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# **Insurance decision against forest fire:**

## **An econometric analysis combining experimental and real data**

### **Abstract**

Storm and fire are responsible for 70% of total forestry damage due to natural hazards in Europe. They are associated to high costs for forest owners. However, very heterogeneous behaviors in terms of forest insurance demand arise across Europe. For example, only 6% of the French private forest area is insured against fire and/or storms. In this paper, we focus on the private forest owners' insurance decision against fire risk. For that purpose, we collect hypothetical data on willingness-to-pay (WTP hereafter) for insurance through a field experiment in which we test different scenarios of private insurance and public assistance. We also deal with real data about forest owners' insurance decision, characteristics of forests and owners.

We simultaneously estimate real insurance coverage and willingness-to-pay for different insurance scenarios, using a selection equation for zero WTP values that we potentially explain by the phenomenon of protest responses against insurance in the expected utility framework. We find that real insurance provision is relevant to explain positive WTP, and we show that unobservable determinant of insurance coverage may explain protest responses. These results confirm the advantage of including observed choices in experiments on insurance demand.

**Keywords:** insurance decision; willingness-to-pay; experimental data; protest responses; corner solution; forest fire.

JEL: C34 (Truncated and Censored Models), C93 (Field Experiments), Q23 (Forestry)

### **Introduction**

Natural hazards such as fire and storm regularly destroy forests worldwide. In European countries, storm and fire are responsible for 70% of total forestry damage due to natural hazards, making them the two most important natural risks in the European forest sector (Schelhaas et al. 2003). In August 2003, wildfires destroyed 10% of Portuguese forests (more than 70,000 hectares burnt in France), while in summer 2007 250,000 hectares of forest burnt in Greece. According to San-Miguel-Ayanz et al. (2017), the average economic damage of fires in EU from 1991 to 2016 is 1.8 million Euros. In 2007, Windstorm Kyrill generated more than 54 million cubic meters of timber damage in Europe, and in 2009 Windstorm Klaus damaged 42 million cubic meters in south-western France.

Due to climate change, these natural events should be exacerbated both in intensity and occurrence, increasing the risk associated to forest management (Spittlehouse and Stewart 2003; van Aalst 2006). Moreover, the effect of climate change on the characteristics of these natural events is largely uncertain, in particular in terms of their frequency. Indeed, the occurrence of natural hazards is increasing in the last decade, while the probability of occurrence of these events is widely uncertain. For example, in Europe the number of fire has been multiplied by six between 1970 and 2000, and continues to increase (Schelhaas et al. 2003), adding uncertainty to the forest owner's decision making process.

In this context, various forest adaptation strategies are advocated, like the reduction of rotation length or density, the adoption of species better-adapted to future climatic conditions, sanitation thinning, etc. (Bolte et al. 2009; Seidl et al. 2011). In parallel, risk-sharing strategy like private insurance is also available to forest owners. It meets the needs to substitute insurance to the traditional provision of post-disaster financial aid, which creates disincentives to protect physical assets through prevention and mitigation measures (World Bank, 2002). In addition, risk pooling allows to reduce the individual's exposure and makes the risk "manageable" (Mills 2007). This idea of using insurance as an adaptation strategy is in accordance with the recommendations to use private-sector insurance as a vehicle to finance climate resilience and adaptation (OECD 2015,

Global Agenda Council on Climate Change 2014, and Article 4.8 of the United Nations Framework Convention on Climate Change (UNFCCC) and Article 3.14 of the Kyoto Protocol).

However, the demand for forest insurance is very heterogeneous within Europe (Zhang and Stenger 2014; Brunette et al. 2015, 2016). In France approximately 800,000 hectares of private forests are insured against fire and/or storms, *i.e.* 6% of the French private forest area. In Spain, among the 6,224,029 hectares of insurable forest lands in 2010 only 77,103 hectares were insured against fire, *i.e.* 1.25% of the total surface (Barreal et al. 2014). In Sweden and Denmark, 95% and 50% respectively of the forest is covered by insurance contract, while in Finland and Norway these figures are respectively of 40% and 35% (Zhang and Stenger 2014). In addition, some countries provide public assistance to forest owners in case of natural hazards occurrence. For example, after storm Klaus, the French government provided an additional 415 million euros for an eight-year program in order to salvage and restore forest stands. After Hurricane Gudrun in 2005, the Danish government provided public assistance of 20 million euros, which covered about half of the estimated losses, in order to clear storm-felled timber and replant those areas with more storm resistant tree species; but funds were provided only for owners who had purchased a basic forest insurance policy. In Germany, some federal states paid 50% of the forest fire insurance premium. Such a premium subsidy is also afforded by the Fujian Forest Disaster Insurance program in China (Dai et al. 2015).

In this context, it seems legitimate to be interested in forest insurance as a tool to face increasing natural hazard occurrence. In particular, it seems relevant to identify the determinants of forest insurance demand in order to better understand individuals' choices. A focus on the role of uncertainty and public assistance also seems relevant.

A recent literature in forest economics aims at determining the factors influencing demand for forest insurance. There are two main categories of studies, based on different types data used for the analysis: the studies based on real data (Gan et al. 2014; Dai et al. 2015; Qin et al. 2016), and the

ones based on hypothetical data (Brunette et al. 2013, 2016; Deng et al. 2015; Sauter et al. 2016). In many cases, due to the low share of insured forests, sufficient data do not exist to analyze the real insurance decisions. In parallel, some studies implement experiments in order to collect hypothetical data on willingness-to-pay for insurance. They found that observable determinants (such as the experience of climatic event or forest size) but also some experimental conditions (such as ambiguity or potential public help schemes) significantly affect demand for forest insurance. Consequently, it seems relevant to consider both types of data, real and hypothetical (from experiment), to capture all potential factors and links influencing the demand for forest insurance (Brunette et al. 2016).

In a context of climate change, uncertainty may be a relevant factor to analyze insurance decision. Few papers analyze the effect of uncertainty on insurance demand. From a theoretical point of view, Alary et al. (2013) are the first to tackle such an issue. Using the KMM model of ambiguity (see Klibanoff et al. 2005), they show that ambiguity aversion raises the optimal insurance coverage. From an experimental point of view, several papers study the impact of uncertainty on the insurance supply and insurer's decisions (Kunreuther et al. 1995; Cabantous 2007; Cabantous et al. 2011), but very few are interested in the insurance demand. Brunette et al. (2013) show that ambiguity increases the individual's WTP for insurance as compared to a risky situation.

The effect of public compensations on insurance demand is relatively well-documented in the literature both theoretically and empirically. The theory acknowledges the fact that public compensation reduces the individual's incentives to insure (Lewis and Nickerson 1989; Kaplow 1991; Coate 1995; Kelly and Kleffner 2003; Kim and Schlesinger 2005; Raschky and Weck-Hanneman 2007; Brunette and Couture 2008). However, empirical studies are not so consensual. Indeed, some papers find that public financial help has no effect on insurance demand (Browne and Hoyt 2002), while others found the opposite result (van Asseldonk et al. 2002; Brunette et al. 2013).

In this paper, we use experimental economics to analyze the determinants of forest fire insurance decision by French private forest owners. We design and conduct a field experiment and use these data combined with observed real insurance decision to elicit WTP of private forest owners for forest fire insurance. Different scenarios are built to account for different levels of uncertainty about the occurrence of fire damages and different types of public assistance on insurance decision. Four modalities of public assistance are considered: (i) no public assistance, (ii) fixed assistance consisting in obtaining a fixed monetary amount from the government in case of fire occurrence, (iii) fixed assistance contingent to private insurance, (iv) insurance subsidy. In this context, we observe a possible phenomenon of protest responses against insurance, *i.e.* leading to zero WTP values, considering the expected utility framework. The original primary dataset is analyzed through an econometric approach in which both insurance decisions, real and hypothetical, are estimated jointly along with a selection process explaining the zero values in stated WTP.

Our results indicate that the real insurance decision is impacted significantly and positively by income, and when the forest property has already been destroyed by fire in the past. Concerning the hypothetical insurance choice, we show that expected loss of forestry revenue and uncertainty on the occurrence of forest fire both increase the WTP for full insurance. Moreover, we find that the type of public compensation can produce a protest reaction: forest owners indicate that they prefer no public assistance at all rather than fixed assistance. Finally, we show that insurance in the real life implies positive WTP in the experiment, and that unobservable determinants of real insurance decision may also explain protest responses.

The rest of the paper is structured as follows. Section 1 presents the methodology of the paper and the models to be tested are gathered in Section 2. Section 3 displays the results and Section 4 proposes a discussion and concludes.

## **1. Methodology and data**

We combine two sources of information, real and hypothetical data. Both types of data are collected during a field experiment conducted on a sample of 42 private forest owners located in the region of Aquitaine in France (see Brunette et al. (2016) for an extensive description).

In the field experiment the variable of interest is the WTP for forest fire insurance in different contexts, which are designed to test the effect of the uncertainty and the different types of public assistance on insurance decision. In the real dataset we observe individual's characteristics (e.g., age, gender), forest property (e.g., size, mode of acquisition), past hazard occurrence and real choice in terms of insurance decision. These real data were obtained from a survey realized when the experiment was completed. The final sample includes 40 respondents, who provide as many observations as scenarios in the experiment.

The experiment was developed with the assistance of the Aquitaine Regional Forest owners' Center (CRPF). Aquitaine is the major French regions in terms of timber production, with an average forest property of 12 hectares. The afforestation rate of Aquitaine is of 44% and it is the most important among the French regions. In parallel, Aquitaine is also among the regions where the fire risk is the higher (Commissariat Général au Développement Durable 2011). Among tree species, the most common in Aquitaine is the maritime pine.

Therefore, for the purpose of the experiment, participants are given a hypothetical framework in which they own an average property of maritime pines in Aquitaine that is exposed to a fire risk. Each participant plays different scenarios. Each scenario includes three types of information: (i) the type of public assistance; (ii) the probabilistic information about the fire risk; and (iii) the average annual revenue that the forest generates.

Regarding the type of public assistance, four modalities are considered:

1. No assistance (NA): in case of fire occurrence, the government does not provide any financial assistance.
2. Fixed assistance (FA): In case of fire occurrence, the government provides a fixed public assistance of €1,500.
3. Contingent fixed assistance (CFA): In case of a fire occurrence, the government provides a fixed public assistance of €1,500 to the insured forest owners.
4. Insurance subsidy (IS): The government subsidizes 50% of the fire insurance premium.

Considering a representative forest owner whose preferences are characterized by a von Neumann Morgenstern utility function ( $u$ ), these four modalities may be written in terms of individual's expected utility as follows:

- NA: (1)  
 FA: (2)  
 CFA: (3)  
 IS: , with (4)

with  $R$  the forest owners' wealth,  $p$  the probability of fire occurrence,  $D$  the associated damage, and  $WTP$  the willingness-to-pay for insurance. It is straightforward from Equation (1) that under expected utility theory (EUT), forest owners' WTP for full insurance should be positive unless there is no risk, *i.e.*  $p$  or  $D$  is 0, or wealth is infinite.

Concerning the probabilistic information about the fire risk, a part of the sample was confronted to these scenarios in a risky context with no uncertainty about the annual probability of fire damage (assessed to 0.2%); while the other part faced uncertainty about the annual probability of fire damage. This ambiguity is implemented following Gardenförs and Sahlin (1982) by providing different values for the annual probability of fire occurrence with an average similar to the risky



situation: 0.05%, 0.15%, 0.25% and 0.35%. We indicated to the participants that these estimates of the probability of fire damage are provided by four different forestry experts.<sup>1</sup>

Finally, these four scenarios are replicated two times with two different annual revenues per hectare and per year (€250 or €500). Consequently, the expected loss (ELOSS) of forestry revenue is represented by a binary variable that takes the values of €0.5/hectare ( $0.2\% \times \text{€}250/\text{ha}$ ) or €1/hectare ( $0.2\% \times \text{€}500/\text{ha}$ ).

Consequently, each of the 40 participants is confronted with eight scenarios, generating 320 observations. For each scenario, the forest owner was asked the maximal amount of annual insurance premium that s/he is willing to pay to be fully covered against potential losses due to fire.

At the end of the experiment, the participants fill out a questionnaire about their individual characteristics and those of their actual forest property. The descriptive statistics are provided in Table 1. In particular, owners are asked whether they have already taken out a fire insurance policy for their forest property. Nine forest owners indicate they bought forest insurance in the past, corresponding to 22.5% of our sample. This proportion is quite high compared to the rate of insured forest owners in France, which is less than 2%. This may be justified by the importance of forest income in the total income (for 25% of forest owners more than 50% of their assets are composed of forest) and the high number of forest owners having already suffered from a fire occurrence in the past (45%). These statistics also reveal that the forest property is mainly acquired by inheritance in the 1990's and the average forest area in the sample is 241 hectares.

The statistics about the forest owner's characteristics indicate that our sample is composed mainly with men, with High school diploma or more (62.9%), that are either retired or farmer. They are on average 58.18 years old, and their household is composed on average of 2.55 persons and 0.90

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<sup>1</sup> Hence, the ambiguity considered here comes from imprecision and not from conflict or disagreement (Cabantous 2007).

children. The distribution of income displays a higher percentage for medium classes (between €1,000 and €2,500).

Unfortunately, we cannot use all of these variables because of multicollinearity issues due to the low number of individual observations and the qualitative property of a majority of variables. For instance, we found high correlation between the variables INCOME and EDUC (education level).

**Table 1.** Summary statistics of individual characteristics of forest owners and of their property (N = 40)

Variable	Definition	Nb of individuals	% of the sample
<b><i>Characteristics of owner's forest property</i></b>			
Insurance coverage (IC)	Fire insurance contract	9	22.5
Acquisition	<i>Mode of forest acquisition</i>		
	Inheritance	15	37.5
	Purchase	7	17.5
	Alliance	2	5
	Inheritance and purchase	13	32.5
	Inheritance and alliance	2	5
	Inheritance, purchase and alliance	1	2.5
%FOREST	<i>% of forest in the assets</i>		
	Cat. 1: < 5%	11	27.5
	Cat. 2: 5-10%	1	2.5
	Cat. 3: 10-15%	4	10
	Cat. 4: 15-20%	3	7.5
	Cat. 5: 25-30%	6	15
	Cat. 6: 35-40%	4	10
	Cat. 7: 45-50%	1	2.5
	Cat. 8: > 50%	10	25
FIRE	Fire occurrence	18	45
AREA	Area of forest property (in hectares)	241	357.88
<b><i>Individual characteristics of forest owners</i></b>			
MALE	Gender	35	87.5
EDUC	<i>Education level</i>		
	General Certificate of Secondary Education	13	37.1
	High school diploma	7	20
	High school diploma +2, +3 and +4 years	7	20
	High school diploma +5 and over	8	22.9
	Non respondent	5	12.5
	<i>Profession</i>		
Retired	Retired people	17	42.5
Farmer	Farmers	10	25
Intermediate	Intermediate professions	1	2.5
Employee	Employees	3	7.5

Manager	Managers	8	20
Other	Other	1	2.5
INCOME	<i>Total income</i>		
	<€1000	6	15
	€1000-2000	11	27.5
	€2000-2500	9	22.5
	€2500-3000	4	10
	>€3000	10	25
		Mean	Std. Dev.
AGE	Age (in years)	58.18	12.24
PERS	Number of persons in the home	2.55	0.96
CHILD	Number of children	0.90	1.13

Descriptive statistics may also inform about the forest owners attitude towards risk. Following, Kunreuther et al. (1995) and Cabantous (2007), we analyze the ratio WTP/ELOSS in order to assess the forest owner's attitude towards risk. When  $WTP/ELOSS > 1$  (respectively  $WTP/ELOSS < 1$ ,  $WTP/ELOSS=1$ ), the individual is risk averse (respectively risk lover, risk neutral). We report simple statistics of variables WTP and WTP/ELOSS in Table 2. On average, they indicate that the forest owners of the sample are risk averse with a ratio WTP/ELOSS of 4.66. In addition, we observe that the WTP reported by forest owners goes from 0 to €100/ha with an average of €3.49/ha. As in previous studies, forest owners are on average predominantly risk averse (Brunette et al. 2013; Mußhoff and Maart-Noelck 2014; Sauter et al. 2016; Brunette et al. 2017).

**Table 2.** Summary statistics of WTP and WTP/ELOSS (N=320)

	Mean	Std. Dev.	Min	Max
WTP (€/ha)	3.491758	9.387642	0	100
WTP/ELOSS	4.658516	11.50618	0	100

N= 320, i.e. 40 forest owners had taken part in eight scenarios.

We now look more carefully at the distributions of WTP and WTP/ELOSS in Tables 3 and 4 and in Figures 1 and 2, respectively.

**Table 3.** Proportion of WTP values in €/ha (N=320)

	0	.0625	.125	.25	.3	.375	.5	.75	1	1.5	2	> 2
<b>Mean</b>	.128	.009	.040	.131	.003	.006	.203	.019	.178	.009	.047	.225
<b>Std. Dev.</b>	.019	.005	.011	.019	.003	.004	.023	.008	.021	.005	.012	.023

**Table 4.** Proportion of WTP/ELOSS values (N=320)

	0	.125	.25	.5	.6	.75	1	> 1
<b>Mean</b>	.128	.016	.072	.197	.003	.016	.222	.347
<b>Std. Dev.</b>	.019	.007	.014	.022	.003	.007	.023	.027

Table 3 reveals that 77.5% of responses for full coverage against fire is comprised between 0 and €2/ha, with 12.8% of zero values, 13.1% of €0.25, 20.3% responds €0.5 and 17.8% are willing to pay €1/ha. Figure 1 makes it possible to observe a high concentration of WTP responses between 0 and €5/ha.

Table 4 indicates that 22.22% of the sample is composed with risk neutral owners, while 34.7% are characterized as risk averse. We can then deduce that the mean WTP/ELOSS, that is 4.66 (Table 2), is drawn from the top by extreme risk averse owners, *i.e.* those reporting very high WTP. Figure 2 shows that, on the same trend, more than 40% of the owners are characterized as risk lovers, *i.e.* WTP/ELOSS inferior to 1.

Figure 1. Distribution of willingness-to-pay

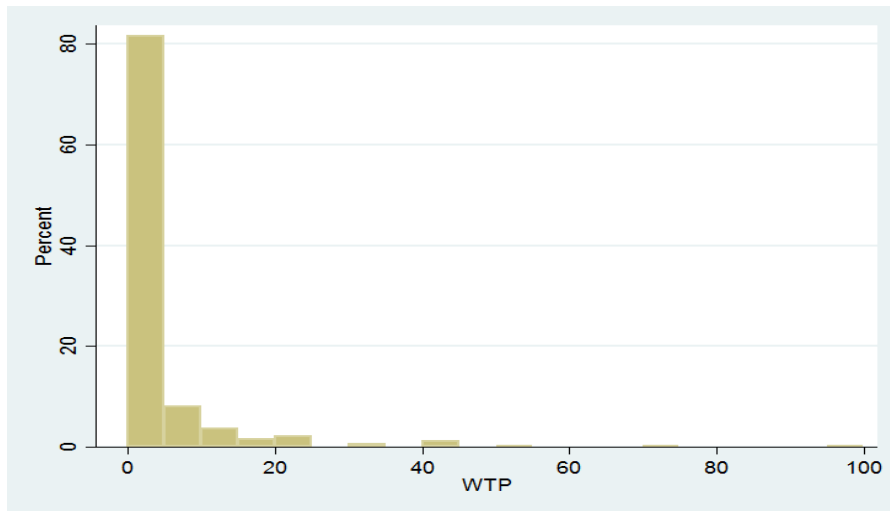
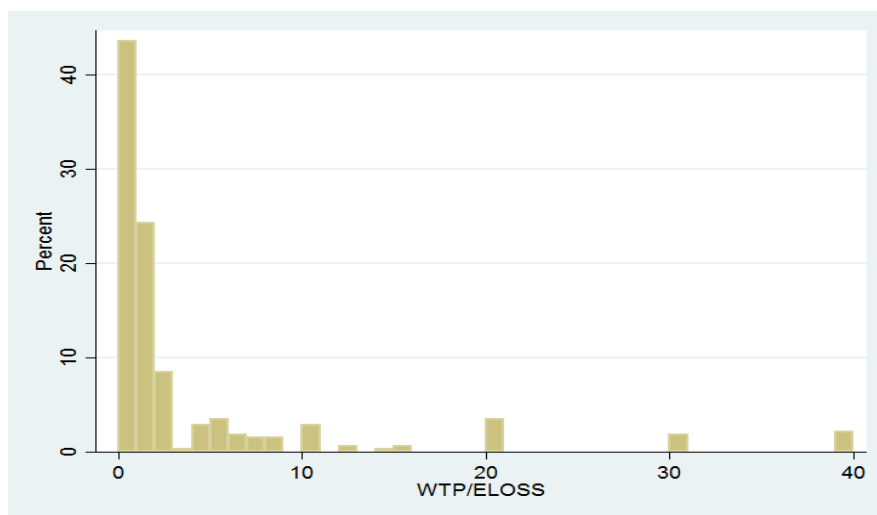


Figure 2. Distribution of WTP/ELOSS (restricted to the interval [0;40])



## 2. Econometric specification

Forest owners surveyed in our sample are asked how much they are willing to pay to be fully insured against fire risk. Table 3 just above displays that 12.8% of the sample indicates zero WTPs to be fully insured against risk, that is not consistent with the prediction of EUT described in Section 1. We propose two potential explanations, based first on optimization error and second on that forest owners may not be EU maximizer.

First, note that the expected loss per hectare is quite low either €0.5 or €1 per hectare. Thus, the WTP to be fully insured against this loss may take low values. Then, it is not excluded that, due to

optimization errors, forest owners with low WTP announce zero values as a corner solution. Second, zero values may be the result of a decision process that is not grounded on EUT. They may represent protest responses from people that do not act as rational producers. Another “more behavioral” explanation comes from the possibility that a forest owner distorts the fire probability such that it is close or equal to 0 and consequently WTP tends (or is equal) to 0 too.

We thus propose two alternative models to consider these two explanations: i) a standard Tobit model that may be suited for optimization error and ii) a double hurdle model with a specific equation explaining protest values or probability distortion in addition to optimization error.<sup>2</sup>

In the first model we make the assumption that the real insurance decision and the hypothetical willingness-to-pay may be correlated because they possibly share unobservable components from the underlying decision process based on individual’s preferences. That is why we specify the following Seemingly Unrelated Regression (SUR) model with *IC* for the real insurance choice and *WTP* for the hypothetical choice:

$$(5)$$

$$(6)$$

where subscript *i* refers to individuals, superscript *C* refers to the first equation of real choice, superscript *W* refers to the second equation of hypothetical WTP, and are vectors of exogenous variables, with the associated parameter vectors and to be estimated. The vector of error terms follows a bivariate normal distribution whose correlation coefficient is denoted and . The variance of is normalized to 1 for identification purpose. The empirical counterparts of the latent variables are defined by:

$$(0 \text{ for not insured})$$

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<sup>2</sup> It means that the two models are nested.

In the second model we explain the zero values obtained in stated WTP by the means of a selection equation. The model is the following:

$$(7)$$

$$(8)$$

$$(9)$$

Equations (7) and (9) are identical to Equations (5) and (6), and Equation (8) is the selection equation, with: if  $\epsilon_i > -\lambda$ , and 0 otherwise.  $\epsilon_i$  is the vector of exogenous variables associated to this Equation. Remark that this Equation just conveys the information that some individuals do not conform to EUT in choosing  $WTP=0$ . It does not discriminate between an EU maximizer and a non EU maximizer for instance since both individuals can choose non-zero WTP. It is worth noting that we introduce the real decision of insurance  $IC$  as an explanatory variable in the selection equation,<sup>3</sup> because buying (or not) real insurance is a potential determinant of the probability to behave (or not) “normally”, *i.e.* announce a non-zero WTP. We assume that  $\epsilon_i$  follow a trivariate normal distribution whose correlation coefficients are denoted  $\rho_{12}$ ,  $\rho_{13}$ , and  $\rho_{23}$ . The variance of  $\epsilon_{1i}$  and  $\epsilon_{2i}$  are normalized to 1 for identification purpose, but  $\epsilon_{3i}$  has to be estimated. The empirical counterpart of the willingness-to-pay is now defined by:

$$WTP_i = \begin{cases} \text{if } \epsilon_i > -\lambda \\ 0 \text{ otherwise} \end{cases}$$

This model is a variant (with an additional equation, *i.e.* the IC equation) of the double hurdle model described in Jones (1989). The likelihood function of this second model is given by:

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<sup>3</sup>The potential endogeneity of  $IC$  in Equation (8) is addressed by instrumenting this variable by the means of Equation (7) in which some significant variables (see Table 6) are excluded from Equation (8).



where the sample is divided into those with zero WTP (denoted 0) and those with positive WTP (denoted +), and with  $f$  the conditional density of WTP. This likelihood can be rewritten by the means of marginal and conditional univariate and bivariate normal cumulative or density functions.<sup>4</sup>

Note that standard errors are computed to allow for intragroup correlation, relaxing the usual requirement that the observations are independent. That is, the observations are independent between individuals (clusters) but not necessarily for one individual who has taken part in the eight scenarios of the experiment. Moreover, we use the Jackknife method to estimate standard errors in a nonparametric way in order to take any misspecification or the presence of heteroscedasticity into account, thus obtaining robust estimates of standard errors.

### 3. Results

Estimation results for the first model are displayed in Table 5 below. First, we observe that the correlation coefficient between the two error terms is not significantly different from zero. This implies that the two decisions are not driven by common unobservable factors such as risk aversion for instance. This result may be explained by the fact that the insurance decision occurred in the past and thus the two decisions are not contemporaneous.

Concerning the real insurance decision (*IC*), we obtain that the income has a significant and negative effect on the decision to insure: the lower classes of income (*INCOM12* and *INCOM34*) have a lower probability of insuring with respect to the highest class of income (*INCOM5*).<sup>5</sup> This

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<sup>4</sup> We use the Conditional Mixed Process program (CMP) in STATA developed by Roodman (2011) that allows estimating consistently our two models in taking into account several forms of endogenous regressors for various qualitative, censored and quantitative variables of interest. In particular, we performed Monte-Carlo simulations to check that this procedure was suited for our second model by providing appropriate parameters recovery.

<sup>5</sup> Note that the variable *INCOM12* gathers the two first classes of the variable *Income* <1,000€ and *Income* belongs to [1,000€; 2,000€]. *INCOM34* gathers classes [2,000€; 2,500€] and [2,500€; 3,000€]. *INCOM5* represents the richest forest owners of the sample and is considered as the reference income class.

result is similar to Deng et al. (2015), but different from Gan et al. (2014) who found that household income did not show a significant impact on the purchase of wildfire insurance. The effect of income on insurance demand is somehow puzzling in the literature. Indeed theory predicts that under the reasonable assumption that preferences exhibit Decreasing Absolute Risk Aversion (DARA) then insurance is an inferior good (see Schlesinger 2000). However, numerous empirical papers (like ours or Deng et al. 2015 in the field of forest economics) find the opposite result. One possible reason is the absence of control for the value of the insured good which leads to an upward bias if “income” and “value of the good” are positively correlated. Another reason could be that liquidity constraints may affect the ability of poor households to afford such an insurance service especially when levels of insurance are discontinuous. Since in our study the variable *AREA* (forest area) is a proxy for the property value, then we may favor another interpretation to explain the puzzle such as liquidity constraints (just mentioned above) or behavioral explanations (which is beyond the scope of this paper).

The variable *FIRE* has a significant and positive impact, meaning that past occurrence of forest fire significantly increases the real insurance decision. This result is in line with Deng et al. (2015) who report that an owner who has suffered from a timber loss due to natural event in the past indicates a higher *WTP*. However, this result differs from the conclusion of Gan et al. (2014). Indeed, they observed that having suffered from a fire in the last ten years, has a significant and negative impact on the probability to adopt forest insurance. They explain this result by indicating that the occurrence of a fire decreases the probability of fire re-occurrence in the near future because vegetation will take some time to regrow. This is probably true when the forest is entirely destroyed. In a context of climate change when owners experience only partial destruction of their goods, we think that this correlation should be positive (if any), which is consistent with our result.

Concerning the hypothetical insurance decision (*WTP*), Table 5 indicates that the expected loss (*ELOSS*) and the presence of ambiguity (*AMBIGU*) have a positive and significant impact on *WTP*, which is consistent with the theory (see Alary et al. 2013). This implies that the forest owner wants to transfer more risk to the insurance company when the probability of fire occurrence is imprecise. We also observe that a fixed assistance has a negative impact, which seems intuitive since the forest owner has less incentive to pay for insurance. This result is also in line with previous results (Brunette et al. 2013). Finally, note that the variable related to the public assistance *CFA* is positive but not significant. Following Sauter et al. (2016), we can argue that such a public assistance is not well-known by French private forest owners since such a contingency does not exist in France, and then, the respondents may be more reluctant as regard to this type of public help.

Remark finally that the variable related to forest area (*AREA*) is positive and not significant for both the hypothetical and real insurance decisions. This result is also found in the literature (Deng et al. 2015).

**Table 5.** Estimation results of the real insurance decision (IC) and WTP

VARIABLE	IC	WTP
ELOSS		5.091** (2.148)
FA		-0.997** (0.409)
CFA		0.131 (0.361)
IS		1.338 (1.305)
AMBIGU		7.443* (3.827)
AREA (in log)	0.225 (0.184)	1.138 (1.239)
PERS	0.570 (0.353)	-0.586 (1.492)
INCOM12	-1.962**	

	(0.839)	
INCOM34	-1.256**	
	(0.562)	
FIRE	0.750*	
	(0.419)	
Constant	-2.652**	-8.023
	(1.217)	(5.491)
ln		2.240***
		(0.436)
	0.193	
	(0.365)	
Observations	320	
Individuals	40	
Number of successful	39	
Jackknife replications		
Log pseudo-likelihood	-1151	

Jackknife robust standard errors in parentheses (adjusted for 40 clusters in individuals). Significance levels: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . Likelihood-ratio tests from pseudo-likelihood are invalid and thus are not computed.

Estimation results of the second model are presented in Table 6 for each of the three equations considered: insurance coverage equation (*IC*), selection equation (*S*) and willingness-to-pay equation (*WTP*).

**Table 6.** Estimation results of the Tobit model with endogenous observed insurance and selection

VARIABLE	IC	S	WTP
IC		2.257*** (0.494)	
ELOSS		0.350 (0.331)	4.709** (2.167)
FA		-0.413* (0.223)	0.383 (0.610)
CFA		0.210 (0.169)	-0.368 (0.237)
IS		-0.114 (0.185)	2.056 (1.762)
AMBIGU		0.305 (0.584)	6.516* (3.462)
INCOM12	-2.028** (0.845)		
INCOM34	-1.519*** (0.543)		
AREA (in log)	0.239 (0.151)		0.458 (1.091)
PERS	0.450 (0.316)		-1.180 (1.682)
FIRE	0.745* (0.368)		
Constant	-2.276** (1.105)	0.370 (0.324)	-1.078 (4.029)
ln			2.230*** (0.457)
	-1.878* (1.103)		
	0.0555 (0.564)		
	-0.362* (0.200)		
Observations		320	
Individuals		40	

Number of	38
successful	
Jackknife	
replications	
Log pseudo-	-1213
likelihood	

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Jackknife robust standard errors in parentheses (adjusted for 40 clusters in individuals).

Significance levels: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . Likelihood-ratio tests from pseudo-likelihoods are invalid and thus not computed here.

First, we observed that results are similar for the real insurance decision (*IC* equation) to those obtained from the first model presented in Table 5. Second, we also notice that results for the WTP equation in Table 6 are almost identical to those presented in Table 5 except for the variable *FA*. Indeed, it appears that *FA* is no longer significant for the WTP equation but it becomes relevant for the selection equation.

The selection equation is not a participation equation *stricto sensu* since each forest owner is supposed to pay a positive amount to be fully insured at a fair rate under expected utility. This could be viewed as an explanation to consistently behave as an expected utility maximizer or not (including the phenomenon of protest responses). Consequently, it is not surprising that the variable *FA* appears significant and negative. Indeed, a fixed assistance discourages owners from paying for a fair insurance contract. This empirical result is consistent with the theoretical conclusion that government assistance reduces the incentive to insure (Kaplow 1991; Coate 1995; Kim and Schlesinger 2005; Raschky and Weck-Hannemann 2007; Brunette and Couture 2008). This result may reflect the so-called “Charity Hazard” defined by Browne and Hoyt (2000), *i.e.* the tendency of individuals to rely on public support rather than undertaking risk-reducing or risk-sharing actions.

In addition, the variable related to the real insurance decision (*IC*) is significant and positive. It is obvious that choosing to be insured in the real life has a positive and significant effect on behaving

consistently with expected utility (or choosing not to protest). Note that because  $IC$  appears in the selection equation ( $S$ ), there is also (potentially) an indirect effect transmitted to  $S$  through the impact of the factors (such as the income variables and FIRE) on the probability that  $IC$  equals one (Greene 2008).

Finally, we look for potential correlations between the error terms of the three equations. We observe that the correlation coefficient is significantly different from zero, suggesting that the variable  $IC$  is endogenous in the selection equation. Moreover, the negative sign of the coefficient shows that there exists unobservable heterogeneity related to owner's preferences reducing the probability to behave as an expected utility maximizer, and thus relevant to explain zero values of  $WTP$ . Similarly, the correlation coefficient between the disturbances of the selection equation and the  $WTP$  equation is negative and significant, validating the existence of a selection bias and by the way the merits of our second model. In turn we conclude in favor of non-standard behavior to explain zero  $WTP$  and possibly the low propensity to buy insurance against forest fire.

#### **4. Discussion and conclusion**

Insurance against natural events has been advocated as a potential adaptation option to face increasing disturbances due to climate change. However, recent empirical studies based on either real or hypothetical data reveal a very low share of total forest area is insured. It also indicates that many important factors impact the forest insurance demand. However, there is only a limited knowledge on forest owners'  $WTP$ s for insurance and their corresponding determinants. Our paper contributes to this issue in several ways.

First, we know that climate change will impact natural hazards occurrence but clearly we do not know in which way. By introducing some uncertainty about the annual fire occurrence probability, we try to apprehend this ambiguous impact of climate change on the occurrence of natural disturbances. We observe that this ambiguity leads to an increase in the willingness-to-pay for

insurance. Then, in a near future, we can expect the insurance demand to increase. However, keep in mind that as the uncertainty increases, the question of insurability of natural event may also be asked. Such a result also highlights the need for future research concerning ambiguity aversion of forest owners that may be a new factor impacting their WTPs for insurance.

In addition, our results indicate that the expected loss has a significant and positive impact on WTP. This expected loss is composed of the probability of occurrence of the negative event and the potential damage. Under the influence of climate change, frequency and intensity of natural events are expected to increase and then, the forest owner's expected loss too. An increase in the insurance demand should be observed.

Second, one of the major challenges in the idea of coupling insurance and climate change adaptation is to clearly define the public-private partnerships and then, the role of the State in such a scheme (Mills 2007). In this paper, we show that a fixed assistance, as implemented in France after windstorm Lothar in 1999 and Klaus in 2009, discourages the forest owner to be willing to pay for insurance. We also obtain that the contingent fixed assistance has no significant impact on the probability of willing to pay a positive insurance amount. Finally, we also test for Insurance Subsidy but such a public assistance seems to be never relevant in the two models. In this paper we focus on a subsidy of 50% of the insurance premium for the owner, but perhaps other type of subsidy may be relevant. For example, we can imagine that the public subsidy would be received by the insurer, so that she can reduce the insurance premium. The implementation of co-insurance contracts with the insurer, Government and the forest owner taking each in charge a predefined percentage of the risk may be another potential solution. Research should be conducted in this direction.

In parallel, since January 2017, the French government has decided that public assistance will never be available in the future in case of natural hazard occurrence. Then, the only possibility for the private forest owners to be indemnified in case of natural event occurrence is the private insurance



market. Such a political decision allows thinking that insurance demand should increase in the near future.

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