measure the impact of these agri-environmental payments on the economic success of farms, an ***economic efficiency without-AEP-payments*** ($EconE_{noAEP}$) measure is calculated.

The measure is based on the standard economic measure while not considering AEP compensation payments.

It should be noted that for calculating the efficiency the factors weighting input and output variables can be freely chosen. In other words, each farm (or DMU) can exclude those variables from the efficiency calculations which are, from the farm's point of view, "unfavourable". Consequently, a DMU may be efficient even if it achieves excellence only in a specific field. This, however, appears to be problematic, in particular from the point of view of sustainability. A more holistic approach is necessary since it makes no sense, for example, to protect soils but spoil groundwater. The respective efficiency measure is called the ***sustainable environmental efficiency*** ($EnvE_{Sust}$). It is calculated with the assurance region global model and demands that every j-th virtual output μy_j make up at least 10 % of the total virtual output μY of each individual farm (COOPER et al., 2007, p. 173; also cf. ALLEN et al., 1997):

$$0.10 \leq \frac{\mu y_j}{\mu Y} \leq 1 \qquad (3)$$

3. Case study "The Bavarian Cultural Landscape Programme"

3.1 The Bavarian Cultural Landscape Programme

The model is applied to assess the Bavarian cultural landscape programme, a regional agri-environmental programme (AEP) corresponding to EU Council Regulation 1257/99. The aim of the programme is to foster the provision of environmental services through agriculture. It offers various measures, ranging from organic farming to the extensification of arable land and grassland cultivation (tab. 1). Farmers can participate voluntarily and are compensated for their financial and organisational expenditure.

Participating farmers have to fulfil certain land-use requirements. Organic farming, for instance, requires that the entire farm is cultivated as defined by EU Council Regulation 2092/91; in compensation farmers receive a yearly payment of €255/ha. With respect to low-intensive grassland use, farmers can choose between two measures: the first demands a minimum as well as a maximum stocking intensity and prohibits area-wide the use of pesticides; the second – more challenging – measure additionally prohibits the application of mineral fertilizers. Compensation payments for these two measures are €100/ha and €205/ha respectively. Diversifying crop rotation on arable land is subsidized with payments between

€50/ha and €180/ha; the cultivation of intensive crops such as maize, wheat and vegetables may not exceed certain limits.

Table 1: Selected measures of The Bavarian Cultural Landscape Programme

Measure		Conditions	Subsidy* €/ha
Organic farming		- farm cultivation according to EU Reg. 2092/91 on organic production - stocking rate: > minimum 0.5 livestock units per hectare main fodder area (farms with more than 50 % grassland use) > maximum 2.0 livestock units per hectare UAA (all	255.-
Extensification of grassland use	reduced version	- no ploughing of grassland - no area-wide usage of pesticides - stocking rate > minimum 0.5 livestock units per hectare UAA > maximum 2.0 livestock units per hectare UAA**	100,-
	enlarged version	according to reduced version, additionally -no mineral fertilizer on grassland	205,-
Diversification of arable land use		- high intensive crops, like maize, wheat, vegetables and beets, up to 30 % of the arable land - maize up to 20% of the arable land	50,- up to 180,-

* funding period 2000-2006

** exceptions up to 2.5 livestock units per hectare UAA possible, then reduced subsidies

Source: BayStMLF (2002); ECKSTEIN and HOFFMANN (2008)

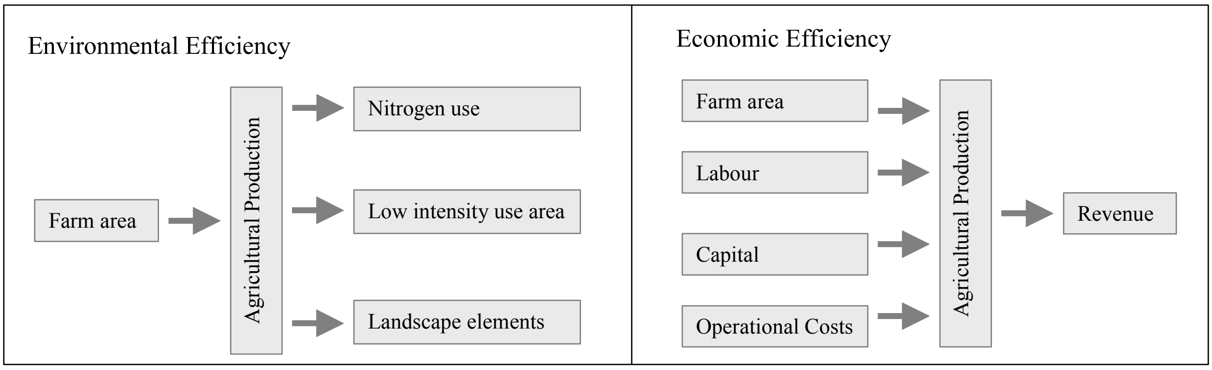
3.3 Definition of input and output factors

Figure 1 gives an overview of the selected input and output variables. It also shows which variables are output factors and which are input factors. Altogether, four factors describe the environmental efficiency and five factors the economic efficiency. It becomes clear that the environmental efficiency concentrates on the environmental services delivered by the farm, whereas the economic efficiency shows how much input a farm needs in order to produce economic output (revenue).

The economic input factor *capital* summarizes the capital value of machinery and equipment and the capital value of buildings arising on a farm. In order to reflect the yearly expenses, the values of the capital assets are depreciated (cf. BALMANN et al. 2001). *Operational costs* are costs which arise on a farm in the short term. They include costs for energy (fuel and power supply), plant protection, fertilizers, fodder, hired machinery and animals. *Labour* considers agricultural work provided by family members and employees; hired machine work is not included in this factor. On the output side, there is one economic indicator, the yearly *revenues* achieved by a farm: it summarizes the revenues achieved with animal and crop production. In addition, subsidy payments granted to the farm are considered. These include the payments for agri-environmental programmes, as well as the less-favoured area payments.

In addition, the direct payments of the European Union are included, since these payments had not been decoupled at the moment of the farm survey and are thus of decisive importance for farm organization.

Figure 1: Input-output analysis



Source: own figure, cf. KANTELHARDT and ECKSTEIN (2007); ECKSTEIN et al. (2008)

As indicators for environmental output we selected the low-intensity use area, the area covered by landscape elements and the use of nitrogen. *Low-intensity use area* is the total amount of arable land which is cultivated in a low-intensive manner. Thus, crops like maize, wheat, winter barley, triticale or beets are excluded, but crops like grain legumes, peas, clover or ryegrass or set-aside areas are considered. Furthermore, the total amount of low-intensity use grassland, such as meadows and pasture with a maximum of two yields per year is included in this variable. The factor *landscape elements* summarize: the area covered by hedges and groves, wetlands such as ponds and reed and other landscape elements such as fringes and stone cairns. As an indicator for an undesired environmental performance, we use the farms' use of *nitrogen*. It considers nitrogen inputs by mineral and organic fertilizers. This indicator represents, in the narrow sense, the risk of water pollution (by nitrogen) and air pollution (by nitrous oxide); in the wider sense, it stands for general land-use intensity and potential pollution risks. To ensure that the selected inputs are correlated with the outputs, nitrogen use is introduced as transformed value on the output side. The transformation is as follows:

$$f(u) = -u + ß \quad (4)$$

where u is a parameter for the nitrogen use and ß a constant to avoid negative values (cf. SCHEEL 2001).

4. Results

The following results are based on a farm survey carried out with a total of 102 farmers. The number of farmers who did not participate in the Bavarian agri-environmental programme was 19. All the others worked on different measures: 27 participated on the reduced and 38 on the enlarged grassland-use extensification measure; 12 selected the diversification of arable land use and 6 went for organic farming.

Table 2: Mean efficiency values with respect to AEP participation

Type of AEP participation (Number of farms)	Efficiency measures				
	$EnvE_{Stan}$	$EnvE_{Sust}$	$EconE_{Stan}$	$EconE_{IRS}$	$EconE_{noAEP}$
No participation (19)	0.53	0.24	0.79	0.79	0.81
Reduced extensification of grassland use (27)	0.58	0.27	0.69	0.71	0.71
Enlarged extensification of grassland use (38)	0.72	0.18	0.77	0.81	0.74
Diversification of arable land use (12)	0.77	0.35	0.59	0.63	0.60
Organic farming (6)	0.79	0.28	0.85	0.89	0.82
Significance (p-value) [1)]	*0.000*	*0.375*	*0.014*	*0.006*	*0.030*

[1)] Kruskal-Wallis H-Test

Source: own calculations

The results of the efficiency calculations presented in Table 2 show that the efficiencies are clearly distinguishable; apart from the $EnvE_{Sust}$ case all differences between groups are significant. The mean efficiencies of the $EnvE_{Stan}$ measure show that farms not participating and farms participating in measures with minor requirements show lower efficiency values than farms participating in more demanding measures. The highest mean efficiency value is obtained by those farmers which work organically.

However, the results for $EnvE_{Sust}$ demonstrate that the achieved efficiencies are often not based on excellent results in all environmental categories. Consequently efficiency rates clearly decrease if farms have to fulfil minimum weights in all categories. This loss of efficiency affects all AEP participation groups. However, in particular organic farming and the enlarged version of grassland extensification lose out, so that diversification of arable land use becomes the most efficient measure. It should again be emphasised that the differences between groups in mean efficiencies of $EnvE_{Sust}$ are not significant.

With regard to economic efficiency it becomes clear that $EconE_{Stan}$ distinguishes significantly between AEP participation groups. Organically working farms and farms participating in the enlarged grassland extensification measure achieve the highest efficiency scores. In comparison, farms participating in the reduced grassland extensification and farms participating in the arable land-use measure perform worse. This finding can be explained with the different level of subsidies, which is higher in the case of organic farming and enlarged grassland extensification, and lower in the case of reduced grassland extensification and arable land-use measure. Farms which do not participate in the AEP, also gain high economic efficiency values due to the absence of AEP production constraints.

As the $EconE_{IRS}$ results show, scale effects are of minor importance. The results are reasonably similar to the $EconE_{Stan}$ case, albeit that farms participating in AEP measures gain slightly in efficiency. This finding shows that for participants in AEP measures scale effects are of higher importance than for non-participants. Also the non-consideration of AEP payments ($EconE_{noAEP}$) has almost no impact on the resulting economic efficiency. However, some farms gain in efficiency while others lose out, especially those who receive high AEP payments (organic farming, enlarged extensification of grassland-use).

The result of the study shows that economic success does not necessarily go with good results in environmental performance. Non-participants at the agri-environmental programme, for instance, gain high economic efficiency due to high-intensity production but at the expense of environmental performance. On the other hand, participants in the diversification of arable land succeed in environmental performance, but lose out in economic efficiency. However, some farms succeed in combining environmental and economic efficiencies. This applies in particular to organic farms but also for farmers who participate in the enlarged grassland extensification measure. This is due to adequate subsidy as well as due to special marketing in the case of organic farming products.

5. Discussion and conclusions

The results show significant differences in environmental performance between participants and non-participants and between the different groups of participants. In particular the environmental achievements of farms not participating in the agri-environmental programme are poor. With regard to participating farms, their environmental achievements increase, as do the requirements they have to fulfil. Furthermore, it could be shown that an environmental soundness of production does not necessarily have a negative impact on the economic performance of farms. This is particularly true for farms whose losses can be wholly compensated by the subsidies, and for farms which can achieve higher prices for their products, such as organic farming.

However, some farms combine a good ecological with a poor economic performance; this applies in particular to the farms participating in the AEP measure "diversification of arable land use". This finding indicates that this group of farmers is not sufficiently compensated for its social services. With regard to these farms, a further analysis of the economic viability seems important, since our results indicate that the above-average ecological performance of these farms is at risk due to their poor economic performance. This result is supported by a study of GANZERT et al. (2007), who analysed farm behaviour with regard to common welfare and management capabilities and found similar results: they came to the conclusion that certain farmers provide an above-average number of social services but run the risk of abandoning farming due to comparatively poor management capabilities.

One consideration is that there may be further parameters which influence both the economic and the environmental performance of the farms, for instance full time or part-time farming. It was shown that within the group of participants the proportion of part-time farming is considerably higher (27 %) than in the group of non-participants (17 %). According to our own calculations, part-time farmers achieve an average environmental efficiency of 0.76; in contrast, full-time farmers achieve an average environmental efficiency of 0.62. Regarding economic efficiency, the results are vice versa. The economic efficiency of full-time farmers achieves an average of 0.76, whereas part-time farmers only reach an average economic efficiency of 0.68.

For the interpretation of the results the selected input and output-parameters have to be considered. To calculate the environmental efficiency of the farms, the parameters "*landscape elements*", "use of *nitrogen*" and "*low-intensity use area*" have been chosen. These parameters mainly refer to the performance of a farm in respect to biodiversity and the protection of species and habitats. However, the environmental performance of agriculture is manifold and may also concern soil, climate or landscape. To show the comprehensive effects, appropriate parameters must be included in the calculations. This is especially important for the evaluation of the agri-environmental programmes because of the multi-dimensional objectives of these programmes.

In conclusion, the Data Envelopment Analysis is an appropriate method to incorporate the environmental performance in the evaluation of enterprises, especially of farms. This is due to the possibility of using variables with environmental relevance without altering them in monetary values. This trait makes DEA also suitable in the case of agri-environmental programmes evaluation, for the effects of AEPs are only in a few cases measurable in monetary terms. With this method, an integrated consideration of economic and environmental performance in agricultural production is possible and thus accounts for the multi-functionality of agriculture.

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