Agri-environmental auctions: choosing the farm area put under contract

Sandra Said *
Sophie Thoyer **

Paper presented at the EAERE Conference- Göteborg – 24_28 june 2008-09-15

* PhD student – Inra-Lameta 2 place Viala 34060 Montpellier cedex 1 (France) –e-mail: said@supagro.inra.fr

** Professor, Department of agricultural and Resource Economics, Supagro-Lameta, 2 place Viala 34060 Montpellier cedex 1 (France) e-mail: thoyer@supagro.inra.fr _ presenter

The authors wish to acknowledge the contribution of Annie Hofstetter, Inra-Lameta*, who helped with the numerical simulations and gave very useful advice on optimisation algorithms*.

Key words: Agri-environment, multiple unit auctions, multi-criteria index
JEL: Q58, H23, C0

Abstract

All theoretical papers modelling agri-environmental auctions neglect the issue of farm size by assuming that farmers bid only for one hectare. We analyse the theoretical outcomes of an agri-environmental auction when farmers bid on the proportion of the farm area they wish to put under contract and on the average compensatory payment. We simulate the effect of the compliance cost structure on auction performance. We also show that imposing stricter requirements in terms of environmental efforts per ha can either lead farmers to increase the proportion of their farmland under contract or to decrease it. Numerical simulations based on a French case study illustrate how various rules concerning the maximum allowed payment per farm affect the distribution of net profits to farmers.

Introduction

Agri-environment schemes were introduced into the Common agricultural policy (CAP) during the late 1980s as a financial instrument to encourage more environmentally-friendly farming practices. After implementation of Agenda 2000, European budgets dedicated to agri-environmental payments (co-financed by the EU and national states) were increased significantly: in the 2000-2006 programming period, they amounted to 13.5 billion € and the share of European agricultural land enrolled in agri-environmental contracts had reached 25% in 2005 (CE, 2005). The allocation mechanism - although variable from one member State to another - is based on the following rule: farmers can choose, on a voluntary basis, to commit themselves for a given period to adopt environmentally-friendly farming techniques on their private land. They sign up for a tailored contract which includes a number of relevant measures chosen amongst a large menu (measures such as extensification practices, management of low intensity pasture systems, preservation of habitats and biodiversity, adoption of organic farming etc) and they receive in return payments that are estimated so as to compensate them for additional costs and loss of income (thereafter cost of compliance) arising from their new farming practices.

Such payments often represent a non negligible –and secure- source of farm income and have contributed to maintain farming in less favourable areas. It is a fact that agri-environmental policies have often been used by member States to supplement farm income, in a way which was compatible with the decoupling requirements of the World Trade Organization. Although supervised by Brussels, allocation rules vary from one member State to another, often reflecting the relative weights that national decision-makers give to genuine environmental concerns and to income-support objectives. This ambiguity about the true objectives of agri-environmental scheme explains partly the disheartened evaluation conducted by the EC (CE, 2005; Primdahl et al, 2003) which pointed out the insufficient environmental outcomes of agri-environmental payments. The EC diagnostic was that disappointing outcomes resulted from ill-designed measures, dispersion of efforts as well as multiple "windfall effects" (farmers being paid for what they were already doing or for what they would have done anyway).

Following an audit of the European Court of Auditors, the EC has made a formal statement to recommend that agri-environmental schemes include quantifiable objectives, be more cost-effective, and to strongly encourage member States to adopt competitive bidding in the allocation process. This last recommendation is quite revolutionary in the European context since the mechanism used so far is based on a menu of regional measures which does not allow to overcome satisfactorily the asymmetries of information on true compliance costs. On the other hand, it is useful to select priority zones and priority actions and to target specific categories of farmers in need of income support. An important question for the European regulator is therefore the design of a competitive bidding process, which could target farmers able to supply greater environmental benefits – as a joint product of farming activities – at a lower cost for society.

There exists already a vast empirical (mainly based on the US and Australian experience) and theoretical literature on agri-environmental auctions (see Latacz-Lohmann et Schilizzi, 2007 for a review). Theoretical models, inspired by the US Conservation Reserve Program and by the pioneering work of Latacz-Lohmann et Van Der Hamsvoort (1997), demonstrate that sealed bid auctions lead to greater efficiency and lower budgetary expenditures than fixed price schemes. Since such auctions are often multidimensional (the regulator seeks multiple environmental outcomes), Johansson and Cattaneo (2006), Cattaneo (2006) and Cattaneo, Lankoski and Ollikainen (2007) analyse how to design a ranking index aggregating the different dimensions of bids. However, all these models make the simplifying assumption that farmers only bid for one unit of land, therefore overlooking the effects of enrolling a larger proportion of farmland both on total costs (due to economies or diseconomies of scale in compliance costs) and on total environmental benefits (due to either increasing marginal benefits or decreasing marginal benefits).

This paper bridges this gap in the literature. We design a "green" auction in which the regulator imposes a given set of management practices. Farmers are invited to make a unique bid on the number of ha of their farmland they wish to put under contract and on the compensatory payment they wish to get. This is the most likely auction scenario that could be developed in Europe: although the Australian authorities have tried to be more innovative by allowing farmers to bid also on the technologies and practices they adopt (see the BushTender pilot study studied by Stoneham et al, 2003, Casan and Gangadharan, 2004), it is much less costly to implement and monitor an auction with a pre-determined level of environmental effort per ha. This paper is organised as follows: in the first section, we use the Latacz-Lohmann and Van Der Hamsvoort's resolution (1997), based on decision theory rather than on game theory, to calculate optimal bidding strategies. In section 2 we demonstrate that the optimal bidding on the area put under contract depends on the structure of environmental gains and compliance costs (section 2). In section 3, we demonstrate that, under certain conditions, imposing stricter management practices can induce farmers to put a greater share of their farmland under contract. Another difficulty for the designer of an auction is to decide on the safeguard rules regarding the payments received by each farmer: in particular, it is likely that a maximum payment per farm will be imposed. Such rule exists in the US Conservation Reserve Program as well as in most agri-environmental schemes in Europe, mainly for equity reasons although it can alter the efficiency of the green auction. In section 4, we conduct numerical simulations to illustrate the impact of two maximum payment rules, an egalitarian rule (the same maximum payment for all per exploitation) and a proportional rule (a maximum payment proportional to farm size). Section 5 concludes.

1. *The auction*

We assume that public authorities announce an agri-environmental scheme in order to manage a specific environmental issue associated with farming practices. For example, the regulator wishes to limit soil and water pollution by pesticides in a cereal farming region. A given set of technical measures is prescribed such as: the quantities and types of pesticides recommended for each crop, the frequency of use, the establishment of buffer strips between fields and waterways. Farmers are then invited to participate in an auction in which they bid on the surface area they agree to include in the scheme and on the compensatory payment they wish to obtain as a compensation for compliance. The auction is a sealed bid multiple contract procurement auction with a discriminatory payment rule: winning farmers get the payment they have bid.

Therefore, each participating farmer i submits a unique sealed bid with two dimensions $b_i(n_i, r_i)$

- n_i denotes the number of hectares on which farmer i is willing to adopt the recommended technical measures, described as a fixed environmental effort $\bar{e}$ per hectare.
- r_i denotes the level of agri-environmental payment per unit of hectare and per unit of environmental effort $\bar{e}$ that farmer i wishes to get as a compensation.

Since bids are multi-dimensional, the challenge for the decision-maker is to design a scoring function capable of aggregating the various benefits embodied in the farmer's bid into a single index used to rank bids. Indices are then ranked from highest to lowest and the decision-maker allocates the contracts to farmers with the highest indices, with a cut-off rule which is either defined by a budget constraint or by a target constraint (e.g. the surface under contract or the total environmental gain). Each winning farmer i then signs a contract, in which he commits himself to provide environmental effort $\bar{e}$ on area n_i of his farmland in return for a total compensatory payment $r_i * \bar{e} * n_i$. Farmers who have not won any contracts do not have to provide efforts and get paid nothing. We assume that there is no moral hazard: farmers' actions are observable and can be monitored. However, the regulator cannot observe farmers' types in terms of compliance costs.

We assume that farmers are risk neutral and that they have private information about their farm profits and their compliance costs. A farmer i will bid $b_i(n_i, r_i)$ in the auction if his expected profit of participation (EP) is greater than his reservation profit π_i if he does not participate:

$$EP = \left[\pi_i + r_i * \bar{e} * n_i - C^i\left(\bar{e}, n_i\right)\right] * prob + \pi_i * (1 - prob)$$

- π_i is the total farm profit when no environmental effort is provided
- $C^i\left(\bar{e}, n_i\right)$ is the total cost of providing environmental effort $\bar{e}$ on area n_i. We assume that these compliance costs increase with the level of environmental effort and with the area under contract. $\dfrac{\partial C^i\left(\bar{e}, n_i\right)}{\partial n_i} = C_n^i > 0$ and $\dfrac{\partial C^i\left(\bar{e}, n_i\right)}{\partial e} = C_e^i > 0$

- $prob$ denotes the probability of winning the auction.

The bid's score

The probability of winning the auction depends on the rank of the farmer's bid. Following Cattaneo (2006), we establish an additively separable scoring rule $I = I_i\left(e_{pi}, r_i, n_i, \bar{e}\right)$ which combines linearly the various dimensions of each bid and the characteristics of the bidder in a single index value comprised between 0 and 1.

$$I_i = w_P e_{Pi} + w_e \frac{g^i\left(\bar{e}, n_i\right)}{G_{max}} + w_d\left(1 - \frac{r_i * n_i * \bar{e}}{M_{max}}\right) \quad \textbf{(1)}$$

with:

- $e_{pi} \in [0,1]$ denotes the priority score given to the area in which the farmer i is located. We assume here that the decision-maker can decide to give greater priority to Natura 2000 areas or/and to environmentally vulnerable zones. For land which is less vulnerable to pollutions or which is already degraded, e_{pi} is close to 0. For land which requires greater protection, for example because it displays high value threatened biodiversity, or there is a vulnerable aquifer, e_{pi} is closer to 1. It is therefore an exogenous measure of environmental gain, associated with the location of bidder's land. It is common knowledge. Alternatively, e_{pi} can be mobilized to indicate the priority given to certain types of farmers (low revenue, young farmers) or to certain types of farming activities.

- $g^i\left(\bar{e}, n_i\right)$ is the function of environmental gain for farmer i. It measures the environmental benefit to society of producing the environmental effort $n_i * \bar{e}$. It could be measured by the reduction of toxic molecules accumulating in soils and leaching into aquifers and rivers. We assume that environmental gain is quantifiable at the level of each farm. In practice, it is often difficult to measure the score adequately but the decision-maker can build his own environmental benefit score. We assume here that the environmental benefit can be measured as a function of n and e, and that it increases when more hectares are contracted, or/and when the environmental effort per hectare is greater: $\frac{\partial g^i\left(\bar{e},n_i\right)}{\partial n_i}=g_n^i>0$ and $\frac{\partial g^i\left(\bar{e},n_i\right)}{\partial e}=g_e^i>0$

- $G_{\max}$ denotes the maximum environmental gain which can be provided by a single farm. It is the same for all farms and depends on the fixed environmental effort $\bar{e}$.
  The environmental gain component $0\le\frac{g^i\left(\bar{e},n_i\right)}{G_{\max}}\le 1$ helps the decision-maker to assess the level of environmental contribution by each farmer compared to the maximum level attainable.
- $M_{\max}$ is the maximum payment per farm. The budget component $\frac{r_i*n_i*\bar{e}}{M_{\max}}$ helps the decision-maker to compare the level of payment made to farmer i compared to the maximum authorized payment per farm.The environmental and budget components of the score illustrate the following tradeoffs: the farmer can decide to require a greater compensation but this reduces his score unless he can offer a high environmental gain (either because his environmental gain function is high or because he increases the number of ha under agri-environmental practices).

- w_p, w_e, w_d reflect the weights that the decision-maker assign to priority areas, environmental gains and public expenditures. $w_p+w_e+w_d=1$

I can be interpreted as a normalized weighted social welfare function made of three normalized social surplus: priority zones, environmental benefits and budget spending.
Such scoring function therefore reflects the priorities of the decision-maker. It is built in a way which gives priority to specific areas or farmers, and which can give different weights to budget spending and to environmental gains. Moreover, it favours the dispersion rather than the concentration of environmental payments: for two farmers offering the same ratio $g^i\left(\bar{e},n_i\right)/r_i*n_i*\bar{e}$, the score will be greater for the farmer requiring the lowest payment. Such index reflects well the policy pursued by most decision-makers in Europe: to ensure that environmental payments, often used also as income support, are accessible to a large proportion of eligible farmers.

Each farmer can calculate privately his score because he knows his costs, his environmental gain function and weights are common information. His bid is accepted provided his score is greater than the cut-off value I_c. The cut-off score is computed by decision-makers after all bids have been submitted. If it is a target auction in which public authorities want to allocate k contracts, then I_c is the score of the kth farmer accepted in the scheme (that is the value of the nth score when ranked from the highest to the lowest). It is more likely that the auction is in fact limited by a maximum budget. In such case, I_c is the score of the last winning farmer once the whole planned budget has been allocated to winning contracts. It is important to note here that the total expenditure is measured by $\sum_j r_j*\bar{e}*n_j$ for the jth winning farmers.

The probability to win

Following Latacz-Lohmann and Van der Hamsvoort (1997), we assume that each bidder, although he cannot know I_c or the score I_j of other bidders j, forms expectations about their distribution. Let's call $f(I)$ the density function of this distribution and $\underline{I}$ the score value under which the bidder's expectation to win is zero. The probability *Prob* of being accepted in the auction is the probability that the score I_i for farmer i is superior to the cut-off value score I_c :

$$prob = P(I_i > I_c) = \int_{\underline{I}}^{I_i} f(I)dI = F(I)$$

If we assume that farmers expect I to be uniformly distributed between $\underline{I}$ and $\overline{I}$ (the score above which the farmer's expectation to win is 1) , then the cumulative distribution function $F(I)$ can be written:

$$F(I) = \begin{Bmatrix} 0 & \text{if} \quad I \prec \underline{I} \\ \dfrac{I - \underline{I}}{\overline{I} - \underline{I}} & \text{if} \quad I \in \left[\underline{I}, \overline{I}\right] \\ 1 & \text{if} \quad I \succ \overline{I} \end{Bmatrix}$$

For example if $\underline{I} = 0$, $\overline{I} = 1$ then $F(I) = I$. It indicates that bidders are very uncertain about the outcome of the auction. We can expect however that if the auction was repeated several times over the years, farmers would get an opportunity to learn more about the score value of other bidders and would therefore form a narrower range of expectations for $\underline{I}$ and $\overline{I}$.

2. *Properties of optimal bidding strategies*

The farmer chooses r_i^* and n_i^* to maximize his expected profit (EP)

$$EP = \left[\pi_i + r_i * \overline{e} * n_i - C^i\left(\overline{e}, n_i\right)\right] * F(I) + \pi_i * \left(1 - F(I)\right) = \left[r_i * \overline{e} * n_i - C^i\left(\overline{e}, n_i\right)\right] * F(I) + \pi_i$$

subject to a number of constraints on decision variables: n_i must be positive and inferior to his total farm area $n_{\max i}$, and the level of agri-environmental payment that he wishes to get $r_i * n_i$ must be positive and inferior to the maximum allowed payment per farm $M_{\max}$.

The bidder is individually-rational if he is better-off when winning the auction than when not winning: The individual rationality constraint (RC) or participation constraint can be written as:

$$RC : \pi_i + r_i * \overline{e} * n_i - C^i\left(\overline{e}, n_i\right) \geq \pi_i$$

$$RC : r_i * \overline{e} * n_i - C^i\left(\overline{e}, n_i\right) \geq 0$$

The optimisation programme of the bidder is therefore the following:

$$\underset{(r_i, n_i)}{Max} \left(r_i * n_i * \bar{e} - C^i \left(\bar{e}, n_i \right) \right) F\left(I\right) + \pi_i$$

$$\begin{aligned} &Subject\ to \\ &0 \le n_i \le n_{\max i} \\ &0 \le r_i * n_i \le M_{\max} \\ &r_i * n_i * \bar{e} - C^i \left(\bar{e}, n_i \right) \ge 0 \end{aligned} \quad \textbf{(2)}$$

The Lagrangean for the problem reads as,

$$L\left(r_i, n_i, \lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5\right) = \left(r_i * n_i * \bar{e} - C^i \left(\bar{e}, n_i\right) \right) F\left(I\right) + \pi_i + \lambda_1 \left(M_{\max} - r_i * n_i \right) + r_i * \lambda_2$$

$$+ \lambda_3 \left(n_{\max i} - n_i \right) + n_i * \lambda_4 + \lambda_5 \left(r_i * n_i * \bar{e} - C^i \left(\bar{e}, n_i\right) \right)$$

At interior solution, the Lagrange multipliers are zero and the first order conditions are:

$$L_n : \left(r_i * \bar{e} - C_n^i \right) * F\left(I\right) = -F_n * \left(r_i * \bar{e} * n_i - C^i \left(\bar{e}, n_i\right) \right) \quad \textbf{(3)}$$

$$L_r : n_i * \bar{e} * F\left(I\right) = -F_r * \left(r_i * \bar{e} * n_i - C^i \left(\bar{e}, n_i\right) \right) \quad \textbf{(4)}$$

Where $F_n = \frac{\partial F\left(I\right)}{\partial n_i}$ and $F_r = \frac{\partial F\left(I\right)}{\partial r_i}$

Assuming that the participation constraint is strictly respected, we derive $\left(r_i^*, n_i^*\right)$ as a candidate interior solution.

$$\frac{C_n^i}{g_n^i} = \frac{w_e}{w_d} * \frac{M_{\max}}{G_{\max}} = \beta \quad \textbf{(5)}$$

$$r_i^* = \frac{M_{\max}}{2 * w_d * \bar{e} * n_i^*} * \left(w_p * e_p + w_e * \frac{g^i \left(\bar{e}, n_i^*\right)}{G_{\max}} - \underline{I} + w_d + \frac{w_d * C^i \left(\bar{e}, n_i^*\right)}{M_{\max}} \right) \quad \textbf{(6)}$$

Let's write $K^i\left(.\right) = \frac{C_n^i}{g_n^i}$

If $K^i\left(.\right)$ is reversible, then n_i^* is the solution of $\left(K^i\right)^{-1}\left(\beta\right)$

The condition for $K^i\left(.\right)$ to be reversible is that it must be continuous and monotonous, then there is an unique solution to the optimisation problem $n_i^* = K^{-1}\left(\beta\right)$

We derive $K^i\left(.\right)$ with respect to n_i: $K_n^i = \frac{C_{nn}^i * g_n^i - C_n^i * g_{nn}^i}{\left(g_n^i\right)^2}$ **(7)**

where $\frac{\partial K^i \left(n_i, \bar{e}\right)}{\partial n_i} = K_n^i$, $\frac{\partial^2 g^i \left(\bar{e}, n_i\right)}{\partial n_i^2} = g_{nn}^i$ and $\frac{\partial^2 C^i \left(\bar{e}, n_i\right)}{\partial n_i^2} = C_{nn}^i$

We will examine only two cases:

- the case when $K^i(.)$ is always increasing $\left(K_n^i > 0\right)$
- and the case when $K^i(.)$ is always decreasing $\left(K_n^i < 0\right)$.

In both cases, we note that $\frac{\partial r^*}{\partial M_{\max}} > 0$, $\frac{\partial r^*}{\partial w_e} > 0$, $\frac{\partial r^*}{\partial w_d} < 0$ and the sign of $\frac{\partial r^*}{\partial n_i}$ is ambiguous
In other words, farmers will increase their bid on r when the total allowed payment increases and when the weight given to environmental benefits increases. On the contrary, bids on r decline when the decision-maker is more sensitive to budget spending.

Case 1: If $C_{nn}^i > 0$ and $g_{nn}^i < 0$, then $K^i\left(\bar{e}, n_i\right)$ is an increasing function with respect to n_i:

Because $K^i\left(\bar{e}, n_i\right)$ is an increasing function, n_i^* increases when β increases.

Proposition 1
If $C_{nn}^i > 0$ and $g_{nn}^i < 0$, n_i^* is positively correlated to w_e, $M_{\max}$, and negatively correlated to $G_{\max}$ and w_d.

When the cost function is convex and the environmental gain function is concave, a greater weight on environmental benefits or a greater maximum payment per farm induces farmers to bid a larger proportion of their farm area. On the other hand, the greater the maximum environmental gain or a greater weight on budget spending decreases the area that farmers are willing to bid. The classical case of diseconomies of scale (leading to increasing marginal costs) can be observed for example if production risks increase at a higher speed for larger areas under reduced pesticide use. At the same time, the environmental benefit function is concave, indicating that marginal environmental gains decline with the number of hectares under the scheme. This is often the case that the first units of pollution reduction yield more benefits than the following due to threshold effects in the way pollution affects water resources. With such structure for compliance costs and for environmental gains, we expect farmers to bid for relatively small proportions of their farmland. We may end up with a the allocation of many small contracts.

Case 2: If $C_{nn}^i < 0$ and $g_{nn}^i > 0$, $K^i\left(\bar{e}, n_i\right)$ is a decreasing function with respect to area n_i:

Because $K^i\left(\bar{e}, n_i\right)$ is a decreasing function, n_i^* increases when β decreases. We end up with the opposite propositions of case 1.

Proposition 2
If $C_{nn}^i < 0$ and $g_{nn}^i > 0$, then n_i^* is positively correlated to $G_{\max}$ and to w_d and negatively correlated to w_e and $M_{\max}$.

A convex environmental gain function can be observed in the case of mammal biodiversity, when large areas of protection must be set-up to improve significantly the quality of habitats and therefore the population. A concave cost function can be observed in cases of economies of scale, for example if the new practices require to invest in equipments whose costs are more efficiently shared over a greater number of ha. We can also assume that adopting a new technology requires high learning costs for the first few ha. In such configuration, reducing the weight on environmental gains or reducing the maximum payment per farm will lead farmers to bid more hectares on the scheme, in order to be more competitive through the environmental benefits they can supply.

If the decision-makers can characterize the shape of environmental benefit and compliance cost functions, then he can choose the parameters of the auction (the weights and the maximum allowed payment) in order to induce farmers to either bid greater areas or to bid lower compensatory amounts.

3. The impact of effort intensity on area put under contract

The decision-maker must also make a decision on the intensity of environmental effort $\bar{e}$ that should be imposed in the auction: from the viewpoint of environmental efficiency, is it preferable to impose stricter measures inducing greater $\bar{e}$ or to encourage farmers to bid for greater area?

To respond to this question, we analyse how n_i^* changes with $\bar{e}$

By differentiating $\beta = K^i\left(n_i\left(e\right),e\right)$, we obtain $K_n * \frac{\partial n_i}{\partial e} + K_e = 0$

$$\frac{\partial n_i}{\partial e} = n_e^i = -\frac{K_e}{K_n} \qquad \textbf{(8)}$$

with $K_n^i = \frac{C_{nn}^i g_n^i - C_n^i g_{nn}^i}{\left(g_n^i\right)^2}$ and $K_e^i = \frac{C_{ne}^i g_n^i - C_n^i g_{ne}^i}{\left(g_n^i\right)^2}$

We will examine four cases:

Sufficient conditions under which we find $n_e^i > 0$

a. the case when $K_n^i > 0$ and $K_e^i < 0$
b. the case when $K_n^i < 0$ and $K_e^i > 0$

Conditions under which we find $n_e^i < 0$

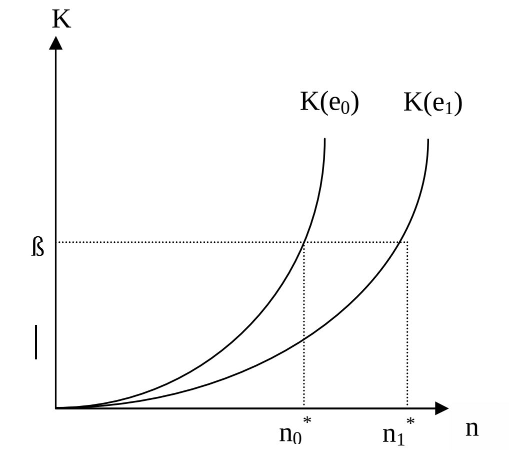
c. the case when $K_n^i > 0$ and $K_e^i > 0$
d. the case when $K_n^i < 0$ and $K_e^i < 0$

1) Conditions under which n_i^* increases when $\bar{e}$ increases

<u>Case a:</u> If $C_{nn}^i > 0$, $g_{nn}^i < 0$ then $K_n^i > 0$ and if $C_{ne}^i < 0$ and $g_{ne}^i > 0$ then $K_e^i < 0$

With convex compliance costs and concave environmental gains, we observe that n_i^* increase with $\bar{e}$ when the cross derivative of compliance costs with respect to n and e is negative, and the cross derivative of the environmental gain function is positive, indicating that area and effort intensity are complement for marginal gains: when the environmental effort is stricter, marginal compliance costs of increasing the area under contract are lower and marginal environmental gains greater. Such case is illustrated by figure 1

Figure 1*: Optimal bids on n when e increases, with complementary effects between area and effort intensity*



for $C_{nn}^i > 0$, $g_{nn}^i < 0$, $C_{ne}^i < 0$ and $g_{ne}^i > 0$

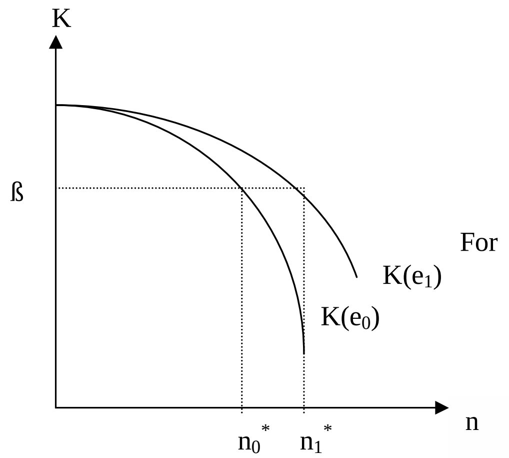
$e_0 < e_1$
$n_0^* < n_1^*$

Mis en forme

Case b: If $C_{nn}^i < 0$ and $g_{nn}^i > 0$ then $K_n^i < 0$ and if $C_{ne}^i > 0$ and $g_{ne}^i < 0$ then $K_e^i > 0$

With concave compliance costs and convex environmental gains, n_i^* increases with $\bar{e}$ when the cross derivative of compliance costs with respect to n and e is positive, and the cross derivative of the environmental gain function is negative. This is due to the substitution effect of area and effort intensity in the environmental gain function and in the cost function.

Figure 2: *Optimal bids on n when e increases, with substitution effects between area and effort intensity*



For $C_{nn}^i < 0$, $g_{nn}^i > 0$, $C_{ne}^i > 0$ and $g_{ne}^i < 0$,

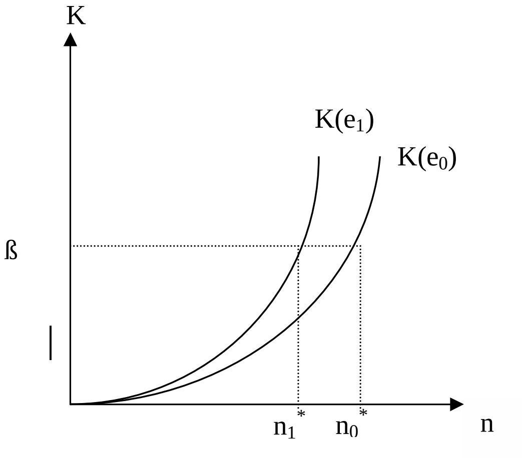
$e_0 < e_1$
$n_0^* < n_1^*$

2) Conditions under which n_i^* decreases when $\bar{e}$ increases

In cases c and d, we describe the configuration of compliance cost and environmental gain functions leading to a reduction of the area bid by farmers when the required environmental effort increases.

Case c : If $C_{nn}^i > 0$, $g_{nn}^i < 0$ then $K_n^i > 0$ and if $C_{ne}^i > 0$ and $g_{ne}^i < 0$ then $K_e^i > 0$

Figure 3: *Optimal bids on n when e increases, with substitution effects between area and effort intensity*



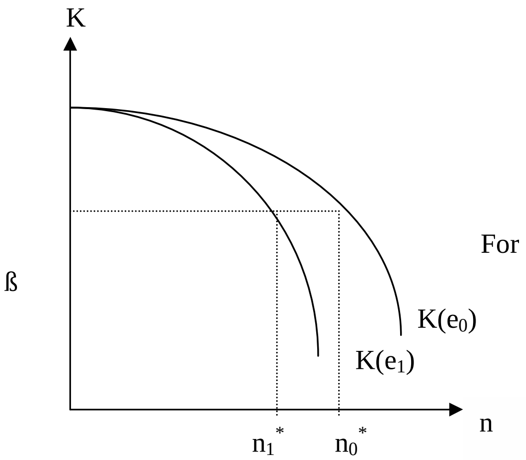
for $C_{nn}^i > 0$, $g_{nn}^i < 0$, $C_{ne}^i > 0$ and $g_{ne}^i < 0$

$e_0 < e_1$
$n_0^* > n_1^*$

Mis en forme

Case d: If $C_{nn}^i < 0$ and $g_{nn}^i > 0$ then $K_n^i < 0$ and if $C_{ne}^i < 0$ and $g_{ne}^i > 0$ then $K_e^i < 0$

Figure 4: Optimal bids on n when e increases, with complement effects between area and effort intensity



For $C_{nn}^i < 0$, $g_{nn}^i > 0$, $C_{ne}^i < 0$ and $g_{ne}^i > 0$,

$e_0 < e_1$
$n_0^* > n_1^*$

The conclusion is that it is necessary for decision-makers to gain a clearer understanding of the shape of compliance cost and environmental gain functions in order to design an auction yielding the desired outcome in terms of the area bid by farmers.

4 . The choice of the maximum payment rule: numerical simulations

The analytical characterization of n* and r* shows that the maximum payment rule affects optimal bidding strategies. It is a fact that decision-makers often choose to impose such rules, although they cannot be justified on the basis of economic efficiency. It reveals that agri-environmental schemes are also indirect ways of providing income-support and of buying political support. France has traditionally used an egalitarian rule stating that all farms are submitted to the same maximum payment per farm, notwithstanding the size of the farm. We have already indicated that such rule embodied in the index described in equation 1 favours the dispersion of payments over a greater range of farmers.

In other countries, the maximum payment per farm is proportional to farm size, allowing larger farms to get greater maximum payments than smaller ones. An index based on this rule (see equation 10) will favour the concentration of environmental payments on a smaller number of farmers.

$$I_i = w_P e_{Pi} + w_e \frac{g^i\left(\bar{e}, n_i\right)}{G_{\max}} + w_d\left(1 - \frac{r_i * n_i * \bar{e}}{M_{\max i}}\right) \qquad \textbf{(10)}$$

$M_{\max i} = \bar{r} * n_{\max i}$ is a maximum payment per farmer which depends on $n_{\max i}$ the total farmland area of farmer i and $\bar{r}$ a fixed average payment per ha

If two farmers make identical bids, this scoring function provides a better rank to the farmer with the greatest farmland area.

We compare here the consequences of these two rules (egalitarian versus proportional) through numerical simulations using therefore two different scoring functions:

We apply thus the above model to an hypothetical auction. We build an hypothetical sample of 40 farmers characterised by $n_{\max i}$ in a range of [30, 120]. We have identified high priority area ($e_{pH} = 0.8$) corresponding to the surface classified as Natura 2000 and low priority areas ($e_{pL} = 0.2$), outside the Natura 2000 zoning.

We use hypothetical cost and environmental gain functions. We build heterogeneity in our sample by introducing high cost function C_H and low cost function C_L, as well as high environmental gain function g_H and low environmental gain function g_L.

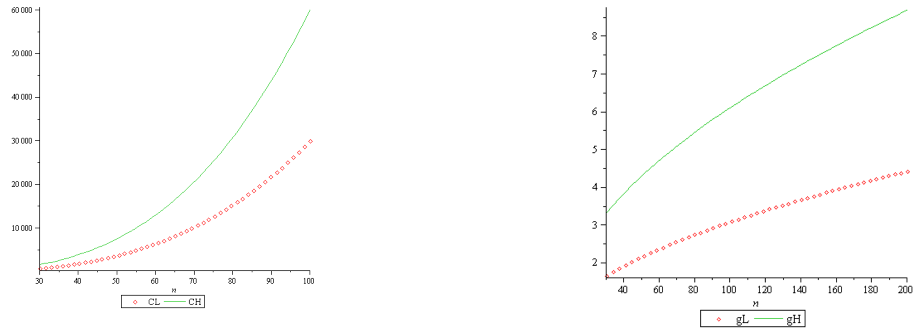
We choose the properties of these functions so as to be in case one when $K^i\left(\bar{e}, n_i^*\right)$ is an increasing function[1] of n_i

[1] Authors have also conducted simulations for the case when K is decreasing but results are not reported here. They will be added in the final version

In first time, we apply the theoretical model to the case where $K^i\left(\bar{e},n_i\right)$ is an increasing function with respect to area. As shown in the figure 3, this case is characterized by the convexity of cost functions ($C_H\left(n_i,\bar{e}\right)=0.06*n_i^3+0.001*n_i^2+0.1*n_i*\bar{e}, C_L\left(n_i,\bar{e}\right)=0.03*n_i^3+0.001*n_i^2+0.1*n_i*\bar{e}$) and the concavity of environmental gain functions ($g_H\left(n_i,\bar{e}\right)=0.001*n_i*\bar{e}+0.6*\sqrt{n_i}, g_L\left(n_i,\bar{e}\right)=0.001*n_i*\bar{e}+0.3*\sqrt{n_i}$).

,

Figure 3: Compliance costs functions and environmental gain functions



To compare the two auctions, we calculated the equivalent fixed maximum payment by using the following rule: $M_{\max}=\dfrac{\sum_{i=1}^{40} n_{\max i}*\bar{r}}{\text{Number of farmers}}$.

The main results of the simulations are presented in table 2.

Table 1: The simulation scenarios

Simulations	*"Proportional"*	*"Egalitarian"*
w_p	0,2	0,2
w_e	0,4	0,4
w_d	0,4	0,4
$M_{\max i}=\bar{r}*n_{\max i}$ and $M_{\max}$	$M_{\max i}=70*n_{\max i}$	$M_{\max}=5115,25$

Table 2: The simulation outcomes

Simulations	***"Proportional"***	***"Egalitarian"***
Budget spending or budget cut-off (*)	77960	78268
Number of enrolled farmers (Selected farmers)	20	25
Number of enrolled hectares	445	585
Average payment to farmer (per enrolled farmer)= $\frac{\sum_j r_j * n_j}{\sum j}$	3898	3131
Average public expenditures (per enrolled hectare) = $\frac{\sum_j r_j * n_j}{\sum n_j}$	175	134
Average public expenditures (per unit of environmental gain) $= \frac{\sum_j r_j * n_j}{\sum g_{enrol}}$	1813	1398
Average cost (per enrolled hectare) = $\frac{\sum_{enrol} C_{enrol}}{n_{enrol}}$	21	24
Enrolled farmers' net profits = $\sum \left(r_{enrol} * n_{enrol} - C_{enrol} \right)$	68647	64294
Budget return efficiency per unit of cost = $\frac{\sum C_{enrol}}{\sum r_{enrol} * n_{enrol}}$	12%	17%
Rate of environmental gain = $\frac{\sum g_{enrol}}{\sum g_{enrol} \left(n_{\max i} \right)}$	55%	63%
Cost to farmer per unit of environmental gain = $\frac{\sum C_{enrol}}{\sum g_{enrol}}$	217	250
Rate of net environmental gain = $\frac{\sum g_{enrol}}{\sum_1^{40} g \left(n_{\max i} \right)}$	28%	36%
The social welfare	0,45	0,48

(*) the budget is 78 000 for the two but spending might be a bit over or under this amount according to the bid of the last winner

Figure 3: Distribution of net profits with respect to maximum farm size under equitable and egalitarian maximum payment rules

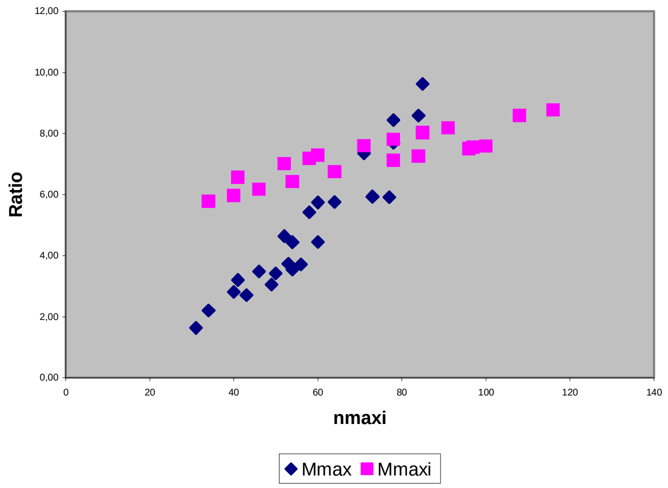
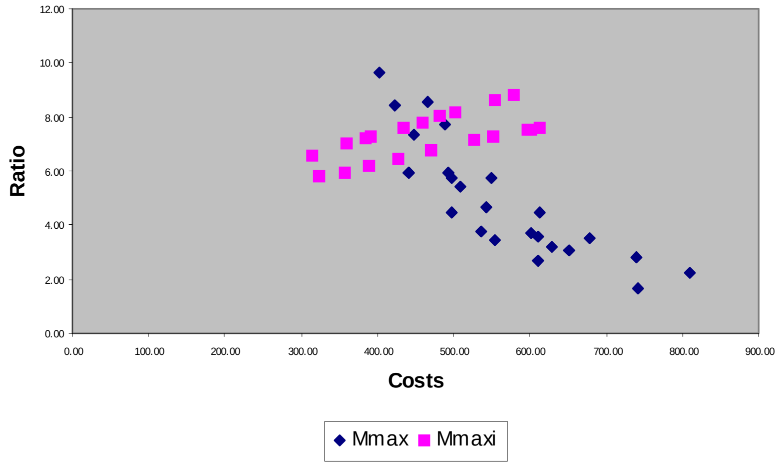


Figure 4: Distribution of net profits with respect to costs under equitable and egalitarian maximum payment rules



*Note : Ratio is (r*n-C)/C*

Table 2 shows that auction performance is greater when the fixed maximum payment rule applies. The budget return efficiency which measures the informational rent distributed to farmers (if efficiency = 100%, it means that payments exactly compensate true compliance costs) is improved in the egalitarian scenario compared to the equity scenario.

The average public expenditures per enrolled hectare as well as the average public expenditures per unit of environmental gain decreases when decision-maker selects the fixed maximum agri-environmental payment.

The social welfare (SW) can be measured by the weighted sum of different criteria:

$$SW = w_P \frac{\sum_{enrol} e_{Pi}}{\sum_{enrol} i} + w_e \frac{\sum_{enrol} g^i\left(\bar{e}, n_i\right)}{\sum_{enrol} g^i\left(\bar{e}, n_{\max i}\right)} + w_d \left(1 - \frac{\sum_{enrol} r_i * n_i * \bar{e}}{\sum_{enrol} M_{\max i}}\right)$$

The last line of table 2 confirms that a fixed maximum payment increases social welfare.
Of course, it means that a proportional maximum payment rule would be more advantageous to farmers as a whole. But it is interesting to analyse what categories of farmers benefit more than others. Figures 3 and 4 show us that the equitable scenario favours large landholders (the average of total farm area of enrolled farmers is equal to 72 ha versus 59 ha in the egalitarian case). On the one hand, a large landholder increases his environmental gain criteria by supplying more hectares, on the other hand he can bid higher r because he also benefits from a larger $M_{\max i}$. On the other hand, small landholders benefit more under the egalitarian scenario.

5. Conclusion

This paper provides an analysis of optimal bidding strategies when farmers are invited to bid simultaneously on compensatory payments and on the proportion of their farm area they wish to put into the agri-environmental scheme. We first demonstrate that bidding strategies can be reversed according to the convexity and concavity properties of both the environmental gain function and the cost function. It indicates that the choices made by policy-makers in terms of the scoring function and the maximum payment per farm should be guided by all information he can gather on the structure of these functions.
Likewise, the paper shows that stricter management practices can under certain conditions – when environmental effort intensity and surface are complementary – induce farmers to increase their bids on the area they wish to put into the scheme. Finally we demonstrate that a fixed maximum payment rule increases the performance of the auction, both in terms of budget returns and allocative efficiency, compared to a proportional maximum payment rule.
This paper therefore provides useful insights on the way such auctions should be designed.

Bibliography

Cason T N., Gangadharan L. (2004). *Auction design for voluntary conservation programs*, American Journal Agricultural Economics 86, n° 5 pp 1211 - 1217

Cattaneo A. (2006). *Auctioning conservation payments using environmental indices*, Contributed paper to the International Association of Agricultural Economists Conference, Gold Coast, Australia, 12-18 August 2006, 17 p

Cattaneo A., Lankoski J., Ollikainen M. (2007) Green auctions with joint environmental benefits. Environmental Economics. University of Helsinki, Department of Economics and Management. Discussion Paper N° 19. Environmental Economics.

EC European Commision (2005). *Agri-environment measures, overview on general principles, types of measures and application*, Directorate general for agriculture and rural development, Unit G-4 Evaluation of mesures applied to agriculture, studies. Mars 2005, 24 p

Latacz-Lohmann U., Van Der Hamsvoort C. (1997). *Auctioning conservation contracts : a theoretical analysis and an application*, American Journal of Agricultural Economics 79, pp. 407-418.

Latacz-Lohmann U., Schilizzi., S (2007). Quantifying the benefits of conservation auctions. EuroChoices, Volume 6, N° 3. PP 32-39

Primdhal J., Peco B., Schramek J., Andersen E., Onate J. (2003). *Environmental effects of agri-environmental schemes in Western Europe*, *Journal of Environmental Management* 67 pp 129-138

Johansson R C., Cattaneo A. (2006). *Indices for working land conservation: Form affects functions*. Review of Agricultural Economics, Vol 28 issue n° 4, pp 567-584

Stoneham G., Chaudhri V., Ha A., Starppazzon L. (2003). *Auctions for conservation contracts : an empirical examination of Victoria's BushTender trial*, The Australian Journal of Agricultural and Resource Economics, 47:4, pp 477-500

Appendix

$$OBJ = \left(r_i * \bar{e} * n_i - C_i\left(n_i, \bar{e}\right)\right) * F\left(I\right)$$

$$F\left(I\right) = \frac{\left(w_p * e_p + w_e * \frac{g_i\left(n_i, \bar{e}\right)}{g\left(\bar{e} * n_{\max i}\right)} + w_d * \left(1 - \frac{r * \bar{e} * n_i}{M_{\max i}}\right)\right) - \underline{I}}{\alpha}$$

$$F_n = \frac{\left(w_e * \frac{g_n\left(n_i, \bar{e}\right)}{g\left(\bar{e} * n_{\max i}\right)} - w_d * \frac{r * \bar{e}}{M_{\max i}}\right)}{\alpha}$$

$$F_r = -\frac{w_d}{\alpha} * \frac{n_i * \bar{e}}{M_{\max i}}$$

$$F_{nn} = \frac{w_e}{\alpha} * \frac{g_{nn}\left(n_i, \bar{e}\right)}{g\left(\bar{e} * n_{\max i}\right)}$$

$$F_{rr} = 0$$

$$F_{rn} = -\frac{w_d}{\alpha} * \frac{\bar{e}}{M_{\max i}}$$

$$OBJ_n = \left(r_i * \bar{e} - C_{ni}^{'}\left(n_i, \bar{e}\right)\right) * F\left(I\right) + F_n * \left(r_i * \bar{e} * n_i - C_i\left(n_i, \bar{e}\right)\right) = 0$$

$$OBJ_r = n_i * \bar{e} * F\left(I\right) + F_r * \left(r_i * \bar{e} * n_i - C_i\left(n_i, \bar{e}\right)\right) = 0$$

$$OBJ_{nn} = -C_{nn}\left(n_i, \bar{e}\right) * F\left(I\right) + 2 * F_n * \left(r_i * \bar{e} - C_n\left(n_i, \bar{e}\right)\right) + F_{nn}\left(r_i * \bar{e} * n_i - C_i\left(n_i, \bar{e}\right)\right)$$

$$OBJ_{rr} = 2 * n_i * \bar{e} * F_r + F_{rr} * \left(r_i * \bar{e} * n_i - C_i\left(n_i, \bar{e}\right)\right)$$

$$OBJ_{rn} = \bar{e} * F\left(I\right) + n_i * \bar{e} * F_n + F_{rn} * \left(r_i * \bar{e} * n_i - C_i\left(n_i, \bar{e}\right)\right) + F_r * \left(r_i * \bar{e} - C_n\left(n_i, \bar{e}\right)\right)$$

- ✓ **First order conditions**

$$\boxed{\frac{C_{ni}^{'}\left(n_i^*, \bar{e}\right)}{g_{ni}^{'}\left(n_i^*, \bar{e}\right)} = \frac{w_e}{w_d} * \frac{M_{\max i}}{g\left(n_{\max i} * \bar{e}\right)}}$$

$$\boxed{r_i^* = \frac{M_{\max i}}{2 * \bar{e} * n_i^*} * \left(\frac{w_p * e_p}{w_d} + \frac{w_e}{w_d} * \frac{g\left(n_i^*, \bar{e}\right)}{g\left(n_{\max i} * \bar{e}\right)} - \frac{\underline{I}}{w_d} + 1 + \frac{C\left(n_i^*, \bar{e}\right)}{M_{\max i}}\right)}$$

- ✓ **Second order conditions**

Sign of the determinant of the Hessian matrix:

$$Det(H) = OBJ_{nn} * OBJ_{rr} - OBJ_{rn}^2$$

$$\left[-C_{nn}\left(n_i,\bar{e}\right) * F(I) + 2 * F_n * \left(r_i * \bar{e} - C_n\left(n_i,\bar{e}\right)\right) + F_{nn}\left(r_i * \bar{e} * n_i - C_i\left(n_i,\bar{e}\right)\right)\right] *$$

$$\left[2 * n_i * \bar{e} * F_r + F_{rr} * \left(r_i * \bar{e} * n_i - C_i\left(n_i,\bar{e}\right)\right)\right] -$$

$$\left[\bar{e} * F(I) + n_i * \bar{e} * F_n + F_{rn} * \left(r_i * \bar{e} * n_i - C_i\left(n_i,\bar{e}\right)\right) + F_r * \left(r_i * \bar{e} - C_n\left(n_i,\bar{e}\right)\right)\right]^2$$