SOCIAL VERSUS PRIVATE EFFICIENCY: A COMPARISON OF CONVENTIONAL AND ORGANIC FARMING SYSTEMS IN VINEYARD PRODUCTION

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Paper prepared for presentation at the 12th EAAE Congress
'People, Food and Environments: Global Trends and European Strategies',
Gent (Belgium), 26-29 August 2008

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Abstract

Organic farming may be seen as an alternative approach to agriculture that tries to integrate environmental concerns in management practices. By means of DEA, in this work we calculate and compare the efficiency of two samples of conventional and organic vineyards, from two different perspectives: in the first instance, the relationship between inputs and outputs is considered, exclusively, that is, the private efficiency; in the second instance, social efficiency is calculated, and the environmental impacts arising from the activity are also included. The comparison of the results obtained in these two scenarios allows us to draw some conclusions on the efficiency of organic farming in dry-farming conditions.

Keywords: organic farming, efficiency, environmental impact

I. INTRODUCTION

Increasing public concern for the environmental externalities of agricultural production has awoken great interest over the last years in organic farming as a production system which can improve the impact of agriculture on the environment.

Organic farming may be seen as an alternative approach to agriculture that tries to integrate environmental concerns in management practices. Currently, organic farming is regulated in the EU (Council Regulation (EEC) No 2092/91[1]) [1] as an environmental labelling program whose technical standards prohibit the use of synthetic chemical fertilisers and pesticides. This main criterion, in addition to the use of several agronomic practices, seeks for the amelioration of both the environmental impact of agricultural production and the safety of organic products.

The technological adaptation of organic farming to these environmental standards gives rise to some serious questions regarding its technical and environmental efficiency. The literature that compares the technological performance of conventional and organic farming is scarce and far from any definitive and/or conclusive results on the technical-environmental efficiency of these systems. Differences between conventional and organic farming as regards the provision of different levels of environmental quality are extensively acknowledged. Works based on long-term experimental field trials, such as the DOC-trial (Switzerland) and the Rodale Institute Farming Systems Trial (US), established in 1978 and 1981, respectively, give evidence of the better results obtained in indicators of environmental impact, although not necessarily in all of them (Dobbs *et al.*, 2003) [3].

With reference to yield comparisons, it is normally accepted that the yields of organic agriculture are lower than those of conventional farming (Offermann and Nieberg, 2000) [4]. However, Lotter (2003) [5] considers that these comparisons are rather incomplete, because two important points are not taken into account. On the one hand, the differences in quality, with higher dry matter content in the case of organic produce. On the other hand, the high variability of climatic conditions and soil fertility between the different farm groups, that make organic farms to outperform conventional ones in conditions of drought, severe weather or flooding.

Studies that compare the technical efficiency and overall factor productivity of conventional and organic farming are rare, but certainly constitute an important progress in the comparison of the technological performance of these two production systems. Among the scarce literature that applies production economics

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[1] Council Regulation (EEC) No 2092/91 [1] has been repealed by Council Regulation (EC) No 834/2007 [2], which will apply as from 1 January 2009.

in this field, we may cite the works by Tzouvelekas *et al.* (2001a and 2001b) [6, 7] and by Oude-Lansink *et al.* (2002) [8]. Tzouvelekas *et al.* compare the technical efficiency of two samples of conventional and organic olive-growing farms [6] and cotton farms [7], respectively. The results shown in these two works, though, are mixed. On the one hand, they find that organic olive-growing farms are less efficient than conventional ones. This is attributed, among other reasons to structural problems, which make it more difficult for organic farms to fully exploit the potential of their technology; lack of scientific research and extension services are also mentioned among the factors that contribute to lower organic efficiency levels with respect to their own frontier. On the other hand, higher efficiency levels are found, with respect to their own frontier, for organic cotton farms, which is attributed, among other factors, to an increased effort put in place by organic farmers due to lower profit margins and a more prudent choice of inputs, both in quantity and quality, due to stricter organic regulations. In addition, the authors point to a more promising potential of organic farms for reducing dependence on external inputs, in line with organic principles, which, in turn, may lead to an increased competitiveness.

Oude-Lansink *et al.* (2002) [8], in their study on Finnish crop and livestock farms, find that organic farms are more efficient than conventional ones when distance is measured with respect to the isoquant of each production system, respectively. Nevertheless, the productivity of organic farming, measured by the distance of their own isoquant to the envelope of the isoquants, or the meta-frontier of efficiency, is lower.

Although, as mentioned above, these studies constitute an important advance in the analysis of the technological performance of organic agriculture, they have a serious limitation, because, as Oude-Lansink *et al.* (2002) [8] explicitly acknowledge, environmental external effects arising from agricultural practices are not included in the analysis, which, they consider, might have important implications.

This work tries to go beyond the aforementioned limitation and becomes, to the best of the authors' knowledge, the first attempt to calculate and compare the efficiency of conventional and organic farms taking into account the environmental impact of the agricultural practices implemented in the farms. This way, two variables, seen as among the most representative of current environmental impact of agriculture, namely, nitrogen excess and pesticide impact, are included in the dataset.

We may say, therefore, that this contribution represents a shift in the predominant view of agriculture only as a private activity and takes a step forward towards viewing it in a social context. This social view implies that the environmental impacts arising from the agricultural practices implemented in the farms are now taken into account, in search of the internalisation of these environmental externalities. In short, we go from a private to a social viewpoint, more appropriate, given the special nature of organic farming. Therefore, the adoption of this social perspective would be just a logical consequence inherent to the very system: if organic farming systems try to reduce their overall environmental impact and, with this aim, adopt certain practices and/or inputs (and exclude others), it is necessary that this is taken into account when comparing the efficiency of the different systems. Otherwise, organic farming systems could be in a situation of clear disadvantage (Roberts and Swinton, 1996) [9].

Making use of a non-parametric methodology (DEA), the output-oriented technical efficiency of two production systems, conventional and organic farming, is measured, under two different perspectives: the first takes the *private* standpoint mentioned above and considers exclusively the relationships between inputs and outputs. The second, or *social* perspective includes also some of the environmental impacts arising in the farms. The comparison of the results obtained in each of these two scenarios allows us to draw some conclusions regarding the efficiency of organic farming systems.

The paper is organised as follows: next, a brief description of the theoretical framework and the methodological application is presented. This is followed by a characterisation of the data set and a discussion of the results obtained. The final section summarises the main conclusions.

II. TECHNOLOGY AND FRONTIER OF EFFICIENCY WITH DESIRABLE AND UNDESIRABLE OUTPUTS AND DIRECTIONAL DISTANCE FUNCTION

Generally, output-oriented efficiency indexes measure the distance of the units to the transformation curve or frontier of efficiency. Within this approach, the presence of environmentally detrimental variables or undesirable outputs is seen as a special feature of the technology. The acceptance of such presence implies that the so-called hypothesis of free disposability of undesirable outputs does not hold (Färe *et al.*, 1989) [10]. This means that the elimination or disposal of one or more of these undesirable outputs cannot be done at free cost, that is, undesirable outputs are *weakly* disposable. In other words, the reduction of an environmentally detrimental variable entails a reduction in the production level or an increment of the inputs used.

Following Shephard (1970) [11], the production set under weak disposability of undesirable outputs is defined as

$$(y,b) \in P(x), \quad 0 \le \theta \le 1 \quad \Rightarrow \quad (\theta y, \theta b) \in P(x)$$

Where $P(x)$ is the output set, y and b are the vector of desirable and undesirable outputs, respectively. This expression means that reductions in these undesirable outputs do not come for free, that is, a reduction in the level of desirable or good outputs or an increase in the level of inputs used are required.

Under strong disposability of undesirable outputs, this production set is defined as:

$$(y,b) \in P(x), \quad y' \le y \quad \Rightarrow \quad (y', b) \in P(x)$$

The frontier of efficiency under strong and weak disposability of undesirable outputs is specified and represented in the following figures (1a and 1b):

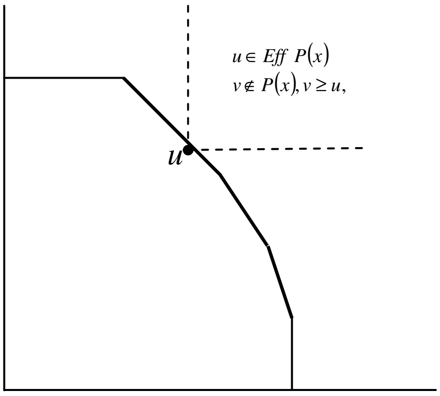

Fig 1a Efficient subset $Eff\ P(x)$ for disposable output sets

Source: [11]

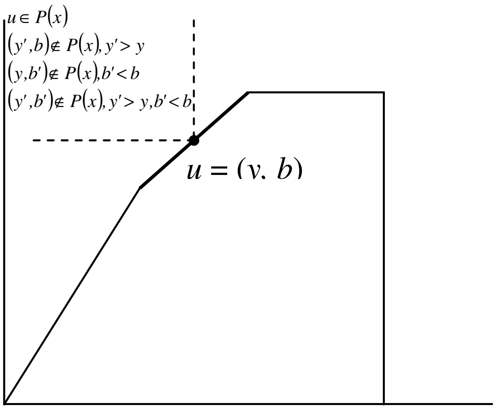

Fig. 1.b Efficient subset $Eff\ P(x)$ for output sets with some weakly disposable outputs

In order to allow for a differentiated treatment of the undesirable outputs, Chambers *et al.* (1996) [12] introduce, following Luenberger (1992) [13], the concept of directional distance function as a complete representation of the technology:

$$\vec{D}_O(x,y,b;g_y,g_b) = \sup\{\beta : (y+\beta g_y, b+\beta g_b) \in P(x)\}$$

Where (g_y, g_b) is the directional vector, which indicates the direction of movement towards the frontier, and can be specified in any given direction.

Hudgins and Primont (2004) [14] point out to the advantage of the directional distance function over other alternatives, such as the hyperbolic and radial measures, in the measurement of efficiency in the multi input-multi output space. Also, the directional distance function has an additive structure, which facilitates a potential interpretation in terms of profit and it is very adequate to accommodate the case of a technology with joint production of desirable and undesirable outputs, because it explicitly allows for a differentiated treatment.

The choice of the most adequate directional vector is usually considered to be up to the researcher and it depends on the objective of the specific application put in place. The most commonly used vector is the own observation, which makes the determination of the directional vector straightforward, although, other options have been used in the literature (Färe *et al.*, 2004 [15]; Färe *et al.*, 2005 [16]; Huhtala and Marklund, 2005 [17]).

III. MEASURES OF PRIVATE AND SOCIAL EFFICIENCY

In this work the directional distance is used to calculate and compare the efficiency of conventional and organic farming in two scenarios. The so-called *social* efficiency takes the environmental impact of agricultural production into account and tries to simultaneously maximise and minimise each unit's desirable and undesirable outputs, respectively. This corresponds to the *weak* efficiency and may be formulated in terms of the directional distance function as follows:

$$\vec{D}\,(x, y, b) = \max \left[\beta / (y + \beta y, b - \beta b) \in P(x)\right]$$

In order to compare the *social* efficiency of conventional and organic farms we consider an efficient frontier for each regulation as well as the envelope of these frontiers as the reference

Figure 2 shows a representation of social efficiency frontiers with undesirable outputs for a given input level, where OEF is the transformation curve between desirable and undesirable output in organic farming and OCD that of conventional farming. OCEF is the envelope of these frontiers.

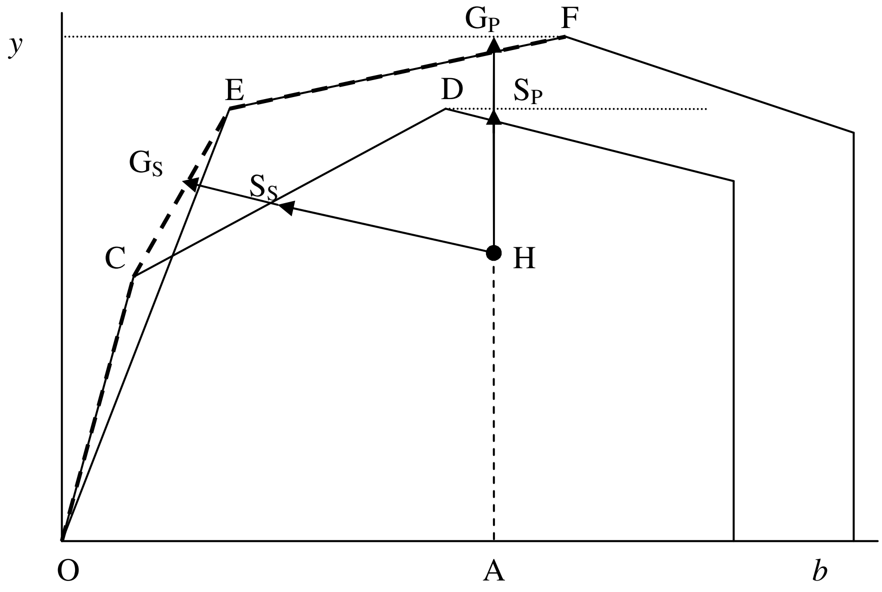

Fig. 2 Transformation curves y – b for conventional and organic farms

With the objective of comparing the *social* efficiency of the farms under conventional and organic regulations we apply three measures:

1. Individual social efficiency (E_S) is measuring the distance of each unit to the social efficiency frontier of its own regulation, that is, conventional or organic. For instance, H unit's E_S is represented by the segment HS_S divided by the segment HO, HS_S / HO.
2. Global efficiency (E_G) is the distance existing from each unit to the envelope. In the case of unit H, HG_S / HO.
3. The Social Technological Gap (STG) measures the distance between the efficiency frontier of each regulation and the envelope, that is, $E_G - E_S / 1 + E_G$. In the case of unit H this is approximated by $S_S - G_S / OS_S$, using a first order approximation to the hyperbolic distance[2].

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[2] This index extends that of Chung (1996) [18] in the following way, $\dfrac{1+E_G}{1+E_S} - 1$

Finally, in order to facilitate the comparability with other results in the literature, *social* efficiency is calculated also under strong disposability of undesirable outputs. This measure, when the directional vector (*y, -b*) is used virtually coincides with the *private* efficiency.

On the other hand, *private* efficiency does not take the environmental impact of the activity into account and it simply measures how much the desirable output has to increase in order to reach the frontier of efficiency. Again, the output directional distance function is used, and it can be expressed as follows:

$$\vec{D}\,(x, y) = \max\,\left[\beta / (y + \beta y) \in P(x)\right]$$

As shown in Figure 2, the only private-efficient units in conventional and organic farming are D and F, respectively. *Private* efficiency of unit H is measured as HS_P / HA, global efficiency is HG_P / HA and the technological gap is equal to $G_P - S_P / 1 + S_P$, which is represented graphically in Figure 1 by $G_P S_P / S_P A$.

IV. DEA SPECIFICATIONS

The present empirical application consists on the computation of the technical efficiency of a sample of farms based on the concept of directional distance function, by the use of non-parametric methodology, DEA. The model presented below (social model) is oriented in such a way that the simultaneous maximisation and minimisation of desirable and undesirable outputs, respectively is sought.

$$\vec{D}_{strong}\left(x_k, y_k, b_k; y_k, b_k\right) = \max \beta$$

subject to

$$\begin{aligned} &\sum_k \lambda_k y_{mk} \geq (1+\beta)\, y_{mk} && m = 1,\ldots,M \\ &\sum_k \lambda_k b_{rk} \geq (1-\beta)\, b_{rk} && r = 1,\ldots,R \\ &\sum_k \lambda_k x_{nk} \leq x_{nk} && n = 1,\ldots,N \\ &\lambda_k \geq 0 && k = 1,\ldots,K \end{aligned} \qquad (1)$$

Where there is a simple of k = 1,…, K farms, m = 1,…, M desirable outputs, n = 1,…, N inputs and r = 1,…, R undesirable outputs. λ_k are the intensity variables or weights and $\left(y_k, -b_k\right)$ is the directional vector. Next, the hypothesis of weak disposability is introduced in the model above, by the change of the undesirable outputs inequality restriction to an equality restriction and the model. The model under this premise is the following:

$$\vec{D}_{weak}\left(x_k, y_k, b_k; y_k, b_k\right) = \max \beta$$

subject to

$$\begin{aligned} &\sum_k \lambda_k y_{mk} \geq (1+\beta)\, y_{mk} && m = 1,\ldots,M \\ &\sum_k \lambda_k b_{rk} = (1-\beta)\, b_{rk} && r = 1,\ldots,R \\ &\sum_k \lambda_k x_{nk} \leq x_{nk} && n = 1,\ldots,N \\ &\lambda_k \geq 0 && k = 1,\ldots,K \end{aligned} \qquad (2)$$

As mentioned earlier, given the great flexibility of specification of the directional vector, its choice should reflect the specific objectives of each particular application. And these specific objectives should ideally represent actual situations and/or problems that need to be addressed. The present model tries to represent the situation in which the environmentally detrimental outputs have to be reduced. The choice of the own observation as the directional vector $(g_y, g_b) = (y, -b)$, that measures the equiproportionate increase and decrease in desirable and undesirable outputs, respectively is, then, amply justified.

On the other hand, the private model is represented by the following programming problem, in which, in line with other literature references, the restriction corresponding to the undesirable outputs has been excluded. The objective of this model, therefore, is just to increase desirable output, with no consideration of the external effects of such increase.

$$\vec{D}\;\left(x_k, y_k, b_k; y_k, b_k\right) = \max \beta$$

subject to

$$\begin{aligned} &\sum_k \lambda_k y_{mk} \geq (1+\beta)\, y_{mk} && m = 1,\ldots,M \\ &\sum_k \lambda_k x_{nk} \leq x_{nk} && n = 1,\ldots,N \\ &\lambda_k \geq 0 && k = 1,\ldots,K \end{aligned} \qquad (3)$$

V. DATA DESCRIPTION

The data used in this paper were obtained from two different sources. The first source was the Department of Agriculture, Livestock and Food of Navarre, that provided us the FADN data corresponding to the 54 conventional farms of the sample, for the year 2001.

The second data source were a series of personal interviews carried out following the FADN methodology to 32 organic farmers, by which equivalent information to that of conventional farms, was obtained. Farms may be classified as either Type 311, Specialist quality wine, or Type 603, Field crops and vineyards combined (Commission Decision 85/377/EEC) [19]. Descriptive statistics are shown in Table 1.

Table 1 Descriptive statistics

	Land (Ha)	Labour (UTA)	Capital (€)	Fert/pest (€)	Output (€)	Nitrogen (kg)	EIQ (units)
Whole sample	54.27	1.61	9008	6562	63081	5038	1887
	(49.5)	(0.75)	(6791)	(5958)	(46749)	(5575)	(829)
Conventional	58.25	1.52	9246	6218	53351	5084	1490
	(52.4)	(0.55)	(6724)	(5574)	(35142)	(5076)	(127)
Organic	47.54	1.76	8606	7141	79501	4960	2557
	(44.2)	(1.00)	(6993)	(6607)	(58633)	(6416)	(1059)

(Average values, standard deviations between parentheses)

The variable set is composed by four inputs, one desirable output and two undesirable outputs. The inputs are: land (hectares of UAA), labour (AWU), capital (hire and depreciation of machinery and buildings, Euros) and expenditure in fertilisers and pesticides (Euros). The desirable output is an aggregated output, total farm revenues (Euros). This way, this variable accounts for quality variations between organic and conventional products, which come in the form of a price premium usually paid to organic products. The undesirable outputs are represented by two indicators of environmental impact. These indicators are: nitrogen excess (kg.) and an index of impact of pesticides (units of EIQ).

The nitrogen excess indicator was calculated following the Soil Surface Balance Methodology (OECD, 2001) [20]. This straightforward method takes the nitrogen cycle as the reference and calculates the difference between the nitrogen entering and leaving the soil in the farm. This way, potential nitrogen excesses and deficits are identified.

The index of impact of pesticides is based in the Environmental Impact Quotient methodology by Kovach *et al*. (1992) [21]. The environmental impact of the active ingredients (a.i.) in pesticides is decomposed in three components (farm workers, consumers and ecological impact) in order to obtain the Environmental Impact Quotient (EIQ) of each a.i.. These individual EIQs are then multiplied by the percentages of a.i. and the pesticide doses applied to obtain the EIQ Field Use Rating, which can be used to compare the environmental impact of the different pesticide management strategies[3].

VI. RESULTS AND DISCUSSION

The results of deterministic DEA models are prone to be very sensitive to measurement errors and outliers. Nevertheless, since the *learning by doing* processes may be of a high importance in a rather new technology such as organic farming in this region, no process of outlier detection or removal has been carried out.

Average results of both Model 1 (Eq. 3) (*private* model) and Model 2 (Eqs. 1 and 2) (*social* model) are shown in Table 2. As mentioned above in this section, the private model does not introduce environmental variables in the computation of efficiency. This way, it is intended to analyse the influence of the organic label on farms' efficiency.

Regarding Model 1, the average distance of conventional farms to the envelope, or whole sample frontier, that is, a frontier obtained using the 86 farms, both conventional and organic, in the sample, is 0.317. The average distance of conventional farms to their own frontier is 0.094. The difference between these two measures is 0.223. With respect to organic farms, the average distance to the WSF is 0.14. The average distance to the organic frontier is, again, 0.14. These two measures, therefore, coincide, and there is no gap.

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[3] More information available at: www.nysipm.cornell.edu/publications/eiq

The results of Model 2 correspond to the introduction of environmental impact variables in the analysis. This way, the initial analysis made with Model 1 is further extended by the inclusion of these environmentally detrimental variables, in line with current objectives of agrienvironmental policies. In this case, directional distance has been computed taking into account the hypotheses described in the previous section, strong and weak disposability of undesirable outputs. The global efficiency (E_{GC}), under strong disposability, of conventional farms is 0.315, whereas the individual social efficiency (E_{SC}) is 0.089. The social technological gap (STG_C) is, therefore, 0.226. In organic farms, also under strong disposability, these measures are 0.138 and 0.136, E_{GO}, and E_{SO}, respectively. Looking now at Model 2 results under weak disposability, E_{GC} is 0.049 and E_{SC} 029, which makes a social technological gap (STG_C) of 0.019. For organic farms, these measures are 0.026 and 0.025, with practically no gap.

Table 2 Average results of Models 1 y 2
(standard deviations between parentheses)

	Model 1 (*private*)		Model 2 (*social*)	
	$\vec{D}_O$ *strong*	$\vec{D}_O$ *strong*	$\vec{D}_O$ *weak*	$\vec{D}_O str - \vec{D}_O wk$
Conventional farms				
Whole sample frontier*	0.317	0.315	0.049	-0.266
(E_{GC})	(0.286)	(0.289)	(0.027)	(0.274)
Own frontier**	0.094	0.089	0.029	-0.06
(E_{SC})	(0.096)	(0.099)	(0.028)	(0.078)
Gap***	0.223	0.226	0.019	
(STG_C)	(0.209)	(0.211)	(0.017)	
Organic farms				
Whole sample frontier*	0.140	0.138	0.026	-0.112
(E_{GO})	(0.153)	(0.155)	(0.034)	(0.135)
Own frontier**	0.140	0.136	0.025	-0.111
(E_{SO})	(0.153)	(0.157)	(0.035)	(0.136)
Gap***	0.00	0.002	0.001	
(STG_O)	(0.00)	(0.009)	(0.006)	

*: Distance measured taking the whole sample as the reference (54 conventional and 32 organic farms).
**: Distance measured taking only the 54 conventional (and the 32 organic) farms as the reference.
***: Difference between the two previous measures
$^{\&}$: first digit: conventional farms; second digit: organic farms; third digit: farms on the efficient frontier

There are some points worth noting with respect to the results described above. First, if we consider the whole sample, organic farms are more efficient than conventional ones, both in the private and the social models. This result seems reasonable if we take into account the fact that the efficient frontier is formed by a majority of organic farms in both models (8/1 and 9/3 organic/conventional farms in models 1 and 2, respectively), which may be caused by an increased effort made by organic farmers due to stricter regulations. In addition, a product quality differentiation factor, in the form of price differentiation, is introduced in the analysis. Thus, it seems logical to expect that conventional farms, that obtain lower prices, will locate further from the frontier. This result is reinforced by the *Z*-values of the Mann-Whitney test, as shown in Table 3, which indicate that significant differences exist between organic and conventional farms, both in Model 1 and Model 2.

Second, conventional farms appear to be more efficient with respect to their own frontier than organic farms, 0.094 against 0.14 and 0.089 against 0.136 for conventional and organic farms, in Models 1 and 2 (strong disposability), respectively. Among the reasons that may contribute to explain this situation we may cite the lack of scientific research and extension services as the most remarkable. In the region of Navarre agricultural extension services in support of organic farming are practically nonexistent, a fact that can be made extensive to other European countries (Lampkin and Padel, 1994) [22]. This implies, apart from the evident lack of technical assistance, more difficulties for the transmission of technological knowledge among organic farmers, which many times comes facilitated, precisely, by these agricultural extension services.

On the contrary, if weak disposability is considered, organic farms are, on average, more efficient, with respect to their own frontier than their conventional counterparts with respect to the conventional frontier, 0.025 against 0.029. That is, if the disposal of the undesirable outputs is costly, organic farms make a more effective use of their resources than conventional farms do.

Third, if we consider the difference between the distance under strong and weak hypotheses as an index of impact of the regulation on undesirable outputs (Boyd *et al.*, 2002) [23], we may say that the average impact of the introduction of such a restriction on the pollutant variables is higher for organic farms, within their own sample, than for conventional farms, -0.111 against -0.06, that is, a 11.1% average output loss compared to 6%. This indicates the opportunity cost this restriction gives rise to regarding the expansion of the desirable output. As mentioned above, organic farms work in a much more constrained regulatory environment than conventional farms do. Thus, it seems reasonable to interpret this higher output loss as the consequence of implementing more restrictions in addition to the ones already in place. This is consistent with the conventional assumption made in environmental economics about the convexity of abatement cost functions. Organic farms are already making an effort towards the internalisation of environmental externalities, or public good provision, and this means that any additional effort comes at a cost. Conventional farms, on the other hand, do not make equal effort in terms of environmental cleanliness and, therefore, there is much more room for improvement in this area, meaning that an environmentally friendlier production, for conventional farms is less costly.

In short, the interest of the inclusion of environmental impacts of agriculture is evident, since they are the result of management practices applied in the farm and, as such, inherent to the productive process. Therefore they should be routinely included in this kind of comparative analyses. *Z*-values displayed in Table 3 indicate that there are significant differences between the results obtained in Model 1 and 2, which supports this interest in the inclusion of environmental external costs.

The scarce literature on this topic shows inconclusive results, already described in the introductory section of this article. Both higher as well as lower efficiency levels of organic, compared to conventional farms are found. Our Model 1 (*private*) results are comparable to the references cited earlier in that environmentally detrimental variables are not included in the analysis. In this case, we find that the efficient frontier is formed by a majority of organic farms, which show higher efficiency levels when pooled with conventional farms in a unique group. Oude-Lansink *et al.* (2002) [8] obtain similar results. Sipiläinen and Oude Lansink (2005) [24], though, find that technical efficiency is higher for conventional farms. On the other hand, when conventional and organic farms are separately examined, we find that conventional farms are more efficient, with respect to their own frontier, than organic farms. This result is also shown by Tzouvelekas *et al.* (2001a) [6], Oude-Lansink *et al.* (2002) [8], Madau (2005) [25] and Sipiläinen and Oude Lansink (2005) [24].

However, if the external effects of management practices are taken into account and it is considered that reduction of environmental impacts is costly, that is, the weak disposability assumption, organic farms perform better than conventional ones, both in the pooled case and separately. The results found in the literature so far do not include environmental impacts of any kind, a fact already acknowledged by Oude-Lansink *et al.* (2002) [8] and Sipiläinen and Oude Lansink (2005) [24]. Our findings, therefore, outline the importance of introducing such a consideration when comparing conventional and organic farming systems.

It is crucial to mention here that our study is based on dry-farming conditions. These conditions, linked to the technical orientation of the farms in the sample, mainly vineyard farms, imply that management practices are very similar. That is, the positive effect that could be attributed to water linked to pesticide and/or fertiliser application, whether from irrigation or more humid climates, is absent in this case. In addition, the severe restrictions regarding input use in organic regulations may lead organic farmers towards better informed and more careful input choices, as Tzouvelekas *et al.* (2001a) [6] point out.

Table 3 Z-values of the Mann – Whitney test for differences between organic and conventional farms and between Model 1 and Model 2

		Z-values
Differences between conventional and organic farms	model1	3.92^{***}
	model2	3^{***}
Differences between model 1 and model 2		7.89^{***}

***: significant at 1% level

VII. CONCLUSIONS

Agrienvironmental measures in support of organic farming are established as a means of guaranteeing the provision of some public goods. These come in form of lower environmental impacts from agriculture, which would not be provided otherwise. Keeping in mind this as their main objective, there are other objectives to which organic farming undoubtedly contributes, such as the economic and social objectives.

In this work, a non-parametric methodology (DEA) has been used to calculate and compare the efficiency of a sample of conventional and organic farms in the Region of Navarre, Spain. The analysis has been carried out from two points of view, and accordingly, two different models have been applied. Firstly, in line with traditional efficiency analyses, a (*private*) model is applied with no consideration of the environmental impact of agricultural activity. Secondly, this environmental impact is explicitly introduced in the so-called *social* model, through the inclusion of two indicators, nitrogen excess and impact of pesticide strategies. Besides, the hypotheses of strong and weak disposability of undesirable outputs are applied in this second model, to reflect the fact that pollution reduction is costly.

Our results indicate that organic farms appear as more efficient than conventional farms, regardless of the inclusion of environmental impacts. The activity of organic farms takes place in a much more constrained regulatory context than in the case of conventional farming. These stricter regulations affect mainly to the choice of inputs that may be used, severely limiting their number. A consequence of this may be a more careful input choice made by organic farmers and an adaptation of managerial practices leading, therefore to higher efficiency levels. In addition, organic agriculture is based on the establishment of whole-farm closed cycles, which may indicate to a certain extent a higher potential for the reduction of dependence on external inputs, leading towards a higher competitivity. In addition, it also seems reasonable to expect that, if the lower environmental impacts arising in organic farms are taken into account, adopting consequently a social point of view, these farms will show better results.

Finally, there is an additional factor worth mentioning. This analysis takes place in dry-farming conditions, that is, the majority of products are obtained through dry-farming practices that exclude irrigation, both in conventional and organic farms. This factor exerts a crucial influence on the results. The process of agricultural intensification initiated decades ago meant a progressive substitution of natural factors for a technological package 'water-inputs', such as fertilisers and pesticides. It seems evident that, in the case of irrigated farming, this may be more beneficial for conventional than for organic farms, given that organic regulations are especially restrictive concerning such inputs. However, in the case of dry-farming, the absence of irrigation to which the application and effectiveness of fertilisers and pesticides is closely linked, implies that the practices of conventional and organic farmers are more alike. This would be removing an effect that benefits mainly to conventional farms and would lead us to consider, as a logical continuation of this research, the extension of the analysis to the case of irrigated agriculture.

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