Attitude towards Risk and Production Decision : An Empirical analysis on French private forest owners

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Abstract

This paper deals with the forest owner's attitude towards risk and the harvesting decision in several ways. First, we propose to characterize and quantify the forest owner's attitude towards risk. Second, we analyze the determinants of the forest owner's risk attitude. Finally, we determine the impact of the forest owner's risk attitude on the harvesting decision. The French forest owner's risk attitude is tackled by implementing a questionnaire, including a context-free measure borrowed from experimental economics. The determinants of the forest owner's risk attitude and harvesting decision are estimated through a recursive bivariate ordered probit model. We show that French forest owners are characterized by a relative risk aversion coefficient close to 1. In addition, we find that the forest owner's risk aversion is influenced positively and significantly by the level of risk exposure, gender (female), the level of education and the fact to be a forester, and negatively by the income. Finally, we obtain that the forest owner's risk aversion has a positive and significant impact on the harvesting decision.

Keywords: Forest owner's risk attitude; Risk aversion; Harvesting decision; Simultaneous Equation Models; Experimental elicitation.

JEL classification: D81, C35, Q23

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1 Introduction

Forest management is exposed to several risks. These risks may be categorized as production risk or market risk. Market risk is due to potential variations of the discount rate and timber price. Indeed, forest management is a long-term investment such that the discount rate and the price may fluctuate during the rotation. Production risk is essentially due to natural events. In Europe, windstorms Lothar and Martin in 1999 damaged 140 million cubic meters in France and 30 million in Germany. Wildfires on summer 2003 burnt 500 000 hectares in Portugal, 150 000 in Spain and 95 000 in France. More generally, in Europe, natural hazards damage each year an average of 35 million m^3 of wood (1950-2000). Storms are responsible for 53% of these damages, fires for 16% and biotic factors for 16% respectively (Schelhaas et al. [38]). Climate change will have a serious impact on these disturbances. The occurrence of harmful disasters such as drought, flooding, wind and fire is assumed to increase (Fuhrer et al. [20]). Populations of pests such as bark beetles and the frequency of the outbreak of tree diseases will be enhanced (Williams and Liebhold [42]). Consequently, the natural disasters represent the main risk that forest owners face.

These natural events may represent important losses both for forest owners and the society: forest owners may suffer loss in present and future value, additional cost of forest restoration, loss of other income and loss of regular income (Birot and Gollier [9]). Moreover, in addition to timber-related economic losses, the crisis following the occurrence of such events is also associated to high public costs, as for example the amount of human and material resources that are needed to fight fires (Pinheiro and Ribeiro [33]). Other losses may include loss of carbon sequestration (Thürig et al. [40]) and amenities.

In such a context, the forest owners take risky decisions. The knowledge of the forest owner's risk preferences is essential to implement coherent forest risk management measure, to set up relevant adaptation strategy to cope with climate change, and also for public policy issue. Consequently, several questions arise: what are the forest owner's risk preferences? What are the determinants of these risk preferences? and finally, what is the impact of these risk preferences on harvesting ? In this paper we try to answer to these questions.

Investigating the forest owner's risk preferences leads to few papers. Lönnstedt and Svensson [32], through telephone interview, show that private forest owners were risk-prone in case of low monetary amount whereas they were risk-averse when large amount were at stake. Brunette et al. [12] estimate the willingness-to-pay of private forest owners to be fully insured against fire risk through an experiment and conclude that private forest owners are risk averse. Finally, Andersson and Gong [5], through a mail survey, find that a majority of private forest owners were risk-neutral or risk-prone. Using the same data, Andersson [4] deals with the determinants of the private forest owners' attitudes to financial risk-taking in forestry decisions. The author shows that a longer period of ownership increases the probability that the owner is risk-averse, while an increased time spent in the forest conducting silvicultural work increases the likelihood that an owner is risk-seeking. In this paper an index of private forest owners' attitudes to risk from a hypothetical survey question involving financial risk is built, representing the owner's willingness to pay for reduction of the risk measured in terms of the variance of the outcome.

In this literature, there is no consensus on the behavior towards risk of forest owners. In addition, the determinants of risk attitude are only partially investigated, forgetting some important characteristics such as the forest owner's income. Finally, the index proposed to reflect the forest owner's attitude towards risk is not estimated empirically, and therefore cannot be considered in other researches.

Many theoretical papers study the impact of the forest owner's risk preferences on various type of decisions such as rotation length (Alvarez and Koskela [3]; Uusivuori [41]) for example. Few papers deal with the impact on an increase in risk aversion on harvesting (Brunette et al. [13]; Koskela [29]) and find that, as risk aversion increases, the probability to harvest reduces. However, to our knowledge, no empirical test of this theoretical result exists.

Finally, investigating the determinants of private forest owners' harvesting decisions leads to numerous papers focusing on the role of non-timber activities, bequest motives and debt (Conway et al. [15]), personal socio-economic characteristics, mainly the level of forest income and non-forest income of owners (Stordal et al. [39]), and social interactions (Garcia et al. [22]). However, to our knowledge none of these studies consider the forest owner's risk attitude as a potential explanatory variable for harvesting decision.

In this context, we propose i) to characterize the forest owner's attitude towards risk; ii) to analyze the determinants of the forest owner's risk attitude; and iii) to determine the impact of the forest owner's risk attitude (and other exogenous variables as well) on the probability of harvesting. For this purpose, we assess the French forest owner's risk attitude by means of a questionnaire, using a context-free measure borrowed from experimental economics (Eckel and Grossman [11]). The determinants of the forest owner's risk attitude and harvesting decision are estimated through a recursive bivariate ordered probit model. We show that French forest owners are characterized by a relative risk aversion coefficient equals to 1.15. In addition, we find that the forest owner's risk aversion is influenced positively and significantly by the level of risk exposure, gender (female), level of education, and the fact to be a forester, while the income has a negative effect. Finally, we obtain that the forest owner's risk aversion has a positive and significant impact on the harvesting decision.

The rest of the paper is structured as follows. Section 2 describes the data. Section 3 presents the econometric model and Section 4 presents the results of estimation. Section 5 discusses these results and Section 6 concludes.

2 Data

This paper combines stated and revealed preferences data. The idea to combine this two types of data began with Cameron [14] and is now largely used (Azevedo et al. [7]). The stated preferences data are employed to develop estimates of forest owner preferences towards risk while the revealed preferences data provide potential determinants to owner's risk preferences and probability of harvesting.

2.1 The stated preferences data

Two methods are commonly used in economics to elicit risk preferences. The first one is a revealed preferences approach based on econometrics that is largely used to quantify the risk preferences of farmers for example (see for example Bontems and Thomas [10]). The other method is a stated preferences approach coming from experimental economics and based on lottery choices. Five procedures range in this category: the Multiple Price List, Random Lottery Pairs, Becker-DeGroot-Marschak auction, Trade-Off design and Ordered Lottery Selection (Cox and Harrison [16]). In our paper, the available data do not allow us to adopt the first method based on econometrics. Then, we opt for the Ordered Lottery Selection of Eckel and Grossman [19] revisited by Reynaud and Couture [35] to generate stated preference data. We adopt this procedure for two major reasons. First, the measurement of risk attitude bears only on one lottery choice while the other procedures imply up to ten lottery choices. Furthermore, this lottery task is only a brief part of a longer survey, so that we think that a shorter elicitation procedure makes the forest owner's answers more likely. Second, the procedure of Eckel and Grossman [19] has already been used to elicit the risk attitude of a population of farmers (Reynaud and Couture [35]), which can be considered rather close to the population of forest owners.

In this procedure, the subject must choose one gamble that she/he accepts to participate in among five possible ones. This choice allows to infer risk aversion and risk neutrality but not risk-prone behavior. Then, Reynaud and Couture [35] extend the procedure of Eckel and Grossman [19] to risk-prone attitudes. The subject must now choose the gamble she/he accepts out of nine options. We assume that individuals have a power utility function, which in turn implies Decreasing Absolute Risk Aversion (DARA), a standard assumption in the literature (Gollier [23]). Table 1 presents the procedure of Reynaud and Couture [35].

Table 1: Procedure of Reynaud and Couture [35]

Choice 50/50 gamble	Payoff 1	Payoff 2	Coef. of RRA ranges	Coef. of RRA code
Gamble 1	40	40	$r > 1.37$	RA5
Gamble 2	32	51	$0.68 < r < 1.37$	RA4
Gamble 3	24	64	$0.44 < r < 0.68$	RA3
Gamble 4	16	78	$0.4 < r < 0.44$	RA2
Gamble 5	12	86	$0.15 < r < 0.4$	RA1
Gamble 6	8	91.5	$-0.13 < r < 0.15$	RN
Gamble 7	6	92.9	$-0.47 < r < -0.13$	RP1
Gamble 8	4	93.4	$-0.93 < r < -0.47$	RP2
Gamble 9	1	93.5	$r < -0.93$	RP3

This table presents the nine gambles available to our sample of private forest owners. Each gamble provides payoff 1 and 2 with an equal probability of 50%. Then, the choice of gamble 1 ensures a gain of 40 euros, corresponding to a coefficient of Relative Risk Aversion (RRA) of $r > 1.37$, i.e. extreme risk-aversion (RA5). Risk Neutrality (RN) appeared with the choice of gamble 6, while the choice of gambles 7, 8 or 9 characterizes risk-prone (RP) behaviors from RP1, low risk-prone attitude, to RP3, high risk-prone attitude.

The procedure here is not incentivized, i.e. gains are purely hypothetical. However, when subjects have to make simple tasks (as one lottery choice) financial incentives do not affect the results (Beattie and Loomes [8]). Moreover, the survey is based on voluntary participation so that it is reasonnable to assume that forest owners reveal their true preferences.

2.2 The revealed preferences data

The data come from a survey implemented in 2010 to analyze the capacity of wood mobilization in France, in the context of the European project Newforex. The database is detailed in Darses et al. [17] and in Abildtrup et al. [1].

The questionnaire was sent to French private forest owners in five regions with different challenges and forest dynamics: Bourgogne, Pays de la Loire, Auvergne, Lorraine, and Provence-Alpes-Côte-d'Azur. Indeed, they have different rates of forest cover (more than 45% in Lorraine compared to less than 15% in Pays de la Loire) and different proportions of private forest (more than 50% public forests in Lorraine compared to less than 20% in Pays de la Loire, Auvergne, and Bougogne).

In France, the size of properties may be very different (more than 2 million properties are less than 1 ha and nearly 10,000 properties are over 100 ha), so we stratified the sample by size class in each region. We then randomly selected owners from each stratum. The sample was drawn from the database of the association of French private forest owners.

The questionnaire was sent by mail and 590 questionnaires were completed. Among these 590 questionnaires, 324 were usable for our study.

The questionnaire was composed of three different parts: 1) forest property; 2) wood production; and 3) forest owners. Table 2 displays descriptive statistics of the variables used at the estimation stage.

Forest property. The average forest area in the database is 65 hectares. Note that 15% of the owners delegate the management of the forest property to a professional. We can observe that 38% of the properties is crossed by a paved road. Table 2 also reveals that 18% of the forest properties are located in the region Lorraine, 17% in Auvergne, 14% in Provence-Alpes-Côte-d'Azur ($PACA$), 28% in Pays de la Loire (PDL) and 21% in Bourgogne. Finally, the variable $EXPO\_RISK$ represents the number of potential risks (nuclear, industrial, technological, earthquake, transport

Table 2: Definition of variables and descriptive statistics

Variable	**Definition**	**Mean**	**Std. Err.**
HARVEST	Binary variable = 1 if timber was harvested over the past five years	0.61	0.48
EXPO_RISK	level of exposure to risk (natural and technological)	1642.9	913.5
AREA	Forest area of the property (in ha)	65.93	140.93
GENDER	Binary variable = 1 if owner is a woman	0.16	0.37
PRICE	Average regional price (in €)	55.28	6.54
AGE	Age (years)	63.86	12.11
FOREST-INCOME	Percentage of forest income	4.15	12.11
INCOME_RANGE	The income range of forest owners	48382.72	29946.06
INCOME_CSP	The average income by socio-professional categories	28871.11	9174.67
LEISURE	Binary variable = 1 if the owner or members of her/his family have leisure activities in the forest	0.22	0.42
DELEGATION	Binary variable = 1 if the owner delegates the management of her/his property to a professional (expert)	0.15	0.36
FORESTER	Binary variable = 1 if the owner is a forester	0.02	0.14
EDUC	Binary variable = 1 if the owner has a level of education equivalent or superior to Master's degree	0.14	0.35
CERT	Binary variable = 1 if the timber is certified (PEFC or FSC)	0.33	0.47
PAVED_ROAD	Binary variable = 1 if the property is crossed by a paved road	0.38	0.48
LORRAINE	Binary variable = 1 if the forest is in the administrative region Lorraine	0.18	0.38
AUVERGNE	Binary variable = 1 if the forest is in the administrative region Auvergne	0.17	0.38
PACA	Binary variable = 1 if the forest is in the administrative region Provence-Alpes-Côte-d'Azur	0.14	0.35
PDL	Binary variable = 1 if the forest is in the administrative region Pays de la Loire	0.28	0.45
BOURGOGNE	Binary variable = 1 if the forest is in the administrative region Bourgogne	0.21	0.41

of dangerous goods, landslide, etc.) faced by inhabitants of the department. It is a proxy of the forest owner's level of exposure to risk. This variable was generated from the GASPAR[1] database (assisted management of administrative procedures relating to natural and technological risks) of the French Ministry of Ecology and Sustainable Development. This means that, on average, in the private forest owner's environment, 1642 potential hazards are listed. Finally, we can also observe that 33% of the forests of our sample are certified. Indeed, they have the PEFC (Program for the Endorsement of Forest Certification schemes) or FSC (Forest Stewardship Council) environmental label.

[1]Gestion ASsistée des Procédures Administratives relatives aux Risques naturels et technologiques: http://macommune.prim.net/gaspar/

Wood production. The key variable $HARVEST$ takes the value 1 if the owner has harvested timber over the past five years and 0 otherwise. This is an accurate proxy for the harvesting process, since a five-year period is long enough to capture any cause of harvesting timber. This is even more true since forests are composed of uneven-age stands. We observe that 61% of the 324 French private forest owners harvested timber over the past five years. In addition, the average regional timber price is 55.28€. This corresponds to the average selling price of wood (roadside) by region of the "Office National des Forêts" (National Forest Office). Moreover, 22% of the forest owners in our sample report that they have leisure activities in their forests (variable $LEISURE$), indicating that amenities are clearly associated with forest management by these owners.

Forest owners. The socio-demographic variables reveal that our database is composed of a majority of non-foresters, who are men, with an average age of 64 years, and a mean level of education inferior to a Master's degree. We can also observe that forest income represents on average 4.15% in the forest owners' total wealth ($FOREST\_INCOME$). In our survey, we asked respondents their income range.[2] Taking the center of each class, the average revenue of the owners is €48,382. The variable $INCOME\_CSP$ is the average annual household income before taxes by professions and socio-professional categories (PCS) in France. It indicates that the average income by socio-professional category is €28,871. This variable comes from the French National Institute of Statistics (INSEE), and has ever been used in Garcia et al. [22].

Risk attitude is also an individual characteristic of the forest owner. Table 3 allows us to observe the distribution of the forest owners among the 9 possible ranges of risk attitudes, from high-risk prone (range 1) to extreme risk-aversion (range 9).

Note that the extreme attitudes are well-represented. Indeed, among the 82.7% of private forest owners that are risk averse, more than 40% belong to the higher range (extreme risk-aversion). In the same vein, among the 8.6% of the sample that are risk-prone, more than 7% are in the lower

[2] Under €6,000; from €6,000 to €12,000; from €12,000 to €18,000; from €18,000 to €25,000; from €25,000 to €35,000; from €35,000 to €50,000; from €50,000 to €100,000; and over €100,000.

Table 3: Proportion of forest owners by Coef. of RRA ranges (in %)

Coef. of RRA ranges	Coef. of RRA code	Proportion of owners
r > 1.37	RA5	43.2
0.68 < r < 1.37	RA4	19.1
0.44 < r < 0.68	RA3	10.5
0.4 < r < 0.44	RA2	5.9
0.15 < r < 0.4	RA1	4
-0.13 < r < 0.15	RN	8.7
-0.47 < r < -0.13	RP1	0.9
-0.93 < r < -0.47	RP2	0.6
r < -0.93	RP3	7.1

range (high risk-prone attitude). In addition, we observe that 8.7% of the sample is characterized as risk neutral.

3 Econometric model : a recursive bivariate ordered probit model

The harvesting decision is influenced by the forest owner's risk aversion (Alvarez and Koskela [3]; Uusivuori [41]) and the characteristics of the owner and her/his property (Garcia et al. [22]). First, we cannot exclude that risk aversion and the harvesting decision share common unobserved factors. Second, it is unlikely that the harvesting decision directly modifies risk aversion, since the latter is an intrinsic characteristic of the individual. Thus, we specify the following recursive bivariate ordered probit model:

$$\begin{aligned} y^*_{1i} &= X'_{1i}\beta_1 + \epsilon_{1i} \\ y^*_{2i} &= X'_{2i}\beta_2 + \gamma y^*_{1i} + \epsilon_{2i} \end{aligned} \tag{1}$$

where y^*_{1i} stands for the relative risk aversion coefficient and y^*_{2i} is the latent variable underlying the harvesting decision y_{2i} ($y_{2i} = 1$ if the owner has harvested timber and 0 otherwise). X_1 and X_2 correspond to the vectors of the explanatory variables of the relative risk aversion coefficient (y_{1i}) and the harvesting decision (y_{2i}), respectively. We also assume that $cov(\epsilon_{1i}, \epsilon_{2i}) = \rho$, which allows us to take into account the potential endogeneity of risk aversion in the harvesting equation.

We define the empirical counterparts of the latent variables as:

$$y_{1i} = \begin{cases} 1 & \text{if} \quad y^*_{1i} < c_1 \\ 2 & \text{if} \quad c_1 \le y^*_{1i} < c_2 \\ & \vdots \\ J & \text{if} \quad c_{J-1} \le y^*_{1i} \end{cases} \tag{2}$$

and

$$y_{2i} = \begin{cases} 0 & \text{if} \quad y^*_{2i} < 0 \\ 1 & \text{if} \quad y^*_{2i} \ge 0 \end{cases} \tag{3}$$

with $c = [-0.93, -0.13, 0.15, 0.4, 0.44, 0.68, 1.37]$. The cutoff, c_j, are known and will therefore not be estimated. Following Sajaia [37], we show that:

$$Pr(y_{1i} = j, y_{2i} = 0) \;\; = Pr(y^*_{1i} < c_j, y^*_{2i} < 0) - Pr(y^*_{1i} < c_{j-1}, y^*_{2i} < 0) \tag{4}$$

and

$$\begin{aligned} Pr(y_{1i} = j, y_{2i} = 1) \;\; = \;\; & Pr(y^*_{1i} < c_j) - Pr(y^*_{1i} < c_{j-1}) - Pr(y^*_{1i} < c_j, y^*_{2i} < 0) \\ & + Pr(y^*_{1i} < c_{j-1}, y^*_{2i} < 0) \end{aligned} \tag{5}$$

The equation system (1) can be estimated by the maximum likelihood method. Indeed, we assume that $(\epsilon_{1i}, \epsilon_{2i}) \sim N(0, \Omega)$ with $\Omega = \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix}$, thus we get:

$$\begin{aligned} Pr(y_{1i} = j, y_{2i} = 0) \;\; = \;\; & Pr(\epsilon_{1i} < c_j - X'_{1i}\beta_1, \gamma\epsilon_{1i} + \epsilon_{2i} - \gamma X'_{1i}\beta_1 - X'_{2i}\beta_2) \\ & Pr(\epsilon_{1i} < c_{j-1} - X'_{1i}\beta_1, \gamma\epsilon_{1i} + \epsilon_{2i} - \gamma X'_{1i}\beta_1 - X'_{2i}\beta_2) \end{aligned} \tag{6}$$

Given that $\begin{pmatrix} 1 & 0 \\ \gamma & 1 \end{pmatrix} \begin{pmatrix} \epsilon_{1i} \\ \epsilon_{2i} \end{pmatrix} \sim N\left(0, \begin{bmatrix} 1 & \gamma + \rho \\ \gamma + \rho & \gamma^2 + 2\gamma\rho + 1 \end{bmatrix}\right)$ we have:

$$\begin{aligned} Pr(y_{1i}=j,y_{2i}=0) &= \Phi_2(c_j - X_{1i}'\beta_1, (-\gamma X_{1i}'\beta_1 - X_{2i}'\beta_2)\zeta, \tilde{\rho}) \\ &\quad -\Phi_2(c_{j-1} - X_{1i}'\beta_1, (-\gamma X_{1i}'\beta_1 - X_{2i}'\beta_2)\zeta, \tilde{\rho}) \end{aligned} \tag{7}$$

Similarly, we obtain:

$$\begin{aligned} Pr(y_{1i}=j,y_{2i}=1) &= \Phi(c_j - X_{1i}'\beta_1) - \Phi(c_{j-1} - X_{1i}'\beta_1) - \Phi_2(c_j - X_{1i}'\beta_1, (-\gamma X_{1i}'\beta_1 - X_{2i}'\beta_2)\zeta, \tilde{\rho}) \\ &\quad +\Phi_2(c_{j-1} - X_{1i}'\beta_1, (-\gamma X_{1i}'\beta_1 - X_{2i}'\beta_2)\zeta, \tilde{\rho}) \end{aligned} \tag{8}$$

with $\tilde{\rho} = \gamma + \rho$, $\zeta = (\gamma^2 + 2\gamma\rho + 1)^{-1/2}$ and Φ and Φ_2 the univariate and bivariate standard cumulative distribution functions, respectively. If $j = 1$, then the probabilities above shrink to:

$$\begin{aligned} Pr(y_{1i}=j,y_{2i}=0) &= \Phi_2(c_j - X_{1i}'\beta_1, (-\gamma X_{1i}'\beta_1 - X_{2i}'\beta_2)\zeta, \tilde{\rho}) \\ Pr(y_{1i}=j,y_{2i}=1) &= \Phi(c_j - X_{1i}'\beta_1) - \Phi_2(c_j - X_{1i}'\beta_1, (-\gamma X_{1i}'\beta_1 - X_{2i}'\beta_2)\zeta, \tilde{\rho}) \end{aligned} \tag{9}$$

If $j = J$, then the probabilities above shrink to:

$$\begin{aligned} Pr(y_{1i}=J,y_{2i}=0) &= \Phi((-\gamma X_{1i}'\beta_1 - X_{2i}'\beta_2)\zeta) - \Phi_2(c_{j-1} - X_{1i}'\beta_1, (-\gamma X_{1i}'\beta_1 - X_{2i}'\beta_2)\zeta, \tilde{\rho}) \\ Pr(y_{1i}=J,y_{2i}=1) &= 1 - \Phi(c_{j-1} - X_{1i}'\beta_1) - \Phi(-\gamma X_{1i}'\beta_1 - X_{2i}'\beta_2)\zeta) + \\ &\quad \Phi_2(c_{j-1} - X_{1i}'\beta_1, (-\gamma X_{1i}'\beta_1 - X_{2i}'\beta_2)\zeta, \tilde{\rho}) \end{aligned} \tag{10}$$

If we assume that the observations are independent, the log-likelihood function can be written as follows:[3]

$$\ln\, L = \sum_{i=1}^{N}\sum_{k=1}^{K}\sum_{j=1}^{J} I(y_{1i}=j,y_{2i}=k)\; \ln Pr(y_{1i}=j,y_{2i}=k) \tag{11}$$

To identify the model parameters, it is necessary to impose an exclusion restriction on vectors X_1 and X_2 (i.e. at least one element of X_1 should not be present in X_2). We exclude in the equation of the harvesting decision the variable $EXPO\_RISK$. Indeed, most of the risks considered in this variable (nuclear, industrial, technological, earthquake, transport of dangerous goods, landslide,

[3]The estimation is done using Matlab, the codes are available from the authors upon request.

etc.) have no direct impact on the harvesting decision but may negatively impact the forest owner's assets (financial, real estate, etc.). Indeed, if the risk exposure incresases, then the wealth reduces and the risk aversion raises (due to the DARA assumption).

Since income is an important explanatory variable in our study, we use a particular procedure to impute a specific income to each forest owner because this variable is potentially endogenous in both equations and especially in the risk equation. Using an interval regression, we explain income classes by means of several variables, including the average income by socio-professional categories, the level of education, age, gender and percentage of forest income. The probability associated of Likelihood Ratio (LR) Chi-Square of this model is equal to 0, suggesting that we cannot reject the hypothesis that our explanatory variables have an impact on income. Using this estimation we calculate the mean predicted income for each forest owner (variable $INCOME\_PREDICT$ in the full model below). This method allows us to take into account the potential endogeneity of the income variable and allows us to compute the expected income of forest owners who did not answer to this question[4]. We also use a bootstrap method to compute consistent standard errors for the full model whose results are described in Section 4. The estimation results of this auxiliary regression are shown in Table 4.

According to our results, the average income per CSP, age and education are the main determinants of household income. The pseudo R-square is 0.37, which seems acceptable to use predicted income as explanatory variable in the bivariate model.

4 Results of the bivariate model

The estimation results of the full model are displayed in Table 5. First, we note that the correlation coefficient of the two error terms ρ, is significant. This suggests that the risk aversion is endogenous in the harvesting equation and that our estimation strategy is appropriate. In addition, we think

[4]More precisely, 16 forest owners do not answer to the question on income, explaining the number of 308 observations in Table 4.

Table 4: Interval regression for Income class

	Income class
INCOME_CSP	1.185***
	(0.325)
AGE	502.8**
	(200.6)
FOREST-INCOME	-13.44
	(160.1)
EDUC	20105.5***
	(4570.2)
GENDER	5137.0
	(5186.8)
Constant	-28329.6
	(19795.5)
lnsigma	
Constant	10.21***
	(0.0572)
Observations	308
Log lik.	-577.8

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

that the number of potential risks (variable $EXPO\_RISK$) is a good instrument of the risk aversion for two reasons. First, when we regress the error term of the equation of harvesting on our instrumental variable, the associated coefficient is not significant. Hence, the number of potential risks satisfies the condition of exogeneity of instruments. Second, the parameter associated with this variable is significantly different from zero in the equation of risk aversion.

We now comment the results of both the risk attitude and the harvesting decision equations.

4.1 Risk attitude

It appears that five variables seem to be determinant when dealing with the risk attitudes of private forest owners, four deal with characteristics of forest owners ($INCOME\_PREDICT$, $GENDER$, $EDUC$, $FORESTER$) and one with a characteristic of the forest property ($EXPO\_RISK$).

The variable concerning the risks associated with the forest property, $EXPO\_RISK$, is positive and significant at the 5% level. This means that the higher the level of risk exposure is, the higher

Table 5: Estimation results

Variable	RISK Estimate	RISK Std. Err.	HARVESTING Estimate	HARVESTING Std. Err.
RISK			0.7510***	0.2802
EXPO_RISK	0.0002**	0.0001		
INCOME_PREDICT	-0.00004***	0.00001	0.00002	0.00002
AREA	-0.0002	0.0006	0.0048*	0.0027
PRICE	-0.0077	0.0241	-0.0146	0.0285
GENDER	0.6972***	0.2267	-0.7569**	0.3872
AGE	0.0055	0.0065	-0.0136*	0.0077
FORESTER	0.7700**	0.3797	-0.4097	0.5114
LEISURE	0.1561	0.1906	0.0713	0.2296
DELEGATION	-0.2135	0.2452	0.8298**	0.3828
EDUC	1.1360***	0.4042	-0.4506	0.7135
AUVERGNE	-0.1954	0.2323	0.1428	0.2602
BOURGOGNE	0.2014	0.3562	-0.4545	0.3704
PACA	0.2040	0.3063	-0.1462	0.3225
CERT	-0.0266	0.1796	0.5678**	0.2805
PAVED_ROAD	0.0801	0.1537	0.2728	0.1987
CONS	2.2346	1.4548	-0.0012	2.1872
ρ			-0.6247**	0.2905

Note: *, **, and *** for significance levels of 10, 5 and 1 per cent, respectively.

the forest owner's risk aversion will be.

The second variable, $INCOME\_PREDICT$, is negative and significant at 5%, meaning that the lower the predicted income is, the higher the risk aversion will be. This result is consistent with our initial DARA assumption and makes our reduced-form model compatible with the underlying structural model.

The variable $GENDER$ is positive and significant at the 1% level. Women are associated with higher risk aversion than men. This result is in line with the ones obtained in a myriad of contexts from financial decisions through environmental issues to betting choices (Jianakoplos and Bernasek [27]). In addition, we use the same procedure as Eckel and Grossman [19] to elicit risk attitude and we find the same result regarding gender.

Our estimation results also indicate that to be a forester (variable $FORESTER$) has a significant (at 5%) and positive effect on the risk aversion.

Finally, the variable $EDUC$ is also significant and positive, meaning that years of schooling increase risk aversion. The impact of the education on risk aversion is not consensual in the literature. Riley and Chow [36] find that risk aversion decreases with education, while others like Hersch [24] and Jung [28] obtain the opposite result. For example, Jung [28] suggests that in early education, education makes individuals more risk averse.

Using the estimated parameters of the equation of risk aversion, we can calculate the predicted value of the coefficient of relative risk aversion of each owner and its average value in the sample, i.e. $E\left(y_{1i}^{*}|X_{1i},\beta_1=\hat{\beta}_1\right)=X_{1i}^{\prime}\hat{\beta}_1$. We obtain a value of 1.1556 (Std. Err. = 0.4381). To our knowledge, this is the first time that such a coefficient has been estimated for private forest owners. Indeed, until now, the value was arbitrarily fixed and sensitivity analysis was performed (see, for example, Brunette et al. [13]). Such an estimation may be very useful for calibrating the model, taking into account forest owner's risk aversion. In addition, this estimation for French private forest owners is in accordance with Arrow [6], who indicated, in his seminal work, that the coefficient of relative risk aversion should be approximately 1.

4.2 Harvesting decision

Concerning the harvesting decision, several variables seem to be determinant, some concern the characteristics of the forest owners ($RISK$, $GENDER$, AGE), while others are characteristics of the forest property ($AREA$, $DELEGATION$, $CERT$).

The variable $RISK$ affects the harvesting decision positively and significantly. This means that the higher the risk aversion is, the higher the probability of harvesting will be. This result is of particular interest because it empirically confirms a result that is currently obtained only with a theoretical approach (Brunette et al. [13]; Koskela [29]).

The variables $GENDER$ and AGE have a significant and negative impact on the probability of harvesting. This result suggests that women forest owners harvest less often than men. This result is similar to that obtained by Lidestav and Ekström [30]. According to these authors, this difference may be an expression of differences in social and cultural aspects related to gender, such as education and the division of labor in the family. In addition, this result indicates that older forest owners harvest less often then younger ones. Stordal et al. [39] also found a similar result and suggested that younger owners may have larger debt or be facing large investments in the property, so that increased harvesting may give these owners better liquidity. Another argument is that increasing age is found to decrease the owners' technical efficiency in timber production (Lien et al. [31]).

The variable $AREA$ affects the harvesting decision positively and significantly. The greater the forest area is, the greater the probability of harvesting will be. This result is in line with Conway et al. [15], Stordal et al. [39] and Garcia et al. [22] who suggest that large forest areas are more susceptible to being used, in terms of the harvesting decision.

The fact of delegating the management of the forest (variable $DELEGATION$) to a professional has a positive and significant effect on the harvesting decision. The underlying idea of delegated forest management is to adopt best practices, allowing for better financial returns, such that the professional is encouraged to harvest more. This result is also obtained by Garcia et al. [22] at the regional level.

The variable $CERT$ is positive and significant at 5%, meaning that a certified forest is more likely to be harvest. Indeed, certification is an indicator of sustainable and environmentally sound management of timber.

Surprisingly, the variable PRICE has a non-significant impact on the harvesting decision (with a negative coefficient). This result is similar to those obtained by Dennis [18] (no significant effect) and at the most to Hyberg and Holthausen [26] (negative effect). According to these authors, this result could be the consequence of trade-offs made by the owners between forest income (income effect) and amenities (substitution effect). According to Provencher [34], this result could also be explained by an expectation of rising prices, which pushes owners to postpone their harvests, despite relatively high prices. However, we show that certification (variable $CERT$) has a positive and significant effect on timber harvesting. These labels usually allow producers to sell more timber at a better price.

5 Discussion

This Section discusses our result as regard to the sampling, i.e. the representativity of our 324 French private forest owners among the whole private forest owners population in France, and the estimation obtained for the relative risk aversion coefficient.

5.1 The sampling

We can analyze the representativeness of our sample by comparing some descritive statistics with those obtained by a survey recently conducted on French private forest owners (Agreste [2]).

First, in our sample the average forest area is 65.93 hectares while in Agreste [2], the average area among the French private forest owners is 8.5 ha. Large forest owners are clearly over-represented. This can be explained by the fact that large forest owners interested in forest management are more willing to participate on a voluntary basis. However, the variable AREA is not a significant variable for the risk aversion regression while it has a positive impact in the harvesting equation.

Second, the mean age in the sample is 63.86 years, which is comparable with Agreste [2], which indicates that French private forest owners have on average 64 years.

Third, our sample is composed with 16% of women and 84% of men. In Agreste [2], these percentages are 30% and 70% respectively. Consequently, the proportion of women is underestimated in our sample. However, our results indicate that the variable $GENDER$ has a significant and positive impact on risk aversion and a significant and negative effect on harvesting decision.

5.2 The coefficient of relative risk aversion

We used the Eckel and Grossman [19] procedure revisited by Reynaud and Couture [35] to elicit forest owner's risk preferences. We obtain a mean relative risk aversion coefficient of 1.15. This value is higher than the estimation obtained on farmers for example. Indeed, Galarza [21] uses a Holt and Laury [25] approach and find that the Peruvian farmers have an average coefficient of relative risk aversion of 0.45. On a sample of 30 French farmers, Bougherara et al. [11] elicit risk preferences using the Holt and Laury [25] approach, and find a coefficient of relative risk aversion of 0.89. This difference may be explained by the procedure itself. Indeed, Reynaud and Couture [35] remark that the Eckel and Grossamn's procedure may generate higher values for the coefficient of RRA than the procedure of Holt and Laury [25] (due to the difference in the number of categories of risk loving). However, using the same approach based on the Eckel and Grossman's [19] procedure, Reynaud and Couture [35] find a coefficient of 0.62 for the French farmers. Our apparently high coefficient may be explained by the intrinsic nature of forest management. Indeed, forest management is a long-term process and the period betweeen the investment and the first financial return may be of several years/decades, so that the risk is perceived differently in agriculture and forestry. In agriculture, the occurence of natural disasters is deeply detrimental from a financial point of view, but the farmer can start a new cycle the next year. The forest manager do not have this opportunity.

6 Conclusion

This paper aims to analyze the forest owner's risk aversion and its impact on the probability of harvesting. For this purpose, we use a database on forest owner's characteristics, forest property and wood production. We implement an ordered probit model to jointly estimate the determinants of risk aversion and the determinants of the probability to harvest. Our results reveal that the mean relative risk aversion coefficient of the French forest owner's is 1.15. The risk aversion is positively and significantly impacted by the level of risk exposure, the gender (female), the fact to be a forester and the level of education, while the income has a negative effect. The positive and significant determinants of the probability of harvesting are the risk aversion, forest area, the delegation of the forest management, the certification of the timber. Finally, gender and age have a negative and significant effect on harvesting.

This study identifies a channel by which characteristics of forest owner, forest property and wood production affect the forest owner's decisions: the forest owner's attitude towards risk. The relationship between these characteristics and risk attitude, as well as the link between risk attitude and probability of harvesting are useful in several ways. First, this study indicates how the characteristics of the forest owner, forest property and wood production influence the behavior of private forest owners. The introduction of risk attitude into research on private forest owners may help to understand their decisions and guide their futur management choices related to climate change adaptation for example. Previous studies showed that the private forest owner's harvesting decision is impacted by risk attitude, so that displaying the underlying relationships is essential. Second, it allows the forest owners to improve the individual knowledge and therefore to adopt more efficient management strategies. Third, this study also contributes to public policy issue. Indeed, we show that risk aversion increases the forest owner's probability to harvest. However, such a reaction to risk has numerous effects for the economy in terms of timber production, carbon storage, provision of non-market services, etc. For example, a higher risk aversion means to harvest more often, so that the time of the carbon storage is lower. In addition, the forest sector should adapt to this new harvesting planning. Consequently, such kind of studies may help to select appropriate strategies or public policy tools.

A way to improve this paper will be to take into account the dynamics of timber production. Indeed, timber comes from a long term dynamic biological process that is not considered in this research. However, to conduct such a study, we would need panel data over the long term, because some characteristics of the forest owner and the property, such as attitude towards risk for example, show very few variations in the short term.

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