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Benchmarking exercise using Data Envelopment Analysis
An application to irrigation water pricing

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Abstract. Water management is subject to conflicting economic and environmental objectives and policy makers require a clear overview of the various outcomes of different water management options. In the present paper we propose a non-parametric benchmarking technique based on Data Envelopment Analysis (DEA), specifically developed to assess the relative efficiency of alternative water pricing policies. The result of the analysis is a ranking of pricing policies, aimed at supporting decision making process. An empirical study case was carried out in Southern of Italy (Apulia region), where irrigation is an important factor of strategic relevance for policy makers. Six different pricing methods were compared. According to the findings, the alternative pricing policies perform similarly in terms of technical efficiency. However, the results show that the alternatives rank differently for the technical efficiency and the ecological efficiency indicator. The ecological efficiency shows up to 10% of inefficiency. We conclude that efficiency may be a convenient method for ranking policy hypotheses in the case of absence of information on stated preferences on some outcomes, as well as some negative environmental impacts.

Key words: Linear programming – Efficiency – Water – Price policies – Irrigation.

Etude comparative par méthode d'enveloppe des données : une application à la tarification de l'eau d'irrigation

Résumé. *La gestion de l'eau répond à des objectifs économiques et environnementaux contradictoires et les décideurs ont besoin d'une vue générale claire des résultats des différentes options de gestion de l'eau. Ce document de réflexion propose une méthodologie basée sur la méthode d'enveloppe des données (Data Envelopment Analysis, DEA), une technique d'analyse non paramétrique spécifiquement développée pour évaluer l'efficience relative de politiques alternatives de tarification de l'eau. A cet effet, une analyse des classements a été effectuée sur la base du score d'efficience relative. Une application a été réalisée dans le sud de l'Italie (Pouilles), où l'irrigation revêt une grande importance stratégique pour les décideurs. Six méthodes de tarification différentes ont été évaluées. Selon les résultats, les politiques de tarification alternatives affichent les mêmes performances en termes d'efficience technique. Par contre, les résultats de la tarification alternative montrent une différence de performance entre les indicateurs de l'efficience technique et de l'efficience écologique. L'efficience écologique affiche une inefficience maximale de 10 %. Notre conclusion est que l'efficience peut être une méthode adéquate d'évaluation des hypothèses de politiques de tarification en cas d'absence d'informations sur les préférences pour certains résultats, ainsi que de certains impacts environnementaux négatifs.*

Mots clés*: Programmation linéaire – Efficacité – Eau – Politiques de tarification – Irrigation.*

I – Introduction

Water management is very often subject to conflicting objectives. On the one hand, water management plans for the future need to comply with environmental criteria in order to ensure ecologic sustainability. On the other hand, economic viability will always be a necessary requirement for agricultural sustainability and the provision of related social services. This is particularly the case in areas where water scarcity induces a dramatic competition in the demand of the resource between agriculture and environmental needs or, in other terms, the trade-off between economic return and environmental protection. The regulation of water uses for the agricultural sector is an urgent issue especially in Mediterranean regions, where the water use share for irrigation ranges from 50 to 60% of fresh water bodies (Dworak *et al.*, 2007), rising up to more than 80% in certain areas.

Selecting the appropriate scientific tools to assess water policy measures and, thereby, support water management decisions under complex circumstances has been identified as one of the major challenges with regard to the implementation of water policy reforms (Messner, 2006). Assessing water policy embraces both economic and ecological dimensions, or attributes. As a consequence common indicators will need to be established, as well as aggregation methods for enhancing a comprehensive framework analysis.

Although a wide variety of functional forms exist that permit indicators to be aggregated, it is worth taking into account the possible incommensurability of different indicators. Although inputs, outputs, and externalities can be measured in physical or value terms, the most difficult task is the comparison of different performances. The greatest difficulty involves interpreting the combination of indicators selected to describe each policy, and therefore to be suitable as a practical administrative decision-support tool. Attempts to consider economic, social and environmental dimensions to perform some comparative analysis have been made for the issue of agricultural sustainability. Gómez-Limón and Sanchez-Fernandez (2010) provide extensive literature in this field and at the same time they propose a practical methodology for evaluating the sustainability of farms by means of composite indicators. The authors conclude that the 'subjective' character of the methods used to build composite indicators (weighting of indicators) is not satisfactory and could be improved.

When the relative importance of each criterion is already known, it is possible to proceed to a multi-criteria analysis (MCA), in order to obtain the ordered rank of the most preferred scenario. This type of methodology is generally considered as a sort of parametric analysis. Comparative studies on the application of different MCA in water resource management has shown that different methods are in close agreement and that there is no clear advantage in using some method above others (Gershon and Duckstein, 1983; Ozlekan and Duckstein, 1996; Eder *et al.*, 1997). The main limitations of MCA relate to the methods for preference elicitation, selection of criteria and decision options (Hajkowicz and Collins, 2007). Among these methods, it is worth mentioning the non-parametric methods, among which Data Envelopment Analysis (DEA) may also be included, which do not require any a priori assumptions about preferences.

Raju and Kumar, (2006) include DEA techniques into a MCA methodology, in which the relationship between all inputs and output are taken into account simultaneously. In fact, the DEA assigns the weights of the assessed indicators for the set of policies, in order to pursue the maximization of the ratio between the weighted (single or multiple) output and the weighted (single or multiple) input. Instead of providing the average performance among policy options, DEA can reveal the best practices in peer groups, as well as the technical efficiency score for each policy. In addition DEA evaluation overcomes the trade-off or compromise amongst the conflicting objectives, taking into account efficiency as criteria for the options ranking.

In the present paper we propose a methodology based on DEA as a benchmarking technique, specifically developed to assess the relative efficiency of alternative water pricing policies. A ranking analysis is carried out according to the relative efficiency score. The paper deals with two aspects of the efficiency. Firstly the technical efficiency, that depends on the optimal allocation of the resource to the most profitable crops. Secondly the ecological efficiency, that considers the externalities caused by the irrigated crops on the environment, in particularly pollution. In both cases, the water pricing scheme will be successful if for the same use of water it will induce an increase of output, or a reduction of the externality. Alternatively, the policy is efficient if for the same level of output or externality produced, it will induce a lower water use.

In order to estimate the efficiency of the policy, a comparison of the direct pricing scheme with indirect pricing schemes is performed. The study is based on the simulation of policy scenarios for the reservoir of the irrigation board named "Consorzio della Bonifica della Capitanata", which is located in the province of Foggia (Apulia region), South of Italy. The simulation is carried out through mathematical modeling and, the outcomes of the simulations (pay-off matrix) are analyzed by the DEA technique. In order to calculate the technical and the ecological efficiency of different water pricing policies, we use a two steps DEA analysis, as first proposed by Korhonen and Luptacik (2004). This methodology allows for the calculation of the relative efficiency and subsequently the ranking of most efficient policies, considering both the technical and the ecological aspects.

The structure of this paper is as follows. In the next section (section 2), the DEA methodology is presented and the conceptual framework proposed in this research is described. The case study is described in Section 3. Section 4 presents the main results, from which conclusions are drawn in Section 5.

II – Methodology

2.1 Overview

Data Envelopment Analysis measures the relative efficiencies of organizations with multiple inputs and multiple outputs (Charnes *et al.*, 1978). The technique is suitable to evaluate the performances of individual organizations, teams, or units, which are called "decision-making units", or DMUs. The basic feature of DEA is the identification of the so-called efficiency frontier, formed by connecting the most efficient units. All units lying on this frontier are said to be operating at 100 percent efficiency. On the contrary, an efficiency score is calculated for each of the inefficient units, measuring the euclidean distance with the closest units lying on frontier. The results of the DEA analysis are generally used to measure the performance efficiency, especially for benchmarking purposes. This methodology is useful whenever there is no information about the relative importance among outputs or inputs, as it does not require assumptions a priori (Callens and Tyteca, 1999). Another advantage of DEA is that the choice of the unit measure adopted to units' input and output will not affect the efficiency score (Coelli *et al.,* 1998).

Since the DEA technique was firstly developed by Charnes, Cooper, and Rhodes in 1978, it has been widely applied to industries as diverse as health care, finance, education, and transportation, as well as many other industries and organizations. The technique is well documented in both operations research (Banker *et al.,* 1984; Dyson and Thanassoulis, 1988; Golany and Roll, 1989; Cooper *et al.*, 1996) and economics literature (Banker and Maindiratta, 1988; Seiford and Thrall, 1990; Leibenstein and Maital, 1992). The DEA bibliography compiled by Seiford (1994) includes more than 400 articles, books, and dissertations between 1978 and 1992. A recent bibliography (Emrouznejad, 2001) reports more than 1,000 applications.

DEA is frequently used to measure the efficiency of decision units, such as firms, industrial plants, as well as governmental departments (e.g. Glass *et al.*, 2006; Bono and Matranga, 2005; Korhonen and Luptacik, 2004). Data Envelopment Analysis has also been applied as a useful methodology for ranking irrigation planning alternatives with mutually differing objectives (Raju and Kumar, 2006). In the research of Raju and Kumar, the DEA is applied to select the most suitable irrigation planning alternative in the context of the Sri Ram Sagar Project in Andhra Pradesh (India), using simulated data. The authors, however, do not include environmental objectives which, as mentioned, can be in conflict and which irrespectively need to be accounted for in the new policy frame of the European Water Framework Directive (WFD/2000/60/EU).

The first non-parametric analysis with multiple outputs (both economic and environmental) is reported in Färe *et al.* (1989), in which a data set consists of 30 US paper mills using pulp and three other inputs in order to produce paper together with four pollutants. Their results showed that the performance rankings of units turned out to be very sensitive to whether or not undesirable outputs were included. However, the general emphasis to the environmental issue has occurred later (Tyteca (1996) presents an exhaustive literature review).

In this paper, we adopt the modified two steps DEA, as first proposed by Korhonen and Luptacik (2004). Korhonen and Luptacik propose to measure the eco-efficiency of 24 power plants in Europe, in two different ways. In the first approach, they measure the eco-efficiency in two steps. The first, technical efficiency, and the second, the so-called ecological efficiency, are estimated separately. Subsequently they attempt to build up a model capable to simultaneously calculate either the 'desirable' and 'undesirable' outputs. The authors found that both approaches achieve almost the same result, in terms of finding the most efficient plants, although the ranking of the power plants resulted slightly different. The first method is adopted in this study, where an efficiency analysis is made of the performances of the local irrigated agricultural system under different water pricing schemes (see also Giannoccaro *et al.,* 2008).

2.2 Conceptual frame

In order to compare the relative efficiency of *n* water pricing scenarios, the analysis is performed on data derived from the simulation of their effects on the farmer's profitability, through a mathematical programming model. A multi-agent regional linear programming model is applied (see Giannoccaro *et al.*, 2010a for more details), consisting of a static linear programming model in which farmers are assumed to maximize their profits, subject to the following constraints: i) input endowments (land, water sources and labour), ii) technical aspects (agronomic rotations, labour and irrigation calendar), and iii) general agricultural policy issues, such as the conditionality for eligibility to the single farm payment under the CAP regime[1]. The decision variables of the model are basically referred to the optimal cropping mix, which determines the utilization of production inputs (land, labour and capital) including water and chemicals, as well as output measured in terms of gross margin, farmer's income and added value.

Two critical discrete stochastic variables representing, respectively, the price volatility of the commodities and the rainfall variability are also included in the model (Etyang *et al.*, 1998; Maatman *et al.*, 2002; Arsham, 1996). In fact, by using traditional linear programming models which consider the average right-hand-side constraint values on water availability, the results tend to overstate the farm outcome, not only in years with poor weather, but on average as well, because of the variability in rainfall. The advantage of using stochastic variables in the linear model is that it includes the stochastic nature of the rainfall distribution, which in semi-arid regions crucially affects farm income (Maatman *et al.*, 2002; Nardone *et al.*, 2007). In addition, partly because weather variations are also reflected in market prices, the technique also accounts for variation in output prices. The model is based on expected utility theory, according to which agents are neutral to risk (Neumann and Morgenstern, 1947).

The two stochastic variables representing the rainfall variability and the price volatility are discrete, and have different occurrence probabilities. The optimal solution is given by the weighted sum of the optimal solutions of each combination of the two variables, by the product of their occurrence probability. In this way, farmers are assumed to exhibit a risk neutral behavior. Therefore, water availability and the price of durum wheat (the main commodity in the area) are determined according to their stochastic probability. Under these conditions, the optimization problem is solved, by assuming the state of the two stochastic variables, are already known to the farmers at the time of decision making. So it is assumed that their decision making occurs under the condition of complete information.

The simulation model used here finds the maximum farmers' net revenue.

The simulation of the policy is performed by modifying water tariffs. From the simulation of each policy scenario, the most significant variables are selected, referred to as inputs, desirable outputs, and undesirable inputs. These variables that will be analyzed by the DEA technique can be classified into two types: economic and environmental variables. Table 1 shows the variables taken into account for running the DEA model[2].

Table 1: Variables taken into account for running DEA analysis

Conventional Resources					
	Input				Output
	Land	Labour	Capital	Water	Gross margin
Unit measure	10^3 hectares	10^3 hours	10^6 EUR	10^6 m^3	10^6 EUR

Environmental Externalities*		
	Undesirable inputs	
	Pesticides risk	Nitrogen surplus
Unit measure	10^3 Kg of rat potentially harmed	10^6 t

Source: own elaboration.
*Note: *) For environmental externality indicators see Berbel and Gutierrez (2005).*

The first step for calculating the relative technical efficiency is performed by the traditional DEA, where the technical efficiency of each of these *j*= 1,…, *n* water policy scenario is estimated. Suppose *m* input items and *k* output items are selected according to Table 1. In particular, for *m=1,2,...i* the subscript for production inputs is assigned, and for *k=1,2,..,r*, the subscript for conventional outputs is identified. The vector of the overall technical inputs is m_{ij} and the vector of overall outputs is k_{rj}.

Therefore, for each water pricing policy, we formed the virtual input and output by (yet unknown) weights (v_i) and (u_r), with i=1,2,...k, and r=1,2,...q :

$$\text{Virtual input}= v_1 m_{1j}+\ldots+v_k m_{ij} \quad (1)$$

$$\text{Virtual output}= u_1 k_{1j}+\ldots+u_q k_{rj} \quad (2)$$

Then, the weights are determined using the DEA (CCR model, input-oriented) technique (Charnes *et al.,* 1978) to maximize the ratio Virtual output/Virtual input subject to:

$$v_1 m_{1j}+\ldots+v_k m_{ij} =1 \quad (3)$$

The second step consists of the measurement of the ecological efficiency through the calculation of the weights to be applied to the desirable outputs (k_r) and the undesirable inputs defined as *m=i+1, i +2,..., p*.

III – Empirical application

3.1 Data collection

The research is referred to the Province of Foggia, located in Southern Italy (Apulia region), where the local land reclamation and irrigation board, the 'Consorzio per la Bonifica della Capitanata' (CBC).

The area, extending over 442,000 ha, of which 80,000 ha are on average irrigated, is characterized by a Mediterranean climate with cold wet winters and hot dry summers. Rainfall varies from less than 400 mm/year to more than 700 mm/year, but there are also recurrent periods of drought, with minimum of 250 mm/year in some exceptional drought seasons.

Irrigation water comes from two main sources: CBC water is stored in large public water reservoirs and allocated directly to the fields by the CBC through high-pressure pipes. Non-CBC water comes from natural sources (wells, rivers). The public irrigation infrastructure in the area is managed by the CBC and delivers some 106,000,000 m^3 between April and November. Local (non-CBC) groundwater is largely utilized providing about 100,000,000 m^3.

The data used to calibrate the LP model is collected from official records (ISTAT, 2000). The procedure is carried out by small iterative adjustments to the gross margin of each crop, until the optimal solution approximates the current cropping pattern of the study area. According to the ISTAT (2000) data, labour is provided by the farming family (in 95% of cases). Farms were classified into three main groups according to farm size and cropping patterns.

Our technical coefficients reflect the agronomic rotations typically adopted by farmers in the area (Noviello and Nardella, 2005; Giannoccaro *et al.*, 2009). Input and output prices are based on the average (2004-2007) local market prices (Bulletin of the Chamber of Commerce). Market prices variability is included in the model only for the variability of durum wheat prices, which is the predominant crop in the area. On the basis of the time series over the last decade, three discrete values for the stochastic variable referred to the wheat price are considered: the average price (180 EUR/ton, accounting for 26.7% of probability of occurrence), a decrease of 26% (60% of probability), and an increase of 26% (13.7 % of probability).

The variability of the water availability is assumed to reflect the Gaussian distribution of the rainfall trend according to an approach proposed by Howitt and Taylor (1993). Over the last 3 decades the variation can be approximated by three water availability levels: average availability (547 mm/year, 73.5% probability of occurrence), water shortage corresponding to a volume decrease of 43.7% relative to the average (13.5% of probability) and water abundance corresponding to a volume increase of 43.7% relative to the average (13.0% of probability). Consequently, the simulation of farmers' decision making is given by the weighted sum (according to the probability of occurrence of each event) of the 3x3 possible outcome combinations generated by the LP model.

3.2 Water policy scenarios

Six water pricing schemes with three different hypothesis of saving 10%, 20%, and 30% of the current water consumption at the basin level, are compared. Two volumetric schemes, and four indirect pricing schemes are considered, of which the main features are as follows:

P0. Baseline: this is the current pricing scheme, which is based on a three-tiered rate system, applied only to pressured water distributed by the CBC, while the non-CBC water is free of charge (apart from private extraction and use costs). The three-tiered rate consist of a volume of water (2050 m^3/ha) at a lower tariff (0.09 €/m^3), sufficient to cover their running costs. An additional water volume (950 m^3/ha) is available at an intermediate tariff (0.12 €/m^3). Finally, a third tariff (0.24 €/m^3) is applied to excessive consumption exceeding the two blocks (above 3000 m^3/ha). In the case of non-CBC water, farmers carry only the private cost (estimated in as an average of 0.09 €/m^3) to lifting, accumulating, and pressuring water;

P1. Vol_tot: the current three-tiered rate system to CBC water is maintained. In addition, the introduction of a single rate volumetric method rate for the non-CBC is assumed, reflecting the environmental cost for water source depletion. In the absence of any other estimate a tariff of (0.03 €/m^3) is assumed here that would be sufficient to reduce the groundwater consumption by 10-20% of the current use;

P2. Input: the introduction of an indirect pricing method is assumed in which the water charge is applied on the basis of the input required by irrigated crops (e.g. plants or seeds, consumable irrigation equipments, ferti-irrigation[3] materials). To reflect an indirect environmental tax on irrigation practice, farmers pay a price surcharge on these inputs, regardless of the actual water consumption (from CBC and non-CBC). The surcharge is different for each crop and is calculated on the basis of average water consumption. This pricing method is intended to induce farmers to cultivate crops requiring lower inputs.

P3. Output: water consumption is charged proportionally to the gross return from irrigated crops, regardless of the water source. The charge rate for each crop is calculated as the ratio between the current value of its specific water consumption, and the corresponding gross return (vines 3%, horticultural crops 2.4-2.8%, olive orchards 1.9%);

P4. Area: a per-area pricing is assumed, based on the current irrigated area, while maintaining a fixed volume, calculated on the area suitable for irrigated agriculture. It is still a relatively easy method to be implemented and also easy to be understood by farmers. A per-area hectare charge is set equivalent to the average CBC cost per hectare of irrigated area (82 €/ha).
P5. Quota: A constant water tariff (0.09 €/m^3) is applied, but each farm is subject to a rigid constraint to water availability. This method is popular among some farmers, as they claim that the water price should remain low and constant, regardless of water availability. This does not result in a real water market, but the farmers accept the concept that the availability may change according to the rainfall regime.

IV – Results

The simulation of each pricing scheme generates different farmer's responses and agricultural system outcomes. From the 6 alternative pricing methods, combined with the three levels or prices (respectively, 10%, 20%, and 30% of water saving), a total of 18 water pricing schemes are compared with the DEA analysis.

Firstly, we analyze only the technical efficiency. This approach is the first step for assessing the water policy options. Table 2 shows the results of the DEA analysis in terms of the technical efficiency score.

Six options out of the 18 simulated options are most efficient. The average efficiency of the sample is 0.99805, and generally very slight differences are found. According to the data, the effects caused either by the pricing schemes and the pricing levels are negligible, in terms of technical efficiency. This may be explained by the fact that multi-input and multi-output farms, in the short term that is assumed in the study, are able to substitute (to a certain extent) high water demand crops with low water demand, or with non-irrigated crops. In other words farmers are able to choose their optimal crop mix within the current set of crop options. From the DEA analysis can be derived that the different crop patterns resulting from changes in water pricing policy are equally efficient.

Table 2: Technical efficiency and DEA 'peer' with Benchmarks.

Policy options	Technical efficiency	Peer with Benchmarks	
C_P1.Vol_tot	1.00000		
A_P5.Quota	1.00000		
C_P2.Input	1.00000		
A_P4.Area	1.00000		
C_P0.Baseline	1.00000		
B_P4.Area	1.00000		
A_P1.Vol_tot	0.99975	A_P4.Area	A_P5.Quota
A_P0.Baseline	0.99974	A_P4.Area	A_P5.Quota
A_P2.Input	0.99955	A_P4.Area	A_P5.Quota
B_P1.Vol_tot	0.99898	A_P4.Area	C_P1.Vol_tot
B_P0.Baseline	0.99896	A_P4.Area	C_P1.Vol_tot
A_P3.Output	0.99840	A_P4.Area	A_P5.Quota
B_P2.Input	0.99763	A_P4.Area	C_P1.Vol_tot
C_P4.Area	0.99716	C_P0.Baseline	C_P2.Input
B_P3.Output	0.99579	A_P4.Area	C_P1.Vol_tot
B_P5.Quota	0.99514	A_P4.Area	C_P1.Vol_tot
C_P5.Quota	0.99270	A_P4.Area	C_P1.Vol_tot
C_P3.Output	0.99109	C_P1.Vol_tot	C_P2.Input

Source: own elaboration.

In benchmarking, an approach originating from Torgersen *et al.* (1996), an efficient unit is ranked high if it appears frequently in the reference sets (peer) of inefficient decision units. The most frequent water pricing policy is A_P4Area. On the contrary, the same policy scheme under the water saving scenario B (B_P4Area) does not constitute an efficient 'peer reference' for any other policy. In Table 3 the ecological efficiency score and DEA 'peer' reference are shown.

Table 3: Ecological efficiency and DEA 'peer' with Benchmarks.

Policy options	Ecological efficiency	Peer with Benchmarks	
A_P0.Baseline	1.00000		
A_P1.Vol_tot	1.00000		
A_P4.Area	1.00000		
A_P3.Output	1.00000		
C_P1.Vol_tot	1.00000		
A_P5.Quota	0.99871	A_P0.Baseline	A_P4.Area
C_P0.Baseline	0.99310	A_P0.Baseline	C_P1.Vol_tot
B_P1.Vol_tot	0.98376	A_P0.Baseline	C_P1.Vol_tot
B_P0.Baseline	0.98374	A_P0.Baseline	C_P1.Vol_tot
B_P4.Area	0.98239	A_P3.Output	A_P4.Area
A_P2.Input	0.97839	A_P3.Output	A_P4.Area
B_P5.Quota	0.96003	A_P0.Baseline	C_P1.Vol_tot
B_P2.Input	0.95825	A_P3.Output	A_P4.Area
B_P3.Output	0.95557	A_P3.Output	A_P4.Area
C_P5.Quota	0.94044	A_P0.Baseline	C_P1.Vol_tot
C_P2.Input	0.93969	A_P3.Output	A_P4.Area
C_P4.Area	0.93030	A_P3.Output	A_P4.Area
C_P3.Output	0.90550	A_P3.Output	A_P4.Area

Source: own elaboration.

Findings stress that ecological efficiency reaches the best value for five over all options analyzed. The average efficiency of the sample is 0.97277 and generally major differences are found. The worst efficiency level is shown in the case of C_P3.Output, for which almost 10% inefficiency with respect to the best one is found. Taking into account the five efficient options, it should be noticed that four out five water pricing policy take place in the water saving scenario A. It seems that rise in price does not result in environmental efficiency improvement.

Finally, in Table 4 both technical and ecological efficiency scores are listed. From the findings it can be noted that only two water pricing options, namely the A_P4.Area and C_P1.Vol_tot are full efficient.

V – Concluding remarks

The reform of water pricing methods is one of the basic policy instruments necessary for the enhancement of the efficiency of using water and of its quality status, as well as the protection of depletion from natural sources depletion. Policy makers require a clear overview of the different outcomes of alternative water management policies and tools need to be improved for supporting the selection of most suitable measures to specific situations. The objective of this research is to provide information for the support of the decision making process towards the selection of water pricing measures for irrigation water.

In the present paper we propose a methodology based on Data Envelopment Analysis (DEA), a non parametric benchmarking technique, specifically developed to assess the relative efficiency of alternative water pricing policies. For this purpose a ranking analysis was carried out according to the relative efficiency score. This efficiency may be a convenient method to rank policy alternatives in the case of an absence of information on stated preferences on outcomes, as well as negative environmental impacts.

Table 4: Technical vs. Ecological DEA efficiency.

Policy options		Technical Efficiency	Ecological Efficiency
1	A_P0.Baseline	0.99974	1.00000
2	A_P1.Vol_tot	0.99975	1.00000
3	A_P2.Input	0.99955	0.97839
4	A_P3.Output	0.99840	1.00000
5	A_P4.Area	1.00000	1.00000
6	A_P5.Quota	1.00000	0.99871
7	B_P0.Baseline	0.99896	0.98374
8	B_P1.Vol_tot	0.99898	0.98376
9	B_P2.Input	0.99763	0.95825
10	B_P3.Output	0.99579	0.95557
11	B_P4.Area	1.00000	0.98239
12	B_P5.Quota	0.99514	0.96003
13	C_P0.Baseline	1.00000	0.99310
14	C_P1.Vol_tot	1.00000	1.00000
15	C_P2.Input	1.00000	0.93969
16	C_P3.Output	0.99109	0.90550
17	C_P4.Area	0.99716	0.93030
18	C_P5.Quota	0.99270	0.94044

Source: own elaboration.

According to the findings, on the one hand, alternative pricing policies perform similarly in technical efficiency term. However, since indirect methods may be easier to implement, under some circumstances they might be preferable, without losses in terms of efficiency. In our experience, for example, it was found that the pricing method based on the irrigated area performed with maximum efficiency. On the other hand, the results show a difference of rank between the technical efficiency and the ecological efficiency indicator. The ecological efficiency shows up to 10% of inefficiency. In this study it appears that a rise in price does not result in environmental efficiency improvement. The policy implication may be important given that water policy reforms are addressed to increase water price, mainly in the European Union where tariffs enforcement is expected according to the 'full cost recovery' (EU/60/2000/WFD).

It is worth mentioning that the study is based on a short-term horizon, with a fixed coefficient linear programming model. Further research shall aim at exploring technological change farmers may decide to introduce, in the long run.

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(1) The single farm payment scheme has been introduced by the Regulation (EC) No 1782/2003 of 29 September 2003 establishing common rules for direct support schemes under the EU Common Agricultural Policy.

(2) In this research an application exercise is shown. More comprehensive analysis is carried out in Giannoccaro *et al*. (2010b).

(3) Ferti-irrigation is a system in which fertilizers are dissolved in the irrigation water before applying the water to the crops.