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AN EX-ANTE EVALUATION OF AGRI-ENVIRONMENTAL CONTRACTS FOR THE PROVISION OF LANDSCAPE ELEMENTS IN AN AREA OF EMILIA-ROMAGNA REGION

Davide VIAGGI[*], Fabio BARTOLINI[**]

Abstract

The objective of this paper is to set up a complete ex-ante evaluation procedure to support Decision Makers in designing efficient and effective agri-environmental contracts, combining elements of private and public decision making. Ex-ante comparison of policy design options (different contract lengths and level of payments) requires both simulations of farmers' behaviour and evaluation of the farms simulations outcomes. Farm level analysis is based on a real options approach including in the simulations the timing of choice and the uncertainty in the future about price and decoupled payments. Aggregate policy impact is identified through the quantification impacts at territorial level and the weights are elicited with MCRID methods. Simulations in the case study show that relevant opportunities to improve policy design are available. Multicriteria Analysis is then used to aggregate impacts of many criteria, including not only effects on the environment, but also economic and social impacts.

Key words: Agri-environmental schemes; Multicriteria Analysis; MCRID, Landscape contracts, Emilia Romagna Region.

JEL classification: Q12; Q18

1. Introduction and Objectives

The Agri-Environmental Schemes are starting their new programs for the period 2007-2013, under regulation 1698/2005. In this regulation the European Commission has confirmed the possibility for each Member State to design and implement agri-environmental schemes at national, regional or local level. The design step is a fundamental phase in the policy cycle and it is based on the definition of the type and the dosage of policy instrument, choice of the target, choice of addressees and choice of the regulation area [Latacz-Lohmann, 2001]. Policy effectiveness has strong relationships with implementation and contract design phases [Latacz-Lohmann, 2001]. Accuracy in the design and in the creation

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[*] Davide VIAGGI (davide.viaggi@unibo.it) is researcher of Agricultural economics Department of Agricultural Economics and Engineering at University of Bologna, Faculty of Agricultural. He received his PhD in: Agricultural Economics. His research interests include: Policy Evaluations, Economics of Contract, Modelling policy impact and effects His teaching interests include: Environmental and natural resources economics, Rural appraisal.

[**] Fabio Bartolini (fabio.bartolini@unibo.it) is Contract Researcher, of Agricultural Economics Department of Agricultural Economics and Engineering at University of Bologna, Faculty of Agricultural. He received his PhD in: Agricultural Economics. His research interests include: Policy Evaluation, Modelling policy impact and effects.

of policies can take into account the needs of all stakeholders involved and can guarantee an efficient and effective program. Furthermore the design of contracts for the production of agri-environmental goods has the meaning to generate participation and to invest in environmental goods, without generating distortive effects on the market [Swinbank, 2000; Latacz-Lohmann and Hodge, 2001; Dobbs and Pretty, 2004].

The objective of this paper is to develop a complete ex-ante evaluation procedure to support Decision Maker (DM) in designing more efficient and effective agri-environmental contracts, through an integrated modelling of elements of private and public decision making. Ex-ante comparison of policy design options in terms of overall effectiveness requires both simulation of farmers' behaviour and evaluation of the farms simulations outcomes. An intermediate step is the aggregation of single farm impacts at territorial level, in order to identify the aggregate impact of each alternative. Alternatives are several contract design options, based on different levels of payments for introduction and maintenance. Farm level analysis is realized using a land allocation model, based on a real options approach. Public analysis is based on the evaluation of the aggregate farms' impacts of several contract alternatives based on interactive multicriteria analysis, where weights are elicited using the Multiple-Criteria Robust Interactive Decision Analysis (MCRID) approach. The model is applied to a case study area in Ferrara Province (NUTS 3).

The structure of the paper is the following: in section 2 the methodology is presented; in section 3 the case study are presented; results and conclusions are reported in sections 4 and 5 respectively.

2. Methodology and data collection.

The objective of this paper is to develop an aggregate ex-ante evaluation of different contract design options, for facilitating the DM in the policy design phase. The methodology (Figure 1) is divisible in two levels: first, analysis of farmers' behaviours in front of new contract design options for the provision of landscape elements; second, public analysis of the choice, in order to identify dominated policy alternatives. Combining both elements of private and public decision making it is possible to outline strategies to improve the efficiency and effectiveness of agri-environmental contracts.

Farmers' behaviours analysis has been developed using a land allocations model that determines the participation in front of new contracts for the provision of landscape elements. Alternatives considered are different ways to implements landscape contracts, changing the amount of payments for both introduction and maintenance phases and the length of the contract of the two phases.

Farmer's choice is determined by the maximum expected value synthesized in equation 1 [Mastens and Soussier 2002]:

$$\begin{aligned} G^* &= G^l, \text{ if } V^l > V^a \text{ and} \\ &= G^a, \text{ if } V^l < V^a . \end{aligned} \tag{1}$$

where

G^l = contract for provision of agri-environmental good;

G^a = better alternative to the contract provided;

V^l, V^a = expected value of transactions respectively of agri-environmental contracts (l) and to the better alternative to the production of agri-environmental goods (a);

G^* = farmer's choice.

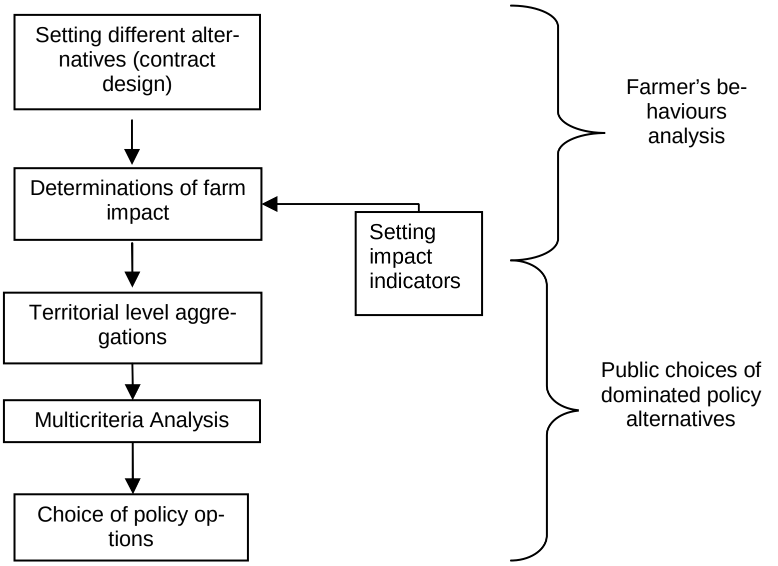

Figure 1. Methodology applied

Expected value of the choice to be involved in agri-environmental contract or not, has been modelled using land allocation model, with real options techniques[1]. See Peerlings and Polman, [2004] for the formalizations of the model and Bartolini et al., [2008] for the complete model setting and calibration.

Each farmer's choice (G^*) determines an impact vector i_{lh}^{v}, measured through economic, social and environmental indicators. For a generic alternative *l* the territorial impacts correspond to:

$$I_l^v = \sum_{h=1}^{H} i_{lh}^{v} s_h \qquad (2)$$

Where:

i_{lh}^{v} = farms performance generated by alternative *l;*

h = *1…*,*H* farm type

v = economic (eco), social (soc) and environmental (env) criteria;

s_h = weights of farm *h* on the territory[2].

The set of indicators identified and used in ex-ante evaluations is shown in

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[1] See Peerlings and Polman, [2004] for the formalizations of the model and Bartolini et al., [2008] for the complete model setting and calibration.

[2] See Bartolini 2007 for the description of the farm type and of the weights associated to each farm type.

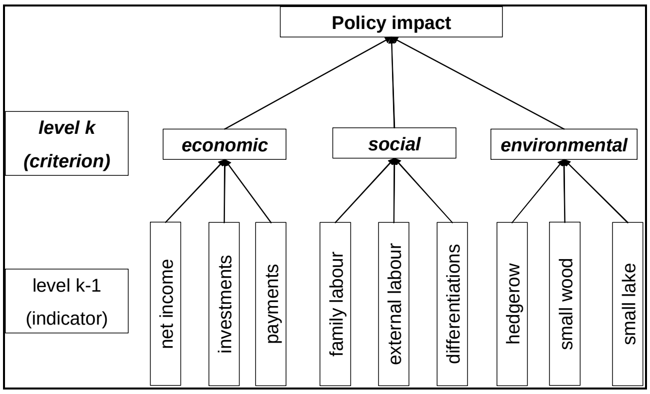

Figure 2. Hierarchical structure of indicators

Indicators are presented in two levels, k level and k-1 level. The aggregate policy impact is identified through the quantification of economic, social and environmental impacts (k or criterion level). Economic indicators are quantified through farm net income, level of investments in AESs and government' payments for AESs. Social indicators identified are both family and external labour and number of farms that received agri-environmental payments. Environmental indicators are quantified through the area under landscape contract, divided into the possible agri-environmental practices (hedgerow, small wood and pond).

The utility value (u_l^i) is generated by the aggregation of weight w_i and impacts I_{il}, for each *v* criterion and for each *l* alternative (Guitouni and Martel, 1998).

The methodology for eliciting weights, as expression of relative importance of objectives for the DM, is based on Multiple-Criteria Robust Interactive Decision analysis (MCRID) from Moskowitz et al. [1992]

The Multicriteria problem can be identified as an aggregation of the utility from single criteria based on the performance for each criterion of one alternative a_j.

$$E[U(a_j)] = \sum_{i=1}^{n} w_i u(a_{ji}) \qquad (3)$$

Where:

j= 1,..,n alternative

i=1,…m criterion

Total utility function at k-level is obtained from the aggregations of several utility functions at k-1 level. Adopting hierarchical MCA suppose to pay high attention to the preferences inter-level and intra-level.

The multicriteria approach used is based on an interactive process with the DM; the information collected from DM is able to reduce weakness during weights elicitation phases.

The key strategy of this methodology is in structuring the DM's choice and the preference expressed as linear programming optimizations; in this way, it is possible to elicit the weight as an interval number in order to include imprecision and uncertainty [Hayashi, 2000]. The minimization and the maximizations of DM' preference for each criterion can be interpreted as upper and lower bound values within which the value of the importance of each criterion can be considered consistent. Several other methods are used in literature for eliciting weights, basically included in interval point scale, or ratio scale [Salo, 1995].

The methodology is applies as follows. The first step started asking DMs the ranking of the importance for the criteria at k-1 level and the alternatives strictly preferred for the same criteria considered. Identification of dominant alternatives is based on paired comparison. The DM's preference can be formalized as:

$$w_i^{k-1} \succ w_l^{k-1} \text{ with } i \neq l \quad (4)$$

$$E\left[U(a_i)^{k-1}\right] \succ E\left[U(a_y)^{k-1}\right] \quad (5)$$

Where

w_i^{k-1} = the weight of *i*-th criterion at the *k*-1 level

w_l^{k-1} = the weight of *l*-th criterion at the *k*-1 level

$E\left[U(a_j)^{k-1}\right]$ = expected utility functions for j-th alternative; can be interpreted as a product between expected score of indicators and the weights $E\left[U(a_j)^{k-1}\right] = w_i^{k-1} * U(j_i)^{k-1} + w_l^{k-1} * U(j_l)^{k-1}$

$E\left[U(a_y)^{k-1}\right]$ = expected utility functions for y-th alternative; can be interpreted as a product between expected score of indicators and the weights $E\left[U(a_y)^{k-1}\right] = w_i^{k-1} * U(y_i)^{k-1} + w_l^{k-1} * U(y_l)^{k-1}$

Structuring the identified preference as linear programming model and through maximizing and minimizing the weight of each criterion, it is possible to identify the maximum and minimum value of the weights that verifies the structure of preference revealed by the DM. Repeating the step for the other k levels, we are able to identify weights for each criterion present in the same level. Following Arrow [1951] the verbally expressed preferences can be rewritten as:

$$w_i^{k-1} - w_l^{k-1} > 0 \quad (4a)$$

$$\sum_{i=1}^{n} w_i^{k-1}\left[U(j_i)^{k-1} - U(y_i)^{k-1}\right] \quad (5a)$$

With both maximization and minimizations for each weight of the same liner programming problem it is possible to identify the DM's local weight [Moskowitz et al., 1992].

$$\max/\min \quad w_i^{k-1} \quad (6)$$

subject to

$$A^{k-1} w_i^{k-1} < rel > b^{k-1} \quad (7)$$

$$D^{k-1} w_i^{k-1} \geq 0 \quad (8)$$

$$\sum_{i=1}^{n} w_i^{k-1} = 1 \quad (9)$$

Where A is m x n matrix containing the constraints, w_i is a n-dimension vector of weights and b is a m-dimensional vector of the right-hand sides for the level k. D expresses the DM strict preference matrix.

The fourth step is to aggregate at the k-level the impact, trough a utility weighted sum the k-1 impact. The aggregations is based on maximum (Equation 10) and minimum (Equation 11) weighted sum of the criteria

$$\overline{U}_j^k = \sum_{i \in S_{kj}}^{n} \overline{w}_i^{k-1} u_i^{k-1} \qquad (10)$$

$$\underline{U}_j^k = \sum_{i \in S_{kj}}^{n} \underline{w}_i^{k-1} u_i^{k-1} \qquad (11)$$

The maximum ($\overline{w}_v$) and the minimum weights ($\underline{w}_v$) are obtained from the minimizations and the maximization process. Restarting the second interactions with the DM (k level), the DM provides a new ranking of the criterion based on the importance and new identification of pairs of alternatives. The final score of the alternatives is based on the aggregations through weighted sum of the partial utility above calculated.

The choice among different alternatives is obtained comparing the total utility deriving from all impacts [Keeney and Raiffa, 1976].

3. Case Study

The Case Study Area is located in one of the “Agricultural Regions” of the Ferrara Province, including the Municipalities of Argenta, Berra, Copparo, Formignana, Jolanda di Savoia, Masi Torello, Portomaggiore, Ro, Tresigallo e Voghiera. The Case Study concerns a plain area, with some parts under the sea level. Usable Agricultural Area is 70,713 ha with farm number equal to 3.630, of which a greater part individually/family run. The average farm size is equal to 19.23 ha, quite high, compared with the average of Emilia Romagna Region. Table 1 shows the trend in crop cultivations.

Table no. 1 – Changing in crop area (ha)

Crop	**Year**								
	1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Cereals	34,186	34,119	39,453	40,659	39,483	43,128	44,947	49,379	45,956
Root and other specialized	23,501	26,321	19,698	18,585	17,640	13,866	13,910	13,217	18,268
Oilseed and protein	60	45	143	5	15	70	81	105	73
Vegetables	3,134	3,191	3,543	3,428	3,099	3,281	3,646	3,926	4,041
Orchards	8,708	8,234	8,171	8,036	7,594	7,644	7,475	7,464	6,376

Sources: Emilia Romagna Region.

The measures simulated concern the introduction and the maintenance of natural spaces and landscape elements. Actual contract design was structured in two time period, introduction and maintenance both of length of 5 years and payments of 2000 €/ha in the first period and 1000 €/ha in the second period. The possible land uses allow under landscape contract are Hedgerows; Small wood; Pond.

Contract design options describe the set of alternatives analyzed through MCA. Alternatives are different ways to design contracts for landscape elements (Table 2). The code of the alternatives reflects the structure of contract design, as it classifies options in terms of length of introduction (years), length of maintenance (years), payments for introduction (€/ha) and payments for maintenance (€/ha). In Table 2 the code L and H identify in the first or second period a reductions (L) or an increase (H) of 1000 €/ha with respect to the present contract design (P). Present contract designed is 5_5_P_P.

Table no. 2– Alternative contract design considered inn MCA comparison

	Alternative code														
Contract Variable	3_3_L_0	3_3_P_0	3_7_H_H	5_7_L_P	***5_5_P_P***	5_7_P_H	5_3_H_0	7_5_L_0	7_5_P_P	7_5_H_P	7_3_H_0	10_3_L_0	10_10_L_0	10_10_L_P	10_10_P_P
length introduction (year)	3	3	3	5	***5***	5	5	7	7	7	7	10	10	10	10
length maintenance (year)	3	3	7	7	***5***	7	3	5	5	5	10	3	10	10	10
payments introduction (1000 €/ha)	1	2	3	1	***2***	2	3	1	2	3	3	1	1	1	2
Payments maintenance (1000 €/ha)	0	0	2	1	***1***	2	0	0	1	1	0	0	0	1	1

The alternative considered for the modelling phases are 144. However, we reduced the number of alternatives through a simplified criterion, based on best scoring in an un-weighed sum of economic, social and environmental impact for each combinations of length in the first and second period; also, where different alternatives produced approximately the same results, only one of them was retained.

4. Results

The complete methodology is available from Bartolini, et al. [2008]. Policy alternatives are first simulated for individual farm typologies. Then results are aggregated at territorial level in order to obtain spatial impact of several contract designs. Basic information used (including farm-related information) was derived from Bartolini, et al. [2008]. Results are presented in the following ways, first are eliciting the value of weights, secondly are presented the impact at territorial level and thirdly the result of multicriteria analysis.

According to the methodology illustrated above, weights used for comparison are elicited in two interactions with DM. The final weights that include the take into account the priority of level of hierarchical structure are showed in Table 3.

Table no. 3–Weights

	w_{ni} **(net inc.)**	w_{in} **(inv.)**	w_{pa} **(pay.)**	w_{el} **(ext. lab.)**	w_{fl} **(fam. lab.)**	w_{df} **(diff.)**	W_{hd} **(hedg.)**	W_{sw} **(small wood)**	w_{la} **(ponde)**
Min.	0,04	0,04	0,33	0,00	0,03	0,00	0,16	0,00	0,40
Max.	0,07	0,10	0,21	0,04	0,13	0,07	0,08	0,11	0,18
Central Value	0,05	0,07	0,27	0,02	0,08	0,03	0,10	0,10	0,24

The first row of Table 3 represents the normalized weights vector obtained from weight minimization; the second one represents the normalized weights vector obtained from weight maximizations. The last row represents the normalized average value of the weights. DM shows differences in the perceptions of importance among indicators. The indicators with higher relevance belong to the set of environmental indicators, within which ponds has a particularly high value. Other indicators with high importance are participation and the reduction of payments. Indicators with less importance are family and external labour, which are not important for the aim of agri-environmental programs.

The normalized impacts of several contracts design, which are resulting from simulations exercise, are presented in Figure3.

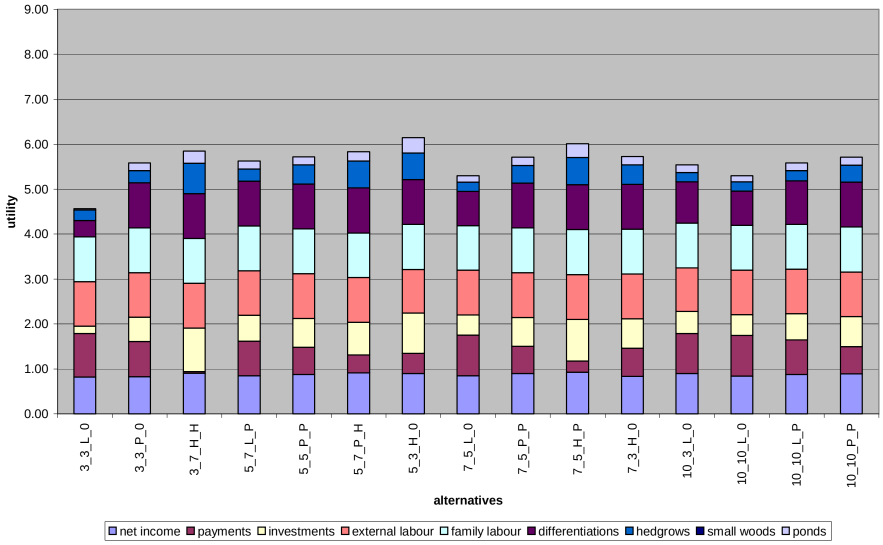

Fig. 3. Normalized territorial impact of different contract design.

In figure 3 impact of each alternative considered can be interpreted as utility using unweighted sum of the normalized impact for each indicator. Social indicators as external and family labour show relevant differences when comparing alternatives. Alternative 5_3_H_0 provides the highest utility, due to the high level of participation and investments in AESs.

The aggregated impact was evaluated using a weighted sum in order to take into account the relevance of each impact for each criterion (Figure 4).

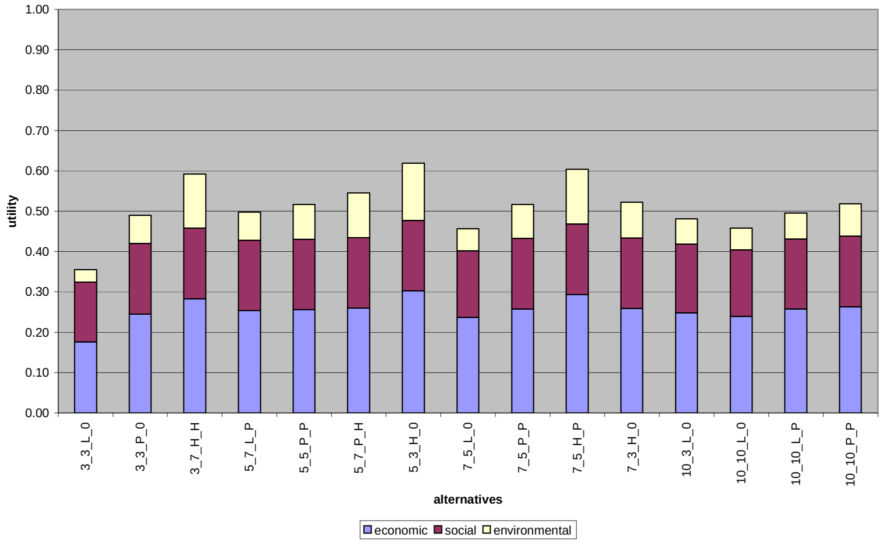

Fig. 4. Weighted Sum

The weights used are the central value identified in the second interactions with the DM (Table 4). Higher level of utility is obtained from alternative 5_3_H_0. Utility can be improved by 10%, through a different combination of length and payments in both periods, with respect to the actual contract design. As discussed before, weights elicited using MCRID include information about uncertainty, as they are quantified by an interval of values obtained from both maximization and minimization process (Table 3). Figure 4 represents the area of utility generated using extreme weights obtained from maximization and minimization.

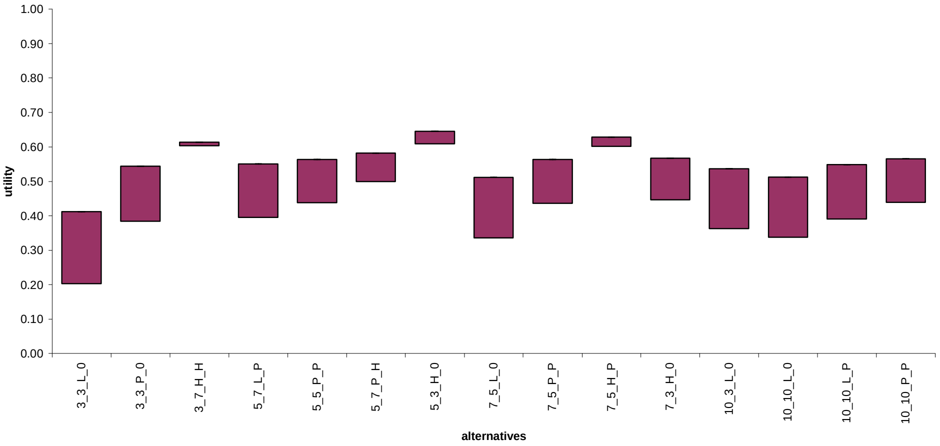

Fig. 4. Comparison between alternative contract design

The dominant alternatives are 3_7_H_H, 5_3_H_0 and 7_5_H_P that also show a low value of uncertainty. All those alternatives are dominant with respect the present contract design for the production of landscape elements. The degree of uncertainty in weights varies substantially and appears higher for the alternatives in the lowest positions.

5. Conclusion

Ex-ante analysis is based on the predicted impacts of the effects of several agri-environmental contract designs. Some of the main concerns of this approach are related to the prediction of farmers' behaviour. This is implemented here through the use of economic modelling tools. This approach may be trusted or not as a means to provide such predictions. In any case it at least makes explicit the need to pay attention to the factors affecting participation and to how contract design will affect such participation.

The simulations in the case study show that relevant opportunities to improve policy design are available. MCA is then used to aggregate impacts of many criteria, including not only effects on the environment, but also economic and social impacts. With an interactive process, in particular with MCRID, it is possible to elicit weights using a structure derived from the explicit preferences of the DM through ranking and comparison between alternatives, and taking into account "uncertainty" through the definition of a range of consistent weights' values. Again, though this formalisation may not be completely satisfactory, it emphasises the importance of an explicit consideration of objectives and their importance for effective decision making.

The results obtained can be improved by including other measures in the simulation phase, and looking at the combination of the impact of those measures. This will also allow a better identification of the total impact and an explicit consideration of trade offs and budget allocation across measures. The analysis can also be improved by including the impact in different geographical areas in order to consider precision and targeting of different measures.

The approach illustrated here is based on the formalizations of both farmer and DM's behaviour. Farmer's behaviour simulation appears a rather established approach, as it may be supported by a high quantity of literature and experience. However, the choice of utility functions to be maximized, the elements of cost to be included and the motivations supporting farmers' involvement in AESs still present potential weaknesses in modelling farmer's behaviours that need more clarifications.

The behaviour of the DM was not simulated here, but formalised and supported through the provision of indicators and the elicitation of preferences. From this point of view, the identification and the quantifications of measurable indicators of impacts of different policy options still appears not completely satisfactory, particularly where attention, as an outcome of the simulation, is concentrated on pressure, rather than impact indicators.

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