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Biodiversity in the forest: potential demand, a complex supply, several stakes

Biodiversity in the forest is at the heart of the environmental and economic stakes. Biodiversity has an economic value revealed by households, and conditions the ecological state of the forest. Sometimes incentives are necessary to preserve it. More generally, this is a question of sustainable or multifunctional management of the forest.

Biodiversity, an important component of multi-functional forests, defines the nature of the ecosystem and conditions the value of forest goods and services (FGS). Biodiversity in forests is at the origin of economic values, which, beyond their own protection, justifies that of the forest ecosystems. The subject of our research is threefold: a/ assess the economic value of biodiversity in the forest and understand the determinants of its demand; b/ analyse the supply of biodiversity and the incentives to be implemented; c/ study the multifunctionality of forest management where biodiversity and timber describe the main functions.

The demand for biodiversity in forests

A contingent valuation survey was carried out at a national level on 4500 households in order to gain a better understanding of the individual preferences towards the forest (Peyron et al, 2002). As well as their willingness-to-pay (WTP) for the preservation of biodiversity, the households had to give information about their recreational activities in the forest when they went on at least one outing per year in the forest. A *proxy* for biodiversity was used, holding back the potential loss of animal and plant species in forest.

- A binary-choice method (referendum), in which the agent answers yes or no to the question "Are you ready to pay the annual amount of X€ for the preservation of French forest biodiversity?"
- An open-ended question: "What is the maximum amount that you are ready to pay for the preservation of biodiversity in forests?"

The telephone survey was carried out at department scale. 1999 households accepted to answer.

The WTP for biodiversity preservation is supposed to depend on the choice to practice or not practice activities in forest. It is indeed right to think that the households who do not spend time in forests attach less importance to the FGS. Not taking this dependency into account would sidestep the assessed results, particularly if the decision to practice a recreational activity is not exogenous and can be explained or not by observable variables. Therefore, two sub-samples are differentiated by recreation in forest.

At first analysis, we assess the WTP from the answers to the survey, taking into consideration recreation in forests. The attached discrete answers (yes and no, coded 1 and 0) and the correlation between both decisions (WTP and recreation) lead to an assessment of the two equations, simultaneously, according to a bivariate Probit model. The selection bias is then corrected by making endogenous the outing decision for recreational activities.

In the open-ended question, the probability of null WTP creates a second source of selection bias: In the sample the simultaneous presence of agents who are not willing to pay and other agents with strictly positive WTP may not be hazardous. The reason for that difference is in the observable or non-observable characteristics of households, also determining the value of the WTP. Taking into account both selection biases (visits in the forest and decision to pay) requires an extension of the standard Heckman model (correction of a selection bias) to a model with a double selection. This extension is the subject of a second analysis (see frame 1).

The referendum: a 55 euro WTP per household for the preservation of biodiversity

Based on the referendum, the purpose of the first analysis is to simultaneously assess the decision for recreation in forests and the probability of paying an annual predefined amount (a bivariate Probit model). Out of the 1999 households, 1070 were analysed. The households left out did not complete the whole questionnaire (184 households), or were considered as protestors (743 households). The latter do not accept the way of paying and think it is the State's role to pay. Of the 1070 households, 74% declared that they visited the forest for recreational activities and 58% declared that they accepted the suggested amount.

The results show that the proportion of households visiting the forest mainly depends on the income, size and localisation of the household. An increasing income and a bigger household size tend to increase the probability of visiting. This probability significantly differs between the five regions of France: higher when the household lives in the Paris region or in the South-East, and lower when the household is in town. Last, if harvesting wood is positively perceived, then the probability of visiting is higher. In the same way, the probability of accepting the suggested amount for biodiversity decreases with the amount but increases with the income: The probabilities of accepting the amount are highest in the Paris region and the North. On the other hand, the assessments of timber collection, household size and accommodation in town have no significant effect on the WTP. We show that the bivariate Probit model is better than any other model. The average WTP is assessed at 54.98€. The WTP differs, in a significant way, in the North - including the Paris region (around 64€), the East (almost 55€), the South-East (barely more than 50€) and the South-West (less than 45€). These differences may be explained by the type and surface-area of the forests and cultural and socio-economic factors.

Open-ended question and double selection

The purpose of this analysis is to assess the WTP from the open question by taking into account the two selection biases. The method used allows the WTP to be calculated for different populations within the sample as a whole. In particular, of the 1070 analysed households, 669 have recreational activities in forests and are ready to pay a non null amount for biodiversity in the forest. For these households, the average WTP is assessed at about 40€. For the households willing to pay for biodiversity in the forest, but not visiting the forest (161 observations), the average WTP is no higher than 33€.

The differences between the WTP assessed may be explained by the difference in the modes of payment but also by the selection rules. A limit to this approach is linked to the nature of the good assessed and to the fact that these estimations under-estimate the national value of diversity. These values must be considered as a lower boundary of the value: the link with the other benefits stemming from the protection of biodiversity should be taken into account (erosion of soils…). The value assigned to biodiversity varies according to the agents' understanding of the environmental good assessed. However, the values obtained help the decision-maker in the orientation of public policies.

Incentives and spontaneous supplies

For some economists, incentives for the preservation of biodiversity have priority over the assessment of its value. Some owners may also make spontaneous supplies without an incentive. And some incentives may turn out to be perverse in terms of environmental objectives.

Spontaneous supplies

Timber is not the only source of income of forest owners (incomes proceeding from other activities). They may also receive incentive payments to monitor timber harvesting and increase the non merchantable FGS. Some owners seem to give value to standing timber and forest landscapes. In France, forest properties are numerous, small in size and predominantly private.

We are in a context of analysis where, for non industrial private owners, profits are associated with forest benefits. The non-market FGS are jointly produced with the timber and fall within the preferences of the producer household through their utility. In this work, we studied the combined production of timber and biodiversity. Biodiversity is measured by the diversity of tree species. This diversity is also linked to market considerations since a different monetary value is associated with each species. The forest owner may decide to favour some species rather than others according to their market value. Conversely, he may decide to diversify his tree-planting to cater for the price volatility of the species.

The empirical analysis is carried out using data on forests managed in uneven-aged clusters, also qualified as continuous and close to nature. The surface in France is estimated at about 75% of the whole forest area. Management in uneven-aged clusters is defined by two fundamental principles: 1) the dynamic support of the ecosystem (various ages, various species), 2) the individual management of each tree. These forests are also characterized by the stability of the volume of standing trees and that of their growth, as well as by the regularity of harvests. The representative unit of observation is that of the smallest plot, which resembles the others. At the same time, we assess the owner's demand for diversity and his timber supply. The latter is defined by the timber harvest and the observations depend on the species in various forests. The econometric modelling is specific to the samples in clusters (or grouped data), see frame 2.

Indices of diversity (Shannon type) were tested, but it is a simple index of richness (sum of species) which adjusts best to the data. For the sample of data from the network of the Association of uneven-aged clusters, diversity and timber production are substitutes. The estimates also show that the timber price has a positive impact on the diversity of the species. The estimated value of the price-elasticity is -0.31, which means that a 10% price drop results in a fall in diversity of a little more than 3%. With this result we calculate and show the impact of the disappearance of a species from a forest: in the case of 14 different species in a forest, a 23% drop in the average timber price could lead to the loss of one species.

The Natura 2000 incentive contracts

The European Union implemented the Natura 2000 network with the intention of protecting and restoring species and natural habitats. The Natura 2000 sites, delimited on the basis of their biodiversity and biogeography, also cover forestland. The implementation of the Habitats Directive may be based on the contractual relationships between public authorities and owners. These contracts determine the preservation objectives, the measures to implement and the payments to transfer. The contract is accepted better and more flexible than a law which would apply uniformly to the habitats and owners: it makes owners the producers of biodiversity.

The presence of informational asymmetries between the public authorities (the Principal in the theory of contracts) and the owner (the Agent) poses the problems of incentives and limits the effectiveness of the policy.

Owners are better informed about their capacity and their opportunity costs in producing environmental goods: it is a problem of adverse selection. As the objective is for all the owners located on the Natura 2000 sites to sign a contract, the Principal attempts to target efficient agents to restore or preserve the habitats, but also the less performing agents. But it is more difficult to convince the latter to participate because their costs to reach these environmental objectives are higher. Furthermore, the investments made by forest owners for the implementation of biodiversity preservation measures are considered as observable but not verifiable, that is to say that owners might not reveal the exact value of these investments: this is the problem of moral hazard. If the owner's payment depends on observation of the ecological state of the forest, and if a low investment has a probability of non-null success in the environmental objective, the agents have little incentive to make high investments while the probability of reaching a high ecological level would be stronger. Moreover, the Natura 2000 contracts could attract forest owners who must undertake works in their forest which belong to the categories of State refundable measures.

In our theoretical analysis of contracts, we specified two types of investments, high and low. With a high investment, the probability of reaching a high ecological level is high (with a high probability for efficient agents). This probability is low with a low investment and even lower with inefficient agents. We consider that the ecological state of the forest is observable but that there is a lack of information on the foresters' capacity and an impossibility of checking the investments made. Public authorities want the least efficient agents to make low investments, and the efficient ones to make high investments. We have the following menu of contracts:

- A basic contract with a low investment and a payment equal to the value of that investment taking into account the (positive or negative) impact of these measures on the owner's forest activity
- A contract in which the owner is asked to take additional measures which, at first, are not wholly paid. Once the ecological level has been recorded, there is a second payment with a bonus for a high level.

We show that the current contracts n France, which do not take into account informational problems or the owners' forest activity, lead to overcompensations for investments and to inefficiency as regards environmental objectives.

Perverse incentives

Incentives as regards forest policy sometimes have objectives that are far from biodiversity preservation. For instance, encouraging the production of staple goods or of strategic ones. It is not surprising that their effects on biodiversity are harmful. The perverse effects on biodiversity appear because of an overexploitation of one or several species and/or of the ecosystem (intensive production of timber in the forest). The objective of another research work consisted in pinpointing potentially perverse incentives for biodiversity by relying on the recent Forest Law (2001) through financial aids (reforesting, facilities for production forests…) and tax measures (income tax, transfer taxes, land clearance tax…).

We show the perverse nature of some forest policy measures by modelling the decisions in the forest with the help of the Faustmann criterion (maximisation of updated profits leading to the optimal age for tree felling). We suppose that a significant increase in biodiversity requires an extension of this period and conversely that an earlier harvest reduces biodiversity. The parameters on which the economic measures act are the expected expenditure and earnings (the cost of inputs…). *Ceteris paribus*, economic measures which increase earnings have a perverse affect on biodiversity by reducing the optimal age of exploitability of the tree stock. In the same way, the measures which cut investment expenditure favour quicker rotation. In principle, aid for replanting or for production facilities has no beneficial effect on biodiversity except if the first of these aids is additional to aid given to the owners opting for a more natural regeneration. Let us also underline the difficulties raised by inventorying and quantifying perverse effects. The analysis is all the more complex in that we must not measure the scope or the value of forestry management at its instantaneous effect or relate it to a limited length of time. Furthermore, attention has been paid to the effects of the measures, some independently from others, ignoring the net impact of all the measures applicable on the territory. Indeed, the perverse effects identified are partial: a measure may turn out to be harmful to some elements of biodiversity, but beneficial to others. The intensive production of timber and the search for a quick return on investment are not the only potential causes of biodiversity loss. The change in use of lands and atmospheric pollution are also decisive.

Stakes for forestry management

There are other stakes linked to biodiversity such as country planning and the definition of multifunctionality. In other words, is it better to fully protect a plot and manage the other, or to exploit both plots in a sustainable way? Arbitration between both types of management in the presence of uncertainty and irreversibility of decisions allows this question to be challenged in current research work: multifunctionality simultaneously developed on both plots depends on the relative value expected from that type of management. Multifunctionality on both plots is favourable when the ecological value of the forest is preserved.

Biodiversity management is at the heart of the major stakes for forestry policy (country planning, water quality, climate change…). Preservation actions must be based on the identification and awareness of the demand, on the management offering and the potential incentives.

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Frame 1: Selection models

Let a latent variable (i.e. a non observed one) be I^* expressing the difference between the indirect utilities of a household before and after biodiversity was preserved and the household was willing to pay the amount t . The latent variable equation can be written as follows:

$$I^* = a_1 + a_2 y - a_3 t + a_4 z + \varepsilon_I,$$

Where y represents household income, z is a set of household characteristics and ε_I the error term.

If $I^* > 0$ the household is willing to pay t. The decision rule is written as follows: $I = 1$ if $I^* > 0$, and 0 otherwise. We estimate a Probit model representing the household's choice to be willing to pay t

$\Pr(I = 1) = \Phi(a_1 + a_2 y - a_3 t + a_4 z),$

where $\Phi(.)$ is the distribution function of a standard normal law. The average WTP is assessed as follows:

$(CAP = (\hat{a}_1 + \hat{a}_2 y + \hat{a}_4 z)/\hat{a}_3 .)$

To take into account forest recreation, we define the decision rule as follows: $V = 1$ if $V^* > 0$, and 0 otherwise, which means that the household is inclined to go to the forest ($V = 1$) if the latent variable V^* characterizing its utility for forest activities is positive, with $V^* = X_V \beta + \varepsilon_V$, where X_V represents the explanatory variables and ε_V is the error term. We jointly estimate I^* and V^* under the assumption of a bivariate normal distribution.

In the case of double selection, two selection equations are associated with two binary variables V (decision of recreation in forest) and Z (decision to pay). Four potential systems correspond to the combinations of binary variables, but only two for which strictly positive WTP are observed. The error terms are jointly distributed like a normal law, and the equation system to be estimated is as follows:

$$\begin{array}{l} V^* = X_V \delta + \varepsilon_V \\ Z^* = X_Z \beta + \varepsilon_Z \\ CAP_1 = X\gamma^1 + \varepsilon_1 \\ CAP_2 = X\gamma^2 + \varepsilon_2 \end{array} \quad \begin{pmatrix} \varepsilon_V \\ \varepsilon_Z \\ \varepsilon_1 \\ \varepsilon_2 \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho & \rho_{V1} & \rho_{V2} \\ \rho & 1 & \rho_{Z1} & \rho_{Z2} \\ \rho_{V1} & \rho_{Z1} & \sigma_1^2 & \rho_{12} \\ \rho_{V2} & \rho_{Z2} & \rho_{12} & \sigma_2^2 \end{pmatrix} \right],$$

Where the ρ represent the covariances and the σ^2 the variances of the multivariate normal law. We adapt the Heckman estimator in case of a double selection. We first estimate the bivariate Probit model corresponding to the first equations (selection). Then in the last two regression (of WTP) equations we transfer the terms correcting the selection biases (called Mills ratios, denoted λ) for which we estimate their parameters:

$$CAP_1 = X\gamma^1 + \rho_{V1}\hat{\lambda}_{V1} + \rho_{Z1}\hat{\lambda}_{Z1} + \eta_1$$

$$CAP_2 = X\gamma^2 + \rho_{V2}\hat{\lambda}_{V2} + \rho_{Z2}\hat{\lambda}_{Z2} + \eta_2$$

Frame 2: Econometric modelling of clusters

We write the timber supply in a logarithmic form:

$\ln y_{ij} = a_0 + a_1 \ln p_{ij} + a_2 \ln z_i + a_3 \ln x_{ij} + u_{ij},$

$i = 1,..., N,\ j = 1,..., J_i,$

where i indicates the cluster (here the forest) and j the individual observations within the cluster (here the species). The total number of clusters is N and the number of species varies according to the forests J_i. y_{ij} .represents the harvesting of species j in the forest i, z_i the price of the species j for the forest i, z_i the index of diversity, and x_{ij} a set of explanatory variables. The error term is as follows: $u_{ij} = \mu_i + \varepsilon_{ij}$ with μ_i the specific effect of the forest capturing non observable heterogeneity and ε_{ij} the remaining error term for all the excluded variables.

For further information

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