A methodology for evaluating agri-environmental schemes for policy design purposes

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Abstract

The objective of the paper is to develop a methodology for supporting the evaluation and design of agri-environmental schemes. The methodology is based on a combination of mathematical programming, contract theory and multicriteria analysis and is tested on a case study in Northern Italy. The methodology proposed can add insights into the policy design process, by taking consistently into account three issues often overlooked: the adaptation of cropping systems to the measures proposed; the diversity of compliance costs among farmers; the multidimensionality of the decision problem.

Keywords: agri-environmental schemes, rural development, Italy, linear programming, contract theory, multicriteria analysis

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1 Introduction and objectives

The second pillar of the CAP is gaining attention and is developing as one of the main strategic issues for agricultural policy, both in EU-15 and in CEECs. It includes a variety of rural development measures, ranging from farm modernisation to agri-environmental schemes (AESs). In spite of the 10 year experience with AESs, the ability to evaluate their results and to provide useful information for policy design is still unsatisfactory. On one side, the evaluation procedure is lagging behind with respect to the implementation process and is using indicators that are only a rough estimation of the actual impact of AESs. On the other side, more detailed and deep analysis may be very much time consuming and often lead to results that are difficult to interpret. Finally, present evaluation procedures do not fit very well for ex ante evaluation of policy design alternatives.

The objective of the paper is to illustrate and discuss a methodology for supporting the design of agri-environmental schemes. The methodology is based on a combination of mathematical programming, contract theory and multicriteria analysis.

The paper is based on a reflection about the use of multicriteria instruments for the evaluation of agri-environmental schemes carried out in the first steps of the project ITAES “Integrated tools to design and implement agri-environmental schemes”, funded under the EU 6th Framework programme.

The paper is organised as follows. In section 2 an overview of AESs’ evaluation methodologies is provided. In section 3 the methodology is illustrated, followed by the results of a case study in section 4. The paper is closed by some final discussion in section 5.

2 The issue of the evaluation of agri-environmental schemes

The evaluation of AESs has been an issue widely treated in the literature in the last decades and one of the main policy issues in the implementation of rural development plans. Various tools have been used for this purpose, both for ex ante and ex post policy evaluation.

While policy making has dealt mostly with ex post evaluation, ex ante evaluation may be considered as one of the main issue of research and has gained attention in policy making after Agenda 2000.

Among the different methodology developed, three kinds of tools will be considered in this paper: mathematical programming, contract theory and multicriteria analysis.

Mathematical programming may be used in order to simulate farm reaction to proposed contracts and technologies. It has the advantage to be able to manage the different activities carried out at farm level and the trade offs between different crops and contracts. On the other side, it takes often contracts as given and mainly assumes a private point of view.

The theory of contracts has been used to identify optimal contracts given a rather simplified representation of the real world, in particular as private objectives, cost functions and the mixes of farming activities are concerned. A number of application to agri-environmental policies exist in the literature (Fraser, 1993; White and Ozanne, 1997; Moxley et al., 1999; Bazzani et al., 2000; White, 2001).

Multicriteria analysis allows the comparison of implementation alternatives using more than one indicator (Zeleny, 1982; Roy, 1985; Saaty, 2000). It has been developed and widely used for a variety of problems, particularly in the field of environmental decision making, including agri-environmental policies (Viaggi, 1998; Casini, 1999) and rural development issues (Bazzani et al., 2002). It has the advantage to take into account many evaluation criteria and to be potentially able to interactively support decision making. On the other hand, it often has problems in translate alternatives into policy feasible and incentive compatible solutions.

3 Methodology

The methodology proposed is designed for ex ante evaluation of AESs. The methodology is based on a combination of mathematical programming, contract theory and multicriteria analysis and runs in the following steps:

Step 1: generation of the supply curve of agri-environmental services using linear programming;

Step 2: identification of policy alternatives based on the supply curves generated and contract theory;

Step 3: feed back of policy alternatives in the linear programming models and generation of the policy results in terms of a number of indicators;

Step 4: evaluation of the results of policy alternatives through multicriteria analysis.

The first step is based on the generation of the supply curves of agri-environmental service by farms, using mathematical programming. In particular, linear programming is used, with the following standard mathematical formulation:

$$\max\ GM = \sum_{k=1}^{n} gm_k x_k$$

s.t.:

$$\sum_{k=1}^{n} a_{hk} x_k \le b_h \quad \text{for } h=1,\dots,m$$

$$x_k \ge 0 \quad \text{for } k=1,\dots,n$$

where:

GM = total gross margin;

gm_k = unit gross margin of production process *k*;

b_h = total availability of factor *h*;

a_{hk} = quantità of factor *h* necessary to activate one unit of production process *k*;

x_k = level of activation of production process *k*.

The constraints considered include land availability, crop rotation and commercial constraints.

Models may be constructed for relevant farm types. For each one, the marginal cost of agri-environmental services can be calculated by parametrising on an agri-environmental services constraint.

In step 2, contract theory is used in order to identify feasible policy design options, under different sets of policy instruments. In this paper, the main focus is on mechanism design under adverse selection. Three policy alternatives have been considered:

A1) a standard menu of contracts under adverse selection;

A2) the awarding of a payment equal to the perceived marginal value of the services provided;

A3) a unique payment able to provide the same percent participation by all farmers.

In order to make policy alternatives comparable, the same budget has been assumed. Two farm types modelled with linear programming where considered. In option A1, following standard principal agent theory (Laffont and Martimort, 2002), the optimisation problem can be cast as follows:

$$\max_{\{(\bar{t},\bar{q});(\underline{t},\underline{q})\}} \nu\left(S(\underline{q})-\underline{t}\right)+(1-\nu)\left(S(\bar{q})-\bar{t}\right)$$

s.t.:

$$\underline{t}-C(\underline{q},\underline{\theta})\geq \bar{t}-C(\bar{q},\underline{\theta})$$

$$\bar{t}-C(\bar{q},\bar{\theta})\geq \underline{t}-C(\underline{q},\bar{\theta})$$

$$\underline{t}-C(\underline{q},\underline{\theta})\geq 0$$

$$\bar{t}-C(\bar{q},\bar{\theta})\geq 0$$

where:

θ=farm type, with $\bar{\theta}$=high cost (inefficient) farm type and $\underline{\theta}$= low cost (efficient) farm type;

$\bar{q}$, $\underline{q}$ =quantity of environmental good produced by inefficient and efficient farm type respectively;

$\bar{t}$, $\underline{t}$ =transfer to inefficient and efficient farm type respectively;

$C(\cdot)$=cost function, with $C_q > 0$, $C_\theta > 0$, $C_{qq} > 0$, $C_{q\theta} > 0$, $C_{qq\theta} > 0$;

ν , $(1-\nu)$=probability of the efficient and the inefficient type respectively;

$S(q)$=social benefit as a function of the environmental good produced.

In the first best outcome of the problem, the optimal quantity of good to be provided by each farm type is determined by:

$$S'(\underline{q}^*)=C'(\underline{q}^*,\underline{\theta})$$

$$S'(\bar{q}^*)=C'(\bar{q}^*,\bar{\theta})$$

In the second best option, the optimal menu of contracts entails no output distortion for the efficient type, while the output of the inefficient type is determined by:

$$S'(\bar{q}^{SB})=C_q(\bar{q}^{SB},\bar{\theta})+\frac{\nu}{1-\nu}\left(C_q(\bar{q}^{SB},\bar{\theta})-C_q(\bar{q}^{SB},\underline{\theta})\right)$$

which implies a downward output distortion.

Option A2 provides for the production of the first best optimum, but the payments are higher than before, as all environmental good provided is paid as the marginal cost at the optimum. In order to guarantee the budget comparability, the services provided are reduced of the same percent amount for both farm types.

Finally, option A3 provides for the awarding of the same percent of farmland to be used for wetland restoration by both farms, which implies to provide for both the marginal compliance cost of the least efficient one.

In step 3, the resulting contracts are then fed back into the linear programming model in order to compute a wider range of indicators, to be used to submit to multicriteria analysis. Indicators have been selected on the basis of local objectives and taking into account EU and OECD pertinent documents (Commissione delle Comunità Europee, 1999; 2000a; 2000b; OECD, 2001).

Multicriteria analysis is used to provide an evaluation of the results from the point of view of different actors. For the purpose of this explorative paper, an unweighted fuzzy Electre III methodology in the form proposed by Bernetti and Casini (1995) has been used.

The methodology is characterised by being unweighted and non-compensative, and takes into account the distance between indicators in order to assess the significance of their differences. In particular three thresholds are used:

t^i indifference threshold;

t^p preference threshold;

t^v veto threshold.

with

$$0 \le t^i \le t^p \le t^v$$

On the basis of such relationship it is possible to calculate two parameters, called, respectively, degree of concordance and degree of discordance:

$$C_j\left(A^h, A^k\right) = \begin{cases} 0 & \text{for} \quad A_j^k \ge A_j^h + t_j^p \\ \dfrac{A_j^h - A_j^k + t_j^p}{t_j^p - t_j^i} & \text{for} \quad A_j^h + t_j^i \le A_j^k \le A_j^h + t_j^p \\ 1 & \text{for} \quad A_j^h + t_j^i \ge A_j^k \end{cases}$$

$$D_j\left(A^h, A^k\right) = \begin{cases} 0 & \text{for} \quad A_j^h + t_j^p \ge A_j^k \\ \dfrac{A_j^k - A_j^h + t_j^p}{t_j^v - t_j^p} & \text{for} \quad A_j^h + t_j^p \le A_j^k \le A_j^h + t_j^v \\ 1 & \text{for} \quad A_j^k \ge A_j^h + t_j^v \end{cases}$$

The former expresses the credibility that A^h be at least as good as A^k. The latter expresses the credibility that A^k be preferred to A^h.

The two indexes are calculated for each couple of indicators of each matrix. The two matrixes derived are then aggregated using the two following criteria:

$$C\left(A^h, A^k\right) = \frac{1}{n}\sum_{i=1}^{n} C_j\left(A_j^h, A_j^k\right)$$

$$D\left(A^h, A^k\right) = \frac{1}{n}\sum_{i=1}^{n} \begin{cases} 1 & \text{for} \quad D_j(\cdot) \le C_j(\cdot) \\ \dfrac{1 - D_j\left(A_j^h, A_j^k\right)}{1 - C_j\left(A^h, A_j^k\right)} & \text{for} \quad D_j(\cdot) > C_j(\cdot) \end{cases}$$

The two indexes compare each alternative with each other, and produce the concordance and the discordance matrix respectively. The former uses a compensative approach, while the other uses a non compensative approach. The product of the two indexes produces the preference matrix:

$$P\left(A^h, A^k\right) = C\left(A^h, A^k\right) \cdot D\left(A^h, A^k\right)$$

Each member of this matrix is equal to the concordance matrix when discordance is equal to 1, while it is lower otherwise. The matrix is used to compute two pre-ranking parameters, called acceptance and refusal parameter respectively:

$$d_h^a = \min_{h \neq k} P\left(A^h, A^k\right)$$

$$d_h^r = \frac{1}{n-1} \sum_{h \neq k} P\left(A^h, A^k\right)$$

The final outranking of alternatives is performed by distinguish three groups:

A^D = altogether dominant alternatives;

A^{ND} = altogether non dominant alternatives;

A^{NC} = non comparable alternatives.

Such distribution is provided through an acceptation threshold ($0 \leq \lambda^a \leq 1$) and a refusal threshold ($0 \leq \lambda^r \leq 1$), under the following rules:

$$\tilde{\tilde{R}} = \begin{cases} d_h^a \geq \lambda^a \Rightarrow A^h \in A^D \\ d_h^a < \lambda^a \cap d^r \geq \lambda^r \Rightarrow A^h \in A^{NC} \\ d_h^a < \lambda^a \cap d^r < \lambda^r \Rightarrow A^h \in A^{ND} \end{cases}$$

Altogether, the methodology allows to compare different policy instruments (including those actually implemented) and to assess their ability to respond to social needs and expectation. Also, it can support negotiations in order to allow the implementation of local needs into policy design in a participatory way.

4 First results

4.1 The study area and the supply of agri-environmental services

The model is tested in a study area located in Codigoro and Jolanda di Savoia (Emilia-Romagna, Northern Italy). The area, close to the Po delta, is characterised by strong agronomic constraints, due to peaty soils that require the cultivation of rice on at least half of the surface, in order to maintain soil characteristics compatible with farming. Rice CMO was recently reformed with a reduction of the net level of protection. As a consequence, in perspective, the economic sustainability of the area may be perceived as being at stake.

At the same time, wetland restoration is a priority in the area, in order to complement the protected areas close to the delta and in order to re-create some of the original landscape and biological features of the area.

In order to construct linear programming, data were taken out of a sample of 41 farms, divided into two types. The distinction between the two farm types is base on the technical-economic orientation. Both of them practice a crop mix based on rice, maize, sugar beet and soy-bean. In addition, type A can produce industrial tomato. Type A accounts for 7,5% of the total surface, while the remaining is made up of farm type B.

The only agri-environmental measure analysed is wetland restoration. Estimated supply curves for the two farm types have the following form:

Farm type A: $C(\cdot) = 2{,}106\text{x}^2 + 763{,}44\text{x}$

Farm type B: $C(\cdot) = 0{,}6685\text{x}^2 + 750\text{x}$

4.2 Design of policy alternatives

The main features of the three policy alternatives designed are illustrated in table n. 1.

Tab. 1: Policy alternatives designed

Alternative	Wetland restoration (%)	Payment per farm (€/100 ha)	Total wetland restoration (%)	Total costs (€/100 ha)
A1	Farm type A= 0,0 Farm type B= 37,4	Farm type A= 0 Farm type B= 28.982	34,6	26.811
A2	Farm type A= 8,3 Farm type B= 35,6	Farm type A= 6.602 Farm type B= 28.448	33,6	26.811
A3	Farm type A= 30,1 Farm type B= 30,1	Farm type A= 26.811 Farm type B= 26.811	30,1	26.811

Alternative A1 is a standard menu of contracts designed under asymmetric information. In this case, the result would be “shutdown” of the least efficient type, i.e. the concentration of all wetland restoration on the more efficient type.

Alternative A2 is based on the awarding of a payment equal to the perceived marginal value of the services provided. In this case, the amount of land devoted to conservation is distributed between the two farm types. Optimal levels are reduced so as to respect the same budget necessary for the first policy option.

Alternative A3 is based on a unique payment able to provide the same percent participation by all farmers.

4.3 Evaluation of policy alternatives

By feeding the policy parameters in the linear programming models, the farm adaptation to contracts is then computed, together with some indicators. The result are then aggregated for the two farm types in order to produce the matrix of impact indicators (table n.2).

Tab. 2: Impact indicators

		A1	A2	A3
Wetland restoration	%	34,60	33,55	30,10
Distribution of wetland restoration	index	0,00	0,25	1,00
Employment	hours/ha	20,52	20,65	21,40
GDP	€/ha	418,07	422,41	458,56
Water	m^3/ha	9093,67	9089,60	9033,86
Nitrogen	Kg/ha	-35,05	-34,66	-35,65
Pesticides	Kg DL50/ha	305,39	308,63	320,65
Rice	%	32,89	33,05	35,00

Indicators have been selected according to objectives expressed in a local environmental agreement and translated into computable parameters by adding environmental coefficients to the linear programming models.

The indicators are then normalised and, at the same time, translated into agri-environmental quality indexes, defined in the range 0-1 (table n.3).

Tab. 3: Agri-environmental quality indexes

	A1	A2	A3
Wetland restoration	0,692	0,671	0,602
Distribution of wetland restoration	0,000	0,247	1,000
Employment	0,519	0,529	0,584
GDP	0,550	0,556	0,604
Water	0,655	0,658	0,698
Nitrogen	0,661	0,653	0,674
Pesticides	0,313	0,306	0,279
Rice	0,144	0,152	0,250

As a first evaluation, it is clear that no alternative is pareto-dominated. The indexes directly related to wetland restoration are themselves contradictory. In fact, going from alternative A1 to alternative A3, the total amount of wetland decreases, while the distribution index increases. Employment, GDP, water nitrogen and rice get better moving from A1 to A3. The amount of pesticides goes the other way round.

The global concordance matrix is represented in table n.4. In order to simplify the analysis, the preference thresholds are defined as follows:

$t^i = \frac{1}{3} t^v$ and $t^p = \frac{1}{2} t^v$

Tab. 4: Global concordance matrix

		A1	A2	A3
	A1	1,00	0,88	0,38
t^v=0,03	A2	0,88	1,00	0,25
	A3	0,75	0,75	1,00
	A1	1,00	0,88	0,46
t^v=0,09	A2	1,00	1,00	0,58
	A3	0,88	0,88	1,00
	A1	1,00	0,88	0,85
t^v=0,27	A2	1,00	1,00	0,86
	A3	1,00	1,00	1,00

The matrix show that the alternatives A1 and A2 have a relevant probability to be not as good as A3. The judgement strongly depends on the preference threshold adopted. Nevertheless, the differences appear rather significant as long as they are still relevant with t^v=0,27.

The global discordance matrix is represented in table n.5

Tab. 5: Global discordance matrix

		A1	A2	A3
	A1	1,00	0,88	0,38
t^v=0,03	A2	1,00	1,00	0,38
	A3	0,75	0,75	1,00
	A1	1,00	0,88	0,75
t^v=0,09	A2	1,00	1,00	0,75
	A3	0,88	0,96	1,00
	A1	1,00	0,90	0,88
t^v=0,27	A2	1,00	1,00	0,88
	A3	1,00	1,00	1,00

It confirms the outcome of the concordance matrix, as alternative A3 expresses a higher probability to be better than A1 and A2 than the other way round.

The matrix of the degree of preference is represented in table n.6.

Tab. 6: Degree of preference matrix

		A1	A2	A3
	A1	1,00	0,77	0,14
t^v=0,03	A2	0,88	1,00	0,09
	A3	0,56	0,56	1,00
	A1	1,00	0,77	0,34
t^v=0,09	A2	1,00	1,00	0,44
	A3	0,77	0,84	1,00
	A1	1,00	0,79	0,74
t^v=0,27	A2	1,00	1,00	0,75
	A3	1,00	1,00	1,00

As a result of the previous matrixes, the likelihood that A1 is better than A3 is rather low, while the opposite is relatively high.

The final ranking is represented in table n.7. The result further depends on the acceptance and refusal thresholds.

Tab. 7: Final ranking matrix

		$\lambda^r = \lambda^a$ =0,1			$\lambda^r = \lambda^a$ =0,3			$\lambda^r = \lambda^a$ =0,5		
		A1	A2	A3	A1	A2	A3	A1	A2	A3
	d^a	0,14	0,09	0,56	0,14	0,09	0,56	0,14	0,09	0,56
t^v=0,03	d^r	0,45	0,48	0,56	0,45	0,48	0,56	0,45	0,48	0,56
	outranking	A^D	A^{NC}	A^D	A^{NC}	A^{NC}	A^D	A^{ND}	A^{ND}	A^D
	d^a	0,34	0,44	0,77	0,34	0,44	0,77	0,34	0,44	0,77
t^v=0,09	d^r	0,56	0,72	0,80	0,56	0,72	0,80	0,56	0,72	0,80
	outranking	A^D	A^D	A^D	A^D	A^D	A^D	A^{NC}	A^{NC}	A^D
	d^a	0,74	0,75	1,00	0,74	0,75	1,00	0,74	0,75	1,00
t^v=0,27	d^r	0,77	0,88	1,00	0,77	0,88	1,00	0,77	0,88	1,00
	outranking	A^D	A^D	A^D	A^D	A^D	A^D	A^D	A^D	A^D

With low preferences thresholds and high acceptance and refusal thresholds it is possible to express a very strong judgement. In this case, A3 is to be selected, while both A1 and A2 are dominated. Lowering the acceptance and refusal thresholds, the ranking is less clear, with A1 and A2 shifting to the non comparable set and, in the case of lowest acceptance and refusal parameters, A1 shifts to the altogether dominant set. Increasing preference thresholds, the ranking of alternatives becomes weaker. With t^v =0,27, all alternatives appear to be acceptable. Hence the decision may be based on further criteria.

5 Discussion

The experience shows that the way in which the AESs are implemented in the area can be improved through structured analysis of their results. At the same time, the suggestions coming from the economic literature have to be strongly mediated with the local conditions and with actual policy making, in order to avoid unexpected results and failures. From this point of view, different methodological approaches can bias analysis towards specific issues that prove not to be necessarily relevant in reality. At the same time, each methodology can contribute with a particular understanding of some feature.

More specifically, the methodology proposed can add insight into the policy design process, by taking consistently into account three issues often overlooked:

- the adaptation of cropping systems to the measures proposed and its effects on objectives that are not directly considered under the design of the measure proposed;
- the diversity of compliance costs among farmers;
- the multidimensionality of the decision problem.

While improved evaluation systems increase the ability to understand the results of AESs, the cost/effectiveness of such evaluation systems for policy purposes may also be considered. The methodology proposed, however sofisticated, cannot substitute the decision process, but can support ex ante policy design by structuring the choice problems in relation to the different issues. In a context of truly multifunctional agriculture and diminishing funds for public intervention these are key issues in order to ensure policy effectiveness and efficiency.

Some developments of the methodology are straightforward, such as the use of weighted multicriteria analysis, the use of multicriteria mathematical programming at farm level, the definition of more complete sets of alternatives and weights.

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