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

Eric Nazindigouba Kere, Marielle Brunette, Jérôme Foncel

CENTRE D'ETUDES
ET DE RECHERCHES
SUR LE DEVELOPPEMENT
INTERNATIONAL

SERIE ETUDES ET DOCUMENTS DU CERDI

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

Marielle Brunette, Jerôme Foncel, Eric Nazindigouba Kéré

Etudes et Documents n° 10

April 2014

CERDI
65 BD. F. MITTERRAND
63000 CLERMONT FERRAND - FRANCE
TEL. 04 73 17 74 00
FAX 04 73 17 74 28
www.cerdi.org

The authors

Marielle Brunette, INRA, UMR 356 Economie Forestière, 54000 Nancy, France
Email: Marielle.Brunette@nancy.inra.fr

Jerôme Foncel, Université Lille 3 Charles-de-Gaulle, UFR de mathématiques, sciences économiques et sociales
Email: jerome.foncel@univ-lille3.fr

Eric Nazindigouba Kéré, Clermont Université, Université d'Auvergne, CNRS, UMR 6587, CERDI, F-63009 Clermont Fd
Email: Eric.Kere@udamail.fr

This work was supported by the LABEX IDGM+ (ANR-10-LABX-14-01) within the program "Investissements d'Avenir" operated by the French National Research Agency (ANR)

La série des *Etudes et Documents* du CERDI est consultable sur le site :
http://www.cerdi.org/ed

Directeur de la publication : Vianney Dequiedt
Directeur de la rédaction : Catherine Araujo Bonjean
Responsable d'édition : Annie Cohade
ISSN : 2114 - 7957

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 found that the forest owner's risk aversion is influenced positively and significantly by gender (female), age, and willingness to protect the environment, while the percentage of forest income in the total patrimony of the forest owner has a negative effect. Finally, we obtain that the forest owner's risk aversion positively and significantly impacts the harvesting decision.

Keywords: Forest owner's risk attitude; Risk aversion; Harvesting decision.
JEL classification: D81, C35, Q23

Acknowledgment

We are grateful to the European project Newforex, the National Institute of Geographic and Forest Information (IGN), and Région Lorraine that funded the survey. The UMR Economie Forestière is supported by a grant overseen by the French National Research Agency (ANR) as part of the "Investissements d'Avenir" program (ANR-11-LABX-0002-01, Lab of Excellence ARBRE). Finally, this work has benefited from the support of the Agence Nationale de la Recherche of the French government, through the program "Investissements d'avenir" (ANR-10-LABX-14-01).

1 Introduction

Climate change leads countries to think about alternatives to fossil fuels. Indeed, the European Union has decided to reduce its GHG emissions by 20% until 2020 and to divide these emissions by four by 2050 (compared to the 1990 level). To reach this objective, the European Union has proposed a 20% increase in the proportion of renewable energies in the Union's overall energy balance. In France, decision makers have proposed to improve energy efficiency by 20% and, especially, to increase the proportion of renewable energies in its energy balance from 12% (in 2006) to at least 23% in 2020, along with developing the uses of wood materials.

In such a context, forest biomass appears at the heart of the debate. Indeed, timber has a neutral impact on GHG and is a renewable and ecological raw material. Therefore, France has decided to increase harvesting in its forests by 21 million cubic meters until 2020.[1] IGN [18] estimates that, in France, the timber volume increased by around 44.8 million cubic meters each year during the period 2006-2010, so that the target set by France seems to be achievable, in theory. However, several potential obstacles can be identified. First, in France, private forests represent 75% of the forest area, so that the mobilization effort comes to bear mainly on private forest owners. Moreover, French forest private ownership is highly fragmented with 3.5 million private forest owners and an average area of around 8.8 hectares. Such observations raise many questions in terms of the feasibility of the French objective, both in terms of the efficiency of small-scale forest management, and in terms of incentives for private forest owners to harvest. Second, although the forest biomass helps fight climate change, it is also sensitive to increasing temperature, water stress, and increases in the frequency and/or intensity of natural hazards, so that uncertainty characterizes the private forest owners' harvesting decision, and the attitude of owners towards this uncertainty may play a significant role. Consequently, better knowledge of the determinants of private forest owners harvesting decision seems to be relevant. In particular, a focus on the effect of attitude towards risk on the harvesting decision is of special interest.

Investigating the determinants of private forest owners' harvesting decisions leads to numerous papers focusing on the role of non-timber activities (Conway et al. [8]; Pattanayak et al. [29]), bequest motives and debt (Conway et al. [8]), distribution of forest capital (Pattanayak et al. [30]), personal socio-economic characteristics, mainly the level of forest income and non-forest income of owners (Stordal et al. [33]), and social interactions (Garcia et al. [12]). However, to our knowledge

[1] "Grenelle de l'environnement" in 2007 and "Assises de la forêt" in 2007-2008.

none of these studies consider the forest owner's risk attitude as a potential explanatory variable for harvesting decisions.

In parallel, many theoretical papers study the impact of the forest owners' risk attitude on various types of decisions, such as rotation length (Alvarez and Koskela [1]; Clarke and Reed [7]; Gong and Löfgren [14]; Uusivuori [34]), forest investments (Kangas [20]), forest owners' consumption (Koskela [21]) and decision to replant or not after a clear cutting (Lien et al. [24]), but not on the harvesting decision. In addition, some empirical studies try to characterize the forest owner's risk attitude through telephone interviews (Lönnstedt and Svensson [25]), mail surveys (Andersson and Gong [3]), or field experiment (Brunette et al. [5]). However, these studies obtain different results. Lönnstedt and Svensson [25] found risk-prone attitudes in the case of low monetary amounts, yet risk-averse attitudes when large amounts were at stake. Andersson and Gong [3] find that a majority of forest owners were risk-neutral or risk-prone. Brunette et al. [5] concluded that forest owners are risk averse. These empirical works do not try to evaluate the forest owner's risk attitude, nor do they analyze the determinants of the forest owner's risk attitude and the impact of the forest owner's risk attitude on the 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 harvesting decision. 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 close to 1. In addition, we found that the forest owner's risk aversion is influenced positively and significantly by gender (female), age, and willingness to protect the environment, while the percentage of forest income in the total patrimony of the forest owner has a negative effect. Finally, we obtain that the forest owner's risk aversion positively and significantly impacts the harvesting decision.

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

2 Data

2.1 The measurement of risk attitude

In this paper, we want to provide a measure of non-industrial private forest (NIPF) owners' attitude towards risk that is context-independent, so we turn to experimental economics. Indeed, experimental economics is often used to elicit individual risk attitude, both in the lab and in the field. In experimental economics, two procedures are well known: the "Multiple Price List" method of Holt and Laury [15] and the procedure of Eckel and Grossman [11]. We adopt the second procedure for two major reasons. First, in the procedure of Eckel and Grossman [11], the measurement of risk attitude bears on only one lottery choice, while the Holt and Laury [15] method implies ten lottery choices. Furthermore, this lottery task is only a brief part of a longer survey, so we think that a shorter elicitation procedure makes the forest owner's answers more likely. Second, the procedure of Eckel and Grossman [11] has already been used to elicit French farmers' attitude (Couture and Reynaud [9]).

In the procedure of Eckel and Grossman [11], the subject must choose one gamble that she/he accepts to participate in among five possible ones. This choice allows the researcher to infer risk aversion and risk neutrality but not risk-prone behavior. Then, Couture and Reynaud [9] extends the procedure of Eckel and Grossman [11] 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 [13]). Table 1 presents the procedure of Couture and Reynaud [9].

Table 1: Procedure of Couture and Reynaud [9]

Choice 50/50 gamble	Payoff 1	Payoff 2	CRRA ranges	CRRA 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 (CRRA) 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 used without financial incentives, i.e. gains are purely hypothetical. However, as indicated by Camerer and Hogarth [6], when subjects have to make simple tasks such as choices between lotteries, financial incentives do not seem to significantly affect the results. Moreover, the survey is based on voluntary participation such that we can assume that forest owners reveal their true preferences.

2.2 Descriptive statistics

The data come from a survey implemented to analyze the capacity of wood mobilization in France, in the context of the European project Newforex.

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) the forest property; 2) wood production; and 3) the forest owners. Table 2 displays descriptive statistics of the variables used in the estimation stage.

Forest property. The average forest area in the database is 65 hectares, which is quite high since the average area among private forest owners in France is 8.8 hectares. This suggests that the forest owners in our sample have an economic interest in forest management and are interested in the question of wood mobilization. We can also observe that forest income represents on average 4.15% in the forest owners' total wealth and that 15% of the owners delegate the management of the forest property to a professional. Finally, Table 2 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.

Table 2: Definitions 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
ENVIRON	Binary variable = 1 if the owner intends to perform work with its neighbors to protect the environment	0.08	0.27
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
LEISURE	Binary variable = 1 if the owner or members of her/his family have leisure activities in the forest	0.22	0.42
BEQUEST	Binary variable = 1 if the owner intends to bequeath her/his forest	0.54	0.50
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
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

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. The variable ENVIRON indicates that only 8% of owners intend to perform work with their neighbors to protect the environment, suggesting a low interest in environmental aspects. In addition, the average regional timber price is 55.28€. This corresponds to the average selling price of wood (roadside) by region of the National Forests Office (Office National des Forêts). Finally, 22% of the forest owners interviewed report having 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. The variable BEQUEST underlines that 54% of the owners intends to bequeath their forest.

Risk attitude is also an individual's 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 range (high risk-prone attitude). In addition, we can observe that 8.7% of the sample is characterized as risk neutral.

Table 3: Proportion of forest owners by CRRA ranges (in %)

CRRA ranges	CRRA 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

3 Econometric model : a recursive bivariate ordered probit model

The harvesting decision is influenced by the forest owner's risk aversion (Alvarez and Koskela [1]; Clarke and Reed [7]; Gong and Löfgren [14]; Uusivuori [34]) and the characteristics of the owner and her/his property (Amacher et al. [2]; Garcia et al. [12]; Max and Lehman [27]). 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:

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

and

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

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 [32], we show that:

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

and

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

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:

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

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:

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

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:[2]

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

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). To do this, we exclude in the equation of the harvesting decision the variable ENVIRON. Indeed, the owners who intend to perform work with their neighbors to protect the environment are generally risk averse and implement adaptation measures to protect themselves. These measures will have an effect on the forest owner's coefficient of relative risk aversion. However, this variable probably does not have a direct effect on the harvesting decision.

4 Results

Our estimation results are presented in Table 4 for both the risk attitude and the harvesting decision.

Risk. The results displayed in Table 4 show that four variables seem to be determinant when dealing with the risk attitudes of private forest owners. The first variable, ENVIRON, is positive

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

Table 4: Estimation results

	RISK		HARVESTING	
Variable	Estimate	Std. Err.	Estimate	Std. Err.
RISK			0.4024**	0.1701
ENVIRON	1.6976***	0.3858		
AREA	0.00005	0.0004	0.0058**	0.0024
PRICE	0.0076	0.0055	-0.0030	0.0067
FOREST-INCOME	-0.0143**	0.0060	0.1020***	0.0310
GENDER	0.3356*	0.1872	-0.5922***	0.2257
AGE	0.0090*	0.0049	-0.0121*	0.0061
FORESTER	0.0311	0.3975	-0.1484	0.6319
LEISURE	0.0691	0.1765	0.2400	0.2007
BEQUEST	0.0539	0.1405	0.5003***	0.1703
DELEGATION	0.0884	0.2451	0.7316**	0.3368
EDUC	-0.1555	0.1405	0.0655	0.1827
LORRAINE	0.0381	0.1737	0.1777	0.2035
ρ			-0.1433	0.1940

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

and significant at the 1% level. This means that the more the forest owner is concerned with the environment the higher her/his risk aversion is. The second variable, FOREST-INCOME, is negative and significant at 5%. In other words, the lower the percentage of forest income in the total revenue of the forest owners, the higher the risk aversion. This result is not incompatible with our initial assumption of CRRA, since we do not consider total wealth but only forest income. The third and fourth variables, GENDER and AGE, concern the socio-demographic characteristics of the forest owners. They are positive and significant at the 10% 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 to environmental issues to betting choices (Jianakoplos and Bernasek [19]). In addition, we use the same procedure as Eckel and Grossman [11] to elicit risk attitude and we find the same result regarding gender. Finally, our estimation results indicate that the older the forest owner, the higher the risk aversion. This result is in accordance with the existing literature in economics (Jianakoplos and Bernasek [19]), finance (Morin and Suarez [28]), and psychology (Hunter and Kemp [16]). In other words, people become less risk prone and more cautious as they get older. In addition, Mather et al. [26] confirm this result in the domain of gains, as in our experiment.

Using the estimated parameters of the equation of risk aversion, we can calculate the predicted value of the coefficient of the relative risk aversion of each owner and its average value in the sample, i.e. $E\left(y_{1i}^{*}|X_{1i},\beta_1=\hat{\beta}_1\right)=X_{1i}'\hat{\beta}_1$. We obtain a value of 1.1527 (Std. Err. = 0.5526). 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. [5]). Such an estimation may be very useful for calibrating the model, taking into account forest owner's risk aversion. In addition, this CRRA estimation for French private forest owners is in accordance with Arrow [4], who indicated, in his seminal work, that CRRA should be approximately 1. We may also compare our estimation with the existing ones, especially for French farmers. Using the Eckel and Grossman procedure, Couture and Reynaud [9] find a CRRA of 0.62 for French farmers.

Harvesting. Concerning the harvesting decision, several variables seem to be determinant. The variable RISK affects the harvesting decision positively and significantly. This means that the higher the risk aversion, the higher the probability of harvesting. This result is of particular interest because it empirically confirms a result that is currently obtained only with a theoretical approach (Koskela [21]). A higher probability of harvesting may be interpreted as a shorter rotation cycle or as a lower density, due to higher thinning. Such risk management measures allow owners to reduce the risk to the stand, so that risk-averse forest owners implemented them. Our result suggests that such risk management measures are undertaken by the French private forest owners. This result also takes part in the current debate about potential adaptation strategies to fight against the impact of climate change. The favored strategies are the reduction of the rotation cycle and of the stand density.

The variable AREA also affects the harvesting decision positively and significantly. The greater the forest area, the greater the harvesting. This result is in line with Conway et al. [8], Stordal et al. [33] and Garcia et al. [12] who suggested that large forest areas are more susceptible to being used, in terms of the harvesting decision.

The variable FOREST-INCOME is positive and significant at 1%, suggesting that the higher the percentage of forest income in the forest owner's total wealth, the higher the probability to harvest. This variable may be an indicator of the intensity of the forest owner's management. Indeed, if the percentage of forest income in the forest owner's total wealth is high, this means that the forest is managed so as to bring economic return and, thus, the higher this percentage, the higher the frequency of harvesting. At the opposite end, if the percentage is low, then the forest's management is not really a main objective of the forest owner. This conclusion is in accordance with Garcia et al. [12] and Stordal et al. [33], who indicated that when the percentage of non-forest income in the forest owner's total wealth is very high, they (non-industrial private forest owners particularly) can afford to give up a part of their forest income in order to gain utility from non-timber benefits.

The results also indicate that being a woman (variable GENDER) has a negative and significant impact, suggesting that women forest owners harvest less often than men. This result is similar to that obtained by Lidestav and Ekström [22]. 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.

The variable AGE has a significant and negative effect on the probability to harvest. Stordal et al. [33] 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. [23]).

If a forest owner intends to bequeath her/his forest (BEQUEST), then she/he increases the harvesting decision. This means that the owners in our study seem to be more attached to bequeathing the forest property than a large stock of timber (associated with a large level of non-timber benefits).

In our study, the variable LEISURE seems to have no effect on the harvesting decision. However, as non-economic variables, such as gender, age, and intention to bequeath, significantly influence the decision to harvest, we can say that the owners are not simple profit maximizers (industrial owners). In addition, the variable LEISURE represents only a part of the existing amenity services provided by forests, so that the forest owner may potentially have a preference for other amenities like, for example, esthetical aspects. Finally, we analyze the effect of LEISURE on the probability of harvesting while the relevant effect may be on the intensity of harvesting.

The fact of delegating the management of the forest (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. [12] at the regional level.

More surprisingly, the variable PRICE has a non-significant impact on the harvesting decision and, in addition, the coefficient is negative. This result is similar to those obtained by Dennis [10] (no significant effect) and Hyberg and Holthausen [17] (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 [31], this result could also be explained by an expectation of rising prices, which pushes owners to postpone their harvests, despite relatively high prices.

Finally, note that ρ, the correlation coefficient of the two error terms, is not significant. This suggests that the endogeneity of risk aversion is irrelevant in the harvesting equation.

5 Discussion and conclusion

France has decided to increase harvesting in its forests by 21 million cubic meters until 2020. Although IGN [18] proved this increase as feasible, the French private forest owners will have to provide the largest effort, as they own around 75% of the forest surface. Therefore, the decision-maker needs to know the relevant levers at their disposal in order to increase the harvesting decision in France. Our study presents important results in this direction. Indeed, the analysis of the determinants of the harvesting decision reveals a positive effect of some variables, displaying several interesting levers for the decision-maker. Thus, the forest owner's risk aversion, the forest surface, the portion of forest income in the total patrimony, the willingness to bequeath and the fact of delegating forest management to a professional all increase the harvesting decision. Consequently, various approaches may be prioritized by the decision-maker. First, the decision-maker may fight against fragmentation by encouraging the forest owners to group together, for example within cooperatives. Second, the decision-maker may encourage forest investment, in order to increase the portion of the forest income in the total wealth of the forest owner. For instance, the decision-maker may adopt a favorable tax system. Third, the decision-maker may encourage bequests through favorable bequest conditions, especially in terms of succession. This would also reduce the average age of owners and thereby increase harvesting. Indeed, age negatively influences the harvest decision. Finally, delegation of forest management should be encouraged in order to increase the harvesting decision. This lever may be linked directly to the first one. Indeed, if the private forest owners regroup their forests into cooperatives, for example, then it will be easier and cheaper to delegate forest management.

In addition, in a context of climate change where uncertainty characterizes the forest owner's environment, dealing with the harvesting decision without considering risk attitude brings only partial information. Indeed, we have known for a long time now that forest owner's risk aversion plays an important role in the harvesting decision. However, the forest owner's risk aversion is not unanimous from an empirical point of view (Lönnstedt and Svensson [25]; Andersson and Gong [3]; Brunette et al. [5]) and, importantly, this risk aversion is poorly known. On these last points, our study delivers interesting results. First, we found that French private forest owners are clearly risk averse, adding our point of view to the debate. Second, we quantify this risk aversion through a relative risk aversion coefficient of 1.15. This estimation may be very useful for further researches, as it allows to parameter forest owner's risk aversion in a simple manner.

References

[1] L.H.R. Alvarez and E. Koskela. Does risk aversion accelerate optimal forest rotation under uncertainty? *Journal of Forest Economics*, 12:171–184, 2006.

[2] G. Amacher, C. Conway, and J. Sullivan. Econometric analysis of forest landowners: is there anything left to study? *Journal of Forest Economics*, 9(2):137–164, 2003.

[3] M. Andersson and P. Gong. Risk preferences, risk perceptions and timber harvest decisions - an empirical study of nonindustrial private forest owners in northern sweden. *Forest Policy and Economics*, 12:330–339, 2010.

[4] K.J. Arrow. Essays in the theory of risk-bearing. *North-Holland*, Amsterdam, 1970.

[5] M. Brunette, S. Couture, and J. Laye. Optimizing forest management when storms have an impact on both production and price: a markov decision process approach. *Cahiers du LEF*, 2012-03:http://www6.nancy.inra.fr/lef/Cahiers–du–LEF/2012/2012–03, 2012.

[6] C. Camerer and R. Hogarth. The effects of financial incentives in experiments: A review and capital-labor-production framework. *Journal of Risk and Uncertainty*, 1(19):7–42, 1999.

[7] H.R. Clarke and W.J. Reed. The trre-cutting problem in a stochastic environment: the case of age-dependent growth. *Journal of Economic Dynamics and Controls*, 13:569–595, 1989.

[8] C. Conway, G.S. Amacher, S. Sullivan, and D. Wear. Decisions non-industrial forest landowners make: an empirical examination. *Journal of Forest Economics*, 9(3):181–203, 2003.

[9] S. Couture and A. Reynaud. Stability of risk preference measures: results from a field experiment on french farmers. *Theory and Decision*, 73:203–221, 2012.

[10] Donald F. Dennis. A probit analysis of the harvest decision using pooled time-series and cross-sectional data. *Journal of Environmental Economics and Management*, 18(2):176–187, March 1990.

[11] C.C. Eckel and P.J. Grossman. Forecasting risk attitudes: An experimental study using actual and forecast gamble choices. *Journal of Economic Behavior and Organization*, 68(1):1–7, 2008.

[12] S. Garcia, N. E. Kéré, and A. Stenger. Econometric analysis of social interactions in the production decisions of private forest owners. *forthcoming in European Review of Agricultural Economics*, 2014.

[13] C. Gollier. The economics of risk and time. *The MIT Press, Cambridge*, page 445p, 2001.

[14] P. Gong and K.G. Löfgren. Risk-aversion and the short-run supply of timber. *Forest Science*, 49(5):647–656, 2003.

[15] C.A. Holt and S.K. Laury. Risk aversion and incentive effects. *The American Economic Review*, 92(5):1644–1655, 2002.

[16] K. Hunter and S. Kemp. The personality of e-commerce investors. *Journal of Economic Psychology*, 25(5):529–537, 2004.

[17] B. Hyberg and D. Holthausen. The behavior of nonindustrial private forest owners. *Canadian Journal of Forest Research*, 15:1014–1023, 1989.

[18] IGN. La forêt en chiffres et en cartes. *IGN*, 2012.

[19] N.A. Jianakoplos and A. Bernasek. Financial risk taking by age and birth cohort. *Southern Economic Journal*, 72:981–1001, 2006.

[20] J. Kangas. Incorporating risk attitude into comparison of reforestation alternatives. *Scandinavian Journal of Forest Research*, 9:297–304, 1994.

[21] E. Koskela. Forest taxation and timber supply under price uncertainty: Perfect capital markets. *Forest Science*, 35:137–159, 1989.

[22] G. Lidestav and M. Ekström. Introducing gender in studies on management behaviour among non-industrial private forest owners. *Scandinavian Journal of Forest Research*, 15(3):378–386, 2000.

[23] G. Lien, S. Størdal, and S. Baardsen. Technical efficiency in timber production and effects of other income sources. *Small-scale Forestry*, 6(1):12, 2007.

[24] G. Lien, S. Størdal, J.B. Hardaker, and L.J. Asheim. Risk aversion and optimal forest replanting : a stochastic efficiency study. *European Journal of Operational Research*, 181:1584–1592, 2007.

[25] L. Lönnstedt and J. Svensson. Non-industrial private forest owner's risk preferences. *Scandinavian Journal of Forest Research*, 15(6):651–660, 2000.

[26] M. Mather, N. Mazar, M.A. Gorlick, N.R. Lighthall, J. Burgeno, A. Schoeke, and D. Ariely. Risk preferences and aging: The "certainty effect" in older adults' decision making. *Psychology and Aging*, 2012.

[27] W. Max and D. E. Lehman. A behavioral model of timber supply. *Journal of Environmental Economics and Management*, 15(1):71–86, March 1988.

[28] R.A. Morin and A.F. Suarez. Risk aversion revisited. *Journal of Finance*, 38:1201–1216, 1983.

[29] S.K. Pattanayak, K.L. Abt, and T.P. Holmes. Timber and amenities on non-industrial private forest land. *In: E. O. Sills and K. L. Abt (eds), Forests in a Market Economy. Dordrecht; Boston: Kluwer Academic Publishers*, pages 243–258, 2003.

[30] S.K. Pattanayak, B. Murray, and R. Abt. How joint is joint forest production? an econometric analysis of timber supply conditional on endogenous amenity values. *Forest Science*, 48(3):479–491, 2002.

[31] B. Provencher. Structural versus reduced-form estimation of optimal stopping problems. *American Journal of Agricultural Economics*, 79(2):357–368, 1997.

[32] Z. Sajaia. Maximum likelihood estimation of a bivariate ordered probit model: implementation and monte carlo simulations. *The Stata Journal, Forthcoming*, 2008.

[33] S. Størdal, G. Lien, and S. Baardsen. Analyzing determinants of forest owners' decision-making using a sample selection framework. *Journal of Forest Economics*, 14:159–176, 2008.

[34] J. Uusivuori. Non-constant risk attitudes and timber harvesting. *Forest Science*, 48:459–470, 2002.