Self-Insurance And Liability Insurance Under One-Sided Ambiguity

François Pannequin[a], Maïva Ropaul[a,b,1]

[a] CREST, École Normale Supérieure Paris-Saclay, Université Paris-Saclay, 61 Avenue du Président Wilson, 94235 Cachan, France
[b] CRED, Université Panthéon-Assas, 12 Place du Panthéon, 75005 Paris, France

Abstract

This paper provides an experimental test of the effects of tort rules on the demand for both insurance and self-insurance. We consider two standard tort rules, namely strict liability and negligence rule, both in risk and one-sided ambiguity contexts. The experiment relies on a magnitude model for a unilateral accident with civil liability. To differentiate between risk and ambiguity, we successively assume that the potential injurer has a perfect or an imprecise knowledge of the probability of accident; in the latter case, we have recourse to the KMM approach (Klibanoff et al. (2005)). Our experimental results indicate that the substitutability property between insurance and self-insurance holds both under risk and ambiguity. Moreover, the data show that under risk with availability of insurance, strict liability and negligence rule are not equivalent in their deterrence effect, contrary to the predictions of the standard model. Finally, ambiguity does not modify the incentives provided by the negligence rule, other things being equal, while we observe an increase in the demand for self-insurance under strict liability.
Keywords: self-insurance, liability insurance, ambiguity, tort law

1. Introduction

Civil liability is a legal device that obligates a party who causes harm to make a repayment to the victim. As liability rules set monetary constraints on those who harm others, they may induce potential injurers to provide precaution (Brown, 1973; Shavell, 1980). Alongside his investment in care, a potential injurer may subscribe to a liability insurance contract, which delivers him an indemnity in case he is held liable for an accident. Tort rules efficiency with availability or unavailability of liability insurance has been extensively studied in the Law and Economics (hereafter "L&E") literature, particularly in situations where the decision-makers have a complete knowledge of the probability distribution of accidents (see e.g. Shavell, 2007). However, this assumption of a full knowledge of the probability distribution is progressively questioned with the introduction of ambiguity in the economic modeling of civil liability (see Teiltelbaum, 2007; Langlais, 2011; Chakravarty and Kelsey, 2012; Mondello, 2013; Franzoni, 2014). Our paper contributes to these recent developments in L&E with a lab experiment on precaution and insurance decisions under one-sided ambiguity.

Ambiguity can be defined as a situation in which probability distribution of possible events is vague, dubious, uncertain (Cabantous and Smith, 2006; Camerer and Weber, 1992; Frisch and Baron, 1988). This specific feature of the decision context questions the standard subjective expected utility (SEU) representation of preferences developed by Savage (1954). The SEU approach suggests that decisions under uncertainty can be assimilated to decisions under risk, as long as the decision-maker has a subjective probability distribution over the state space. Ellsberg's experiments (1961) provide evidence that ambiguity induces choices which

[1] Corresponding author: maiva.ropaul@ens-paris-saclay.fr

are incompatible with the SEU model. Hence, theoretical predictions in the economics of tort law cannot be transposed from a situation of complete knowledge to a situation characterized by ambiguity.

In this paper, we consider unilateral accidents with one-sided ambiguity. The unilateral accident model implies that only the potential injurer may invest in precautionary measures, while the potential victim cannot (see e.g. Shavell, 2007). Regarding one-sided ambiguity, we consider situations for which the potential injurer has *ex ante* imprecise information on the probability of accident, while the insurer or public authorities have precise information. Hence, the injurer faces ambiguity, whereas insurance companies and courts face risk. It is reasonable to suppose asymmetric ambiguity for some accidents. Indeed, public authorities and insurers have access to large time-series data sets or they face the population average. Consequently, they may extrapolate the probability distribution of accidents. Meanwhile the policyholder may be uncertain about his own probability of accident. Indeed, the policyholder does not have access to the insurance companies data. As underlined by Vergote (2010), "*the information available to the insured is mostly the personal historical data and hearsay*". The consideration of asymmetric ambiguity in theoretical analysis of the insurance market is relatively new (Andersson, 1999; Villeneuve, 2000; Jeleva and Villeneuve, 2004; Etner and Spaeter, 2010). To our knowledge, there is no study that combines insurance choices, precaution choices, liability rules and one-sided ambiguity. Therefore, our paper fills this gap between L&E and Economics of insurance.

The L&E literature distinguishes four different precaution technologies (see Dari-Mattiacci and De Geest, 2005): the magnitude model (precaution investment dedicated to loss reduction, which corresponds to self-insurance in the sense of Ehrlich and Becker (1972)), the probability model (precaution investments are dedicated to probability reduction), the joint probability-magnitude model and the separate probability-magnitude model. Our analysis lies within the magnitude model. Thus, we consider situations where precaution decreases the magnitude of the victim's harm. Depending on the liability rule, self-insurance expenses may result in a decrease in the monetary repayment that the injurer is obligated to make in the event of an accident.

This focus on self-insurance is motivated by the relatively little amount of empirical evidence on the substitution property between insurance and self-insurance. Carson et al. (2013) find empirical evidence for this substitution in the case of homeowner insurance and catastrophic risks. Pannequin et al. (2014), in an experimental setting, also corroborate this property but obtain an imperfect matching to the theory. Our paper contributes to the experimental economics literature by proposing an original experiment designed to analyze self-insurance and insurance behavior for different liability regimes under both ambiguity and risk.

We consider two classical liability regimes: strict liability and negligence rule. Strict liability is a legal rule whereby the injurer has to make a repayment to the victim of harm, no matter what were the preventive measures adopted *ex ante*. Whereas negligence rule imposes liability on the potential injurer if and only if the level of precaution is inferior to a legal standard set by the court. The negligence rule implies that for a level of self-insurance superior to a legal standard, the payoff of the injurer is certain and equal to his initial wealth minus the cost of self-insurance. If the level of precaution is higher or equal to the legal standard, the negligence rule has the property to eliminate ambiguity. Meanwhile, strict liability never removes ambiguity. Therefore, strict liability and negligence rule may yield different incentives to provide precaution and to buy insurance coverage under ambiguity.

Until recently, there were few experiments on liability rules.[2] Our experimental approach particularly builds upon the previous experiment by Angelova et al. (2014). Our experiment differs somewhat, as their study focuses on self-protection - an investment in prevention intended for reducing the accident probability, while we consider self-insurance, an investment that can lessen the magnitude of damages. Moreover, precautionary measures in their setting are modeled by a binary decision: either the agent invests a lump sum cost $c > 0$, either she does not invest. In our experiment, we allow for a wider range of investment possibilities in self-insurance. Contrary to Angelova et al., in our experiment, we do not deal with insolvency, but we introduce ambiguity and the opportunity to buy insurance coverage.

[2]Recent experiments include Lampach and Spaeter (2016) and Lampach et al. (2016). For earlier experiments, see King and Schwartz (1999,2000); Dopuch and King (1992); Dopuch et al. (1997); Wittman et al. (1997); Korhnauser and Schotter (1990).

We gather data on risk-averse subjects. These subjects are divided into two categories: ambiguity-averters and ambiguity-lovers. We derive three important findings on the basis of these experimental data. First, in a risk context, theory predicts substitutability between insurance and self-insurance for risk-averters. Our data not only confirm this prediction under risk, but also provide empirical evidence that this substitutability property holds in ambiguity context. Second, in a setting with risk and availability of insurance, theory predicts that risk-averters have a similar demand for self-insurance under strict liability and negligence rule. Our data cast into doubt this commonly accepted prediction. Third, introducing ambiguity does not modify incentives for precaution under negligence rule, other things being equal. Contrary to strict liability, for which we find an increase in the demand for self-insurance. Surprisingly, this result holds both for ambiguity-averters and ambiguity-lovers.

The remainder of this paper is as follows. Section 2 introduces the theoretical framework and behavioral predictions upon which the experiment is built. Section 3 presents the design and procedures of the experiment. Results are displayed and discussed in section 4. Section 5 ends the paper with some concluding remarks.

2. Theoretical framework

2.1. Assumptions and notations

We consider a standard unilateral accident model. Let be a producer whose activity is likely to generate an accident. In this setting, the potential victim is not able to invest in preventive measures to decrease the probability or the magnitude of the accident. Only the producer can affect those latter parameters. Moreover, the producer is supposed to be not harmed by the accident.

When an accident occurs, the magnitude of damages is a function of a, the investment in self-insurance. The level of damages is noted $x(a)$ with $x'(a) < 0$ and $x''(a) > 0$. These conditions on $x(a)$ induce that the more the agent invests in self-insurance, the lower are the potential damages on the one hand; the returns to scale of self-insurance being decreasing on the other hand. We also suppose $-x'(a) > 1$, which requires that the marginal cost of self-insurance (equal to 1) is inferior to the marginal decrease in damages $-x'(a)$.

The producer is supposed to operate on a market with imperfect competition. The technology of production on this market gives a gross return $W_0 > 0$, which one can interpret as the initial level of wealth of the producer. [3] We suppose that the producer is not exposed to an insolvency issue in the event of an accident. To rule out this possibility, we suppose $W_0 - x(0) \geqslant 0$, which means that the producer can cover the damages with his assets even if he has not previously invested in self-insurance.

When the probability of accident is known, this probability is noted q. When an accident occurs, the producer is submitted to a liability rule. Therefore, the level of wealth of the producer is noted $W_N = W_0 - a - pI$ when no accident occurs, and $W_A = W_0 - a - pI + h(a, I)$ in case of accident, with $h(a, I)$ a function describing the result of the liability rule and the insurance policy. The decision-maker can purchase an amount of insurance I at price p. He receives an indemnity I in case he is held liable for an accident. We limit the insurance coverage I to a maximum amount equal to $x(a)$ to ensure that the producer has no incentive to encourage occurrences of accidents.

2.2. Social welfare function

In this setting, the social planner perfectly knows the probability distribution. We assume a paternalistic social planner, who minimizes the expected direct costs of accident and precaution. $SC(a) = qx(a) + a$. Given this operationalization of the social welfare function, the socially optimal level of self-insurance is $a^s \; s.t. \; \frac{1}{q} = -x'(a^s)$, both under risk and ambiguity. We also assume that the social planner sets a legal standard for the negligence rule $\bar{a}$ equal to the social optimum a^s previously defined, both under risk and ambiguity.

However, it can be argued that both risk and ambiguity aversion could be included in the social welfare

[3] In this paper we do not endogenize the output level of the producer and her decision to enter the market.

function, as shown by Franzoni (2014) and Teitelbaum (2007). Indeed, the main drawback of this assumption is that the social planner does not consider the psychological costs of risk and ambiguity. Nevertheless, these simplifying assumptions help us to create a reliable experimental setting. Indeed, they allow to create the same legal standard for negligence rule both in the risk and ambiguity treatments. Therefore, the amount of self-investment required to comply with the legal standard is the same in these two treatments. Hence, we can compare the results for the negligence rule regime under the risk and the ambiguity treatments. Indeed, in this experimental setting we are interested in how ambiguity modifies the demand for self-insurance, other things being equal.

2.3. Liability regimes

Under the strict liability rule, the injurer is liable under all circumstances, no matter if he is at fault or not. Therefore, $h(a, I) = -x(a) + I$. When an accident occurs, the producer has to compensate the victim for the harm $x(a)$, but the insurance can cover this extra cost with an indemnity I. The last liability scheme is the negligence rule where the victim bears the cost of accident unless the injurer is found negligent. Negligence lies in the insufficiency of investment a in prevention compared to a legal standard $\bar{a}$. Therefore, for $a < \bar{a}$, $h(a, I) = -x(a) + I$ and for $a \geqslant \bar{a}$, $h(a, I) = 0$. The legal standard $\bar{a}$ in this setting is equal to the socially optimal level of self-insurance, noted a^s. The level of self-insurance is such that it minimizes the total social cost of accident $SC(a) = qx(a) + a$, which means that a^s is such that $\frac{1}{q} = -x'(a^s)$.

Expected utility. Individual preferences are supposed to be characterized by a utility function $U(W)$ with $U'(W) > 0$ and $U''(W) < 0$ for risk-averse agents and $U''(W) = 0$ for risk-neutral agents.[4] Therefore the expected utility of the agent depends on self-insurance a and insurance I and can be written

$$\begin{aligned} EU(a, I; q) =&(1 - q)U(W_0 - a - pI) \\ &+ qU(W_0 - a - pI + h(a, I)) \end{aligned} \tag{1}$$

In this setting, the insurer is assumed to be risk neutral and to charge an actuarial price of insurance. Insurance market is assumed to be competitive, there is no profit, while transaction costs are neglected. As a consequence, the price of insurance p is actuarial and equal to the probability of accident q. The expected utility can then also be written

$$\begin{aligned} EU(a, I; q) =&(1 - q)U(W_0 - a - qI) \\ &+ qU(W_0 - a - qI + h(a, I)) \end{aligned} \tag{2}$$

2.4. Modeling ambiguity in the standard model of civil liability

Evaluation function of the expected utility under ambiguity. We describe attitudes towards ambiguity using the smooth ambiguity model by Klibanoff, Marinacci and Mukerjy (2005, hereafter "KMM"). This model decomposes the individual welfare evaluation under ambiguity into two steps (see Etner, Jeleva and Tallon, 2012). Firstly, the decision-maker computes his expected utility (EU) for a given decision with respect to all possible priors. Secondly, the decision-maker considers the expectation of these EUs transformed with an increasing function $\phi(.)$. This function describes the decision-maker's attitude towards ambiguity. When $\phi(.)$ is concave, the decision-maker is said to be ambiguity-averse: the concavity ensures that the decision-maker puts a larger weight on the "bad" EUs. Conversely, when $\phi(.)$ is convex the decision-maker is said to be ambiguity-loving.

Relying on KMM's modeling allows to distinguish the effects of risk-aversion and ambiguity-aversion. While risk-aversion induces that any mean-preserving spread in the payoff of a risky lottery reduces the welfare of risk-averters, KMM suggests that a mean-preserving spread in a probability distribution decreases the welfare of ambiguity-averters (see Alary, Gollier and Treich, 2013). Intuitively, this implies that the introduction

[4]We do not model the behavior of risk loving agents in this paper. Risk lovers typically arbitrate between full insurance and risk retention as documented in Pannequin et al. (2014).

of ambiguity in a decision context leads the ambiguity-averter (resp. ambiguity-lover) to increase (resp. decrease) his level of precaution and his insurance coverage in comparison with a risk context. However, this intuition may be erroneous depending on the liability regime in place.
In presence of ambiguity, the decision-maker is uncertain about the value of the probability of accident. This uncertainty is represented following the KMM model with a second-order probability distribution $F(\pi)$, where π is a possible value of the unknown probability. We can now write the expected utility as $EU(a, I; \pi) = (1-\pi)U(W_0 - a - pI) + \pi U(W_0 - a - pI + h(a, I))$. We assume that the insurer perfectly knows the probability of accident. Moreover, we assume the price of insurance to be actuarial. Therefore, the price of insurance p is fixed and equal to q in the ambiguity context. The expected utility can be rewritten

$$EU(a, I; \pi) = (1 - \pi)U(W_0 - a - qI) + \pi U(W_0 - a - qI + h(a, I)) \tag{3}$$

In presence of ambiguity, the expected utility at π of the decision-maker is evaluated by a function ϕ with $\phi'(.) > 0$, with $\phi''(.) = 0$ for an ambiguity-neutral agent, $\phi''(.) < 0$ for an ambiguity-averse agent and $\phi''(.) > 0$ for an ambiguity-loving agent. Based on KMM (2005) and Snow (2011), we make the assumption that the agent has unbiased beliefs i.e. $E_F[\pi] = q$. This assumption allows to disentangle the effect of beliefs and the effect of attitudes towards ambiguity on the agent's behavior.

Therefore, the expected utility of an ambiguity-averse or ambiguity-loving agent can be written

$$E_F[\phi(EU(a, I; \pi))] \tag{4}$$

Whereas the expected utility of an ambiguity-neutral agent is $(1 - E_F(\pi))U(W_0 - a - qI) + E_F(\pi)U(W_0 - a - qI + h(a, I))$. Indeed, when the agent is ambiguity neutral, $\phi(.)$ is a linear function. Consequently, under the assumption of unbiased beliefs on the probability of accident, the evaluation under ambiguity of the expected utility of an ambiguity-neutral agent becomes $(1 - q)U(W_0 - a - qI) + qU(W_0 - a - qI + h(a, I))$.

Choices of an ambiguity-averse and an ambiguity-loving agent. It is straightforward to see that the decisions of the ambiguity-neutral agent are identical under risk and ambiguity. Concerning the ambiguity-averse agent, to compare the self-insurance and insurance choices under risk and ambiguity, we apply the proposition by Rothschild and Stiglitz (1970) according to which the expected value of any concave function of a random variable increases with a mean-preserving contraction, and decreases with a mean-preserving spread. Similarly, the expected value of any convex function of a random variable decreases with a mean-preserving contraction, and increases with a mean-preserving spread in the distribution of this random variable.
Let $(a*, I*)$ be the optimal decision of the agent under risk. If an increase in a (resp. I) at point $(a*, I*)$ results in a mean-preserving contraction in the distribution of the expected utility at point $(a*, I*)$, we know that $E_F[\phi(EU(a, I; \pi))]$ is increasing in a (resp. I) at point $(a*, I*)$. In this event, the agent is willing to increase her demand for a (resp. I) under ambiguity compared to risk.
The increase in a results in a mean-preserving contraction in the distribution of the expected utility at point $(a*, I*)$ if

$$\forall\pi,\ \frac{\partial^2 EU}{\partial a \partial \pi}|_{(a*,I*)} > 0$$

Indeed, under this condition at $\pi = q$, $EU'_a(a^*, I^*; \pi) = 0$, at $\pi > q$, $EU'_a(a^*, I^*; \pi) > 0$, and $\pi < q$, $EU'_a(a^*, I^*; \pi) < 0$. [5] Thus, for $\pi = q$ the mean EU is unchanged. For high values of the EU ($\pi < q$), an increase in a evaluated at point a^* decreases the EU. For low values of the EU ($\pi > q$), an increase in a evaluated at point a^* increases the EU. Then, $E_F[\phi(EU(a, I; \pi))]$ increases in a at a^*, which gives $E_F[\phi'(EU(a, I; \pi))\, EU'_a(a, I; \pi)] > 0$. In this case, this means that the ambiguity-averse agent is willing to invest in a higher amount of self-insurance a (resp. I) under ambiguity compared to risk, while the prior q is unchanged. Meanwhile, the ambiguity-loving agent is willing to decrease her demand for a (resp. I). Conversely, if $\forall\pi$, $\frac{\partial^2 EU}{\partial a \partial \pi}|_{(a*,I*)} < 0$, an increase in a (resp. I) at point $(a*, I*)$ results in a mean-preserving

[5] At point $(a*, I*)$ and for $\pi = q$, $EU'_a(a^*, I^*; \pi) = 0$ corresponds to the first-order condition in the risky context.

spread in the distribution of the expected utility. Hence, in this event an ambiguity-averse agent is willing to decrease her demand for a (resp. I) at point $(a*, I*)$ under ambiguity, while the ambiguity-loving agent is willing to increase her demand.

2.5. Behavioral predictions

The computational details can be found in AppendixA.1 for the risk context and AppendixA.2 and AppendixA.3 for the ambiguity context. Our theoretical results regarding self-insurance are summarized in tables 1 and 2. Theoretical results regarding insurance demand are presented in table 3.

Table 1 shows the theoretical results under risk. It indicates that risk-neutral individuals always demand the same level of self-insurance, whatever are the opportunities to buy insurance coverage or the liability rule. Table 1 also shows a substitution between self-insurance and insurance for risk-averters under strict liability: risk-averters increase their demand for self-insurance when the opportunities to buy insurance coverage decrease.

Concerning insurance demand in risk context, 3 shows that a risk-averse individual has a full insurance coverage such that his demand I^* is equal to $x(a^*)$ under strict liability, the potential level of damages she would face in the event of an accident. On the contrary, a risk-neutral agent is indifferent to his level of insurance coverage, and his demand $I^* \in [0; x(a^*)]$ under strict liability. If the negligence rule is implemented, both the risk-neutral and the risk-averse individuals choose a null insurance coverage $I^* = 0$. Hence, the demand of a population composed of risk-neutral and risk-averse individuals is higher under strict liability than under negligence rule. Meanwhile, we show that when it is possible to buy insurance coverage, the demand for liability insurance under negligence rule is null.

Table 2 presents the theoretical results in ambiguity contexts. They are derived from equation (4), and detailed in AppendixA.2 and AppendixA.3. Under strict liability, ambiguity-averters increase their demand for self-insurance compared to a risk context. On the contrary, the demand for self-insurance does not vary under negligence rule and remains equal to a^s.

Under strict liability, ambiguity-lovers decrease their demand for self-insurance compared to a risk context. The results are undetermined under the negligence rule. AppendixA.2 indicates in particular that the strict liability regime induces a demand inferior to a^s for the risk-neutral and risk-averse individuals if insurance is available. When insurance is not available, the model predicts a demand inferior to a^s for the risk-neutral. Concerning the risk-averters, when there is no insurance, the model indicates a decrease in the demand but it cannot predict if the level of the demand will be inferior or not to a^s without further assumptions.

Ambiguity-averse individual's demand for insurance is null under negligence rule. On the contrary, if the strict liability regime is implemented, the demand for insurance increases compared to the risk context and is positive, both for risk-averse and risk-neutral individuals.

Ambiguity-loving individual's demand for insurance decreases compared to the risk context if the strict liability regime is implemented. For ambiguity-lovers, results are undetermined under the negligence rule without further assumptions.

Table 1: Theoretical results for self-insurance demand for risk contexts.

	Insurance	**No insurance**
Strict liability	risk-neutrals and risk-averters choose a^s	risk-neutrals choose a^s, while risk-averters choose $> a^s$
Negligence rule	risk-neutrals and risk-averters choose a^s	

a^s is the self-insurance level that minimizes the costs of precaution and accident $SC(a) = qx(a)+a$, with $\frac{1}{q} = -x'(a^s)$. The legal standard for precaution under negligence rule equals a^s in our setting.

Table 2: Theoretical results for self-insurance demand for ambiguity contexts.

	Insurance	**No insurance**
Strict liability	ambiguity-averters choose $> a^s$ ambiguity-lovers choose $< a^s$	ambiguity-averters choose $> a^s$ ambiguity-lovers decrease their demand compared to risk
Negligence rule	ambiguity-averters choose a^s; ambiguity-lovers: undetermined result without further assumptions	

a^s is the self-insurance level that minimizes the costs of precaution and accident $SC(a) = qx(a)+a$, with $\frac{1}{q} = -x'(a^s)$. The legal standard for precaution under negligence rule equals a^s in our setting.

Table 3: Theoretical results for insurance demand.

	Risk	**Ambiguity**
Strict liability	risk-neutral chooses $I^* \in [0; x(a^*)]$ and risk-averter chooses $I^* = x(a^*)$	ambiguity-averters increase their demand and ambiguity-lovers decrease their demand
Negligence rule	$I^* = 0$ for risk-neutrals, risk-averters and ambiguity-averters. Undetermined results for ambiguity-lovers under ambiguity.	

3. Experiment

The experiment consists of three parts. The first part is dedicated to the measure of attitudes towards risk and ambiguity. The second part brings a laboratory choice situation that reproduces the features of the theoretical model. The third part collects data on the socio-demographic characteristics and other control variables.

3.1. Attitudes towards risk and ambiguity

In the first part of the experiment, attitudes towards risk and ambiguity were measured with a multiple price list procedure *à la* Holt and Laury (2002, 2005) and Chakravarty and Roy (2009), as shown in figures B.1 and B.2. The subjects could randomly begin with the elicitation of attitudes towards risk or ambiguity. This sequence, involving the two multiple price lists, was randomly selected by the computer. At the beginning of this first part of the experiment, it was announced that the players could win up to 10 euros in this section. The computer would select randomly one of the decisions that the player had taken during this part. The result of this draw was communicated at the end of this part of the experiment for each participant and the gains were disclosed at the end of the experiment.
The attitudes towards risk and ambiguity are measured with an ordinal variable between 0 and 11, corresponding to the number of option A that the individual has made in figures B.1 and B.2. The higher this coefficient is, the more risk or ambiguity averse the subject is. The individual is either neutral or averse towards risk or ambiguity for a coefficient superior or equal to 6.

3.2. Liability game

3.2.1. Treatments

The second part of the experiment consisted of a series of decisions split into two groups, one group corresponding to negligence rule ("NR" treatment), and the other group corresponding to strict liability ("SL" treatment).
We implemented eight different treatments, which differ in the liability regime (NR or SL), the availability or unavailability or insurance ("I" and "NI") and finally the presence of risk or ambiguity ("RK" and "AM"). Each treatment was repeated three times in a row. All treatments were played by all participants. However, the appearance order of the treatments was randomly selected by the computer to eliminate any order bias. The computer selected either the participant would begin with the negligence rule decisions group or the strict liability. Once a group was chosen, the participant had to play all the possible treatments of this group before being allowed to play with the other decisions group. Then, for each of these groups, the computer chose randomly and independently for each group either to begin with availability or unavailability of insurance. Finally, for each of these latter case, the computer randomly and independently selected to begin with risk or ambiguity. This way we collected 24 self-insurance decisions and 12 insurance decisions per participant. The treatments of the experiment are summarized in table 4.

Table 4: Different treatments of the experiment.

	Strict liability		Negligence rule	
	Insurance	No insurance	Insurance	No Insurance
Risk	SL-RK-I	SL-RK-NI	NR-RK-I	NR-RK-NI
Ambiguity	SL-AM-I	SL-AM-NI	NR-AM-I	NR-AM-NI

3.2.2. Simulation of risk and ambiguity

For each treatment and each of the three decision periods by treatment, with a probability of 10% in the RK treatment and with a probability $\pi \in \{0\%; 10\%; 20\%\}$ in the AM treatment, an accident would occur and result in a loss for the participant, depending on the treatment and his choices. It was explained to the participants that they exercised an activity that was exposed to a 10% risk (RK) or an *a priori* unknown probability (AM) to generate an accident. They were told that if the accident occurred, the environment would suffer damages and that they would have to pay compensations, resulting in a loss in their wealth.
Risk and ambiguity were simulated with a computer based draw from an urn, which graphical representation was displayed on screen (see figure B.3). The description of the urn was common to both treatments RK and AM: " *A ten different color balls urn is used for the lottery. These balls can be colored in red, black, blue or yellow. The urn contains: 1 red ball; 7 yellow balls; 2 balls whose color is unspecified but which can be both blue or both black, or one black and one blue.*"
In RK treatments, we completed this description followingly: "*A draw will take place. If the red ball is picked, an accident occurs. The accident probability is therefore 10 %.*" In AM treatments, it was not the draw of the red ball which generated accident. The participant was asked to pick between the color blue and the color black, while both the graphical representation of the urn (figure B.3) and the description of the possible urns was displayed on screen (see figure B.4). An accident occurs if a blue ball was drawn and the participant had chosen color blue; or a black ball was drawn and the participant had chosen color black.

3.2.3. Self-insurance and insurance choices

At the beginning of each decision period, participants were endowed with 10,000 Experimental Currency Units (ECU). 10,000 worth 10 euros. When an accident occurred, the participant could lose her entire wealth if she had not invested in self-insurance or insurance. In each period, the participant made her self-insurance and insurance choices. We have designed the parameters of the experiment such that 400 ECU is the level of self-insurance which minimizes the joint cost of precaution and accident (a^s in the theoretical model).
Self-insurance and insurance choices are made by the participant using multiple choices tables (see for instance figure B.5). The consequences of his choices on the level of wealth in the event of an accident or an absence of accident was displayed on screen before the participant's validation. The participants had to choose their level of self-investment in each decision period with the help of a decision table, providing them ten possible different levels from 0 ECU to 1,000 ECU. The more one invested in self-insurance, the less important the damage was, as shown in the figure B.5.
The effect of self-insurance on the environmental damage was identical between the SL and NR treatments. However, the corresponding loss in wealth for the participant differed. In the SL treatment, the individual loss equaled the damages. In the NR treatment, if the participant invested a positive amount equal or superior to 400, the loss in wealth was reduced to zero. If the level of self-insurance was inferior to 400, then the loss equaled the damages. This threshold was labeled as a "critical value" for the participants, and we did not mention the term of "legal standard" - we did not as well mention other terms referring to liability or a legal framework of any kind. Given the values of the parameters in this experiment, 400 is also the value of self-insurance that minimizes the social cost of accident. When insurance was available, the participants could purchase insurance coverage up to the amount of possible loss they could suffer in the event of an accident.
For each decision the subjects had to make, an automatic computer displayed the consequences of their choices on their level of wealth in the event that an accident occurred or not. Consequently, the choices were not submitted to computational issues for the subjects of the experiment. Participants could earn up to 20 euros in this part, which means 10 euros per group of decisions (negligence rule group and strict liability group). At the end of each group, one of decisions made by the participant was randomly selected by the computer. The result of the draw was communicated at the end of each group of decisions. The corresponding earnings were communicated at the end of the experiment.

3.3. Control variables

The third part of the experiment collects socio-demographic data on the participants. We also give a questionnaire aimed at measuring the degree of altruism and attitudes towards the environment. Our measures of altruism is based on the Schwartz theory of basic values (Schwartz, 2012) and especially on the version of the Schwartz survey used in the European Social Survey. This survey allows to distinguish between universalism and benevolence. Benevolence corresponds to the willingness to preserve and enhance the welfare of people with whom one is in frequent personal contact, whereas universalism is about the welfare of all people and nature. We measure attitudes towards the environment by constructing an ecocentric scale (see Milfont and Duckitt, 2010). This scale indicates the degree of concern or regret over environmental damage.

4. Results

The data analysis allows to address two questions. First, we can observe if, in average, the participants provide the level of self-insurance which minimizes the joint cost of precaution and accident. Second, we can measure the variations of demand depending on the treatment and the attitudes towards ambiguity.

4.1. Descriptive statistics

4.1.1. Sample

We conducted the experiment between May and September 2015 at the École Normale Supérieure de Cachan, in the Paris area. Overall, 124 subjects participated in the experiment. Among the participants, 2 are removed from the data analysis because of the inconsistency of their behavior in the first part of the experiment. Indeed, an inconsistent behavior in this part of the experiment prevents from correctly eliciting their attitudes towards risk or ambiguity. Moreover, to test our theoretical predictions, we dropped the risk-loving subjects. Indeed, our behavioral predictions are valid only for risk-neutral and risk-averse individuals. The degree of risk-aversion is determined by the observation of the choice of the subject when playing the multiple price list described in figure B.1. Thus, the final sample contains 72 subjects. As each subject is asked to participate to each treatment with three decision periods, we collected 1,728 self-investment choices and 864 insurance choices. The summary statistics of the sample are displayed in table C.5.
Our sample contains 41.70% of ambiguity-lovers while 58.30% are either ambiguity-averse or ambiguity-neutral. The degree of ambiguity-aversion is determined by the observation of the choice of the subject when playing the multiple price list described in figure B.2.

4.1.2. Average demand for self-insurance

Figure D.6 displays the average demand for self-insurance per iteration with 95% confidence interval for SL-RK-NI and SL-AM-NI. It can be compared with figure D.7, which displays similar information for SL-RK-I and SL-AM-I. Figure D.7 shows that the demand for self-insurance does not vary in average between risk and ambiguity, under the condition of insurance coverage availability. Meanwhile, figure D.6 indicates an average increase in the demand for self-insurance when ambiguity is introduced in absence of insurance opportunities. This first glimpse at the data shows that ambiguity distorts strict liability incentives only in absence of insurance opportunities.
Now, regarding the average demand for self-insurance under negligence rule, we can have a look at figures D.8 and D.9. They both show stability in the average demand for self-insurance regarding the four NR treatments. There is nos significant difference in the average demand for self-insurance between those different treatments. Hence ambiguity does not seem to disturb the incentives provided by the negligence rule.
We can also compare the average demand for self-insurance to our reference level of 400 ECU which minimizes the direct cost of accident and precaution. If insurance is unavailable, under strict liability, the average demand is higher than 400 ECU. This result is significant at a 5% level of confidence, as shown by figure D.6. This corroborates our theoretical prediction. However, the average demand for self-insurance does not match theory for other treatments, as shown by figures D.7, D.8 and D.9. We have to deeply study the distribution of the demand to confirm or infirm this first analysis.

4.1.3. Average demand for insurance

Figure D.10 displays the average insurance demand per iteration for the four insurance treatments. This figure shows that ambiguity does not modify incentives to buy insurance in average. There is no significant difference between the demand under SL-RK-I and SL-AM-I on the one hand, and between NR-RK-I and NR-AM-I on the other hand. However, the graph clearly shows that the demand for insurance is higher under strict liability than under negligence rule.

4.2. Test of the deterrent effect of the liability regimes under risk

Result R1: Non equivalence of the deterrent effect of strict liability and negligence rule when insurance is available. The unilateral accident model predicts equivalent incentives between SL-RK-I and NR-RK-I. Our experimental data do not confirm this theoretical prediction. Our results indicate that negligence rule gives better incentives than strict liability to provide a^s.

Table C.7 shows the number of self-insurance decisions equal to our reference level 400 ECU (a^s in our model). The table reveals that the proportion of decisions equal to 400 ECU is significantly lower under SL-RK-I than under NR-RK-I. Indeed the proportion of decisions equal to 400 ECU is within the 95% confidence interval $[0.643; 0.765]$ for NR-RK-I and $[0.158; 0.268]$ for SL-RK-I.

Result R2: Non equivalence of the deterrent effect of strict liability and negligence rule if insurance is not available. The theoretical prediction is a non equivalence between SL-RK-NI and NR-RK-NI for risk-averters. Our data confirm this prediction.

Table C.7 indicates that the proportion of decisions equal to 400 ECU is within the 95% confidence interval $[0.722; 0.833]$ for NR-RK-NI and $[0.085; 0.175]$ for SL-RK-NI. Therefore, the experimental data indicate that in a risk context without insurance, the negligence rule (NR-RK-NI) leads a majority of subjects to provide the amount of self-insurance a^s (400 ECU), while strict liability (SL-RK-NI) does not.

Moreover, the experimental data show that the demand for self-insurance is higher under strict liability than under negligence. This can be highlighted by the results of the Dunn's test displayed in table C.6. The null hypothesis considered for each pairwise comparison is that the probability of observing a randomly selected value from the first group of comparison that is larger than a randomly selected value from the second group equals one half. If self-insurance choices can be assumed to be continuous, the Dunn's test may be understood as a test for median difference. Table C.6 indicates that we can reject the null hypothesis that the probability of observing a randomly selected value from the SL-RK-NI that is larger than a randomly selected value from NR-RK-NI equals one half. Both for ambiguity-averters and ambiguity-lovers, there is a significant difference in the distribution of the demand of strict liability and negligence rule in this context, with a higher demand under SL-RK-NI than under NR-RK-NI.

Result R3: Substituability between self-insurance and insurance under risk and strict liability. The result of the Dunn's test in table C.6 shows that there is a significant difference in the distribution of the demand for self-insurance between SL-RK-NI and SL-RK-I. Indeed, the z-test statistic for the pairwise comparison of treatments SL-RK-NI and SL-RK-I is 3.216 for the ambiguity-averters and 4.442 for the ambiguity-lovers, both significant at a 1% confidence level. Therefore, the Dunn's test displays a higher demand under SL-RK-NI than under SL-RK-I. Hence, other things being equal, the introduction of liability insurance in a strict liability regime characterized by risk induces a decrease in the demand for self-insurance.

4.3. Test of the deterrence effect of the liability regimes under ambiguity

Result A1: Ambiguity-averse individual' s demand for self-insurance. Table C.6 reports the results of the Dunn's test for the ambiguity-averters. The table shows that there is a significant difference in the distribution of the demand for self-insurance between SL-RK-NI and SL-AM-NI, with a higher demand under SL-AM-NI than under SL-RK-NI. Therefore, under strict liability without insurance, the introduction of ambiguity induces an increase in the ambiguity-averters' demand for self-insurance, compared to a risk context.

Moreover, the Dunn's test reveals that ambiguity does not modify the incentives provided by the negligence rule: there is no significant difference in the distribution of the demand between NR-RK-NI and NR-AM-NI on the one hand, and between NR-RK-I and NR-AM-I on the other hand. However, table C.6 does not confirm an increase of the demand in SL-AM-I compared to SL-RK-I, contrary to our behavioral prediction.

Result A2: Ambiguity-loving individual's demand for self-insurance. Our experimental results do not confirm our theoretical predictions for the ambiguity-loving subjects. Table C.6 displays the results of the Dunn's test for the ambiguity-lovers. Contrary to our theoretical predictions, the table indicates that there is no decrease in the demand for self-insurance of the ambiguity-lovers when ambiguity is introduced in a strict liability regime.

On the one hand the Dunn's test indicates an increase in the demand when ambiguity is introduced in the strict liability regime without insurance. Therefore the ambiguity-lovers adopt a behavior similar to the ambiguity-averters when we compare SL-RK-NI and SL-AM-NI. Concerning the ambiguity-lovers, this experimental result reveals an inconsistency between the attitudes towards ambiguity and the demand for self-insurance under ambiguity in a setting without insurance. On the other hand, there is no significant difference in the distributions of the demand when the treatments SL-RK-I and SL-AM-I are compared. Thus, the introduction of ambiguity in a strict liability regime with insurance does not modify the demand for self-insurance of the ambiguity-lovers.

Besides, there is no cleat theoretical prediction on the demand under the negligence rule. Table C.6 indicates that the ambiguity-lovers do not modify their demand for self-insurance when ambiguity is introduced in a negligence based liability regime, similarly to the ambiguity-averters.

Result A3: Substituability between self-insurance and insurance under ambiguity and strict liability. Table C.6 provides evidence for substituability between insurance and self-insurance under ambiguity for the ambiguity-averters when strict liability is implemented. Indeed, the table shows that there is a significant difference in the demand for self-insurance between SL-AM-NI and SL-AM-I, with a higher demand under SL-AM-NI compared to SL-AM-I. Hence, under ambiguity, the introduction of insurance in a strict liability regime induces a decrease in the demand for self-insurance of the ambiguity-averters. Moreover, the experiment provides evidence for substituability between self-insurance and insurance for the ambiguity-lovers under ambiguity. The results of the Dunn's test displayed in table C.6 show a z-test statistic equal to 6.502 and significant at a 1% confidence level for the pairwise comparison of the treatments SL-AM-NI and SL-AM-I. Hence, there is a statistically significant difference in the distribution of the self-insurance demand of ambiguity-lovers between SL-AM-NI and SL-AM-I with a higher demand in the absence of insurance (SL-AM-NI).

4.4. Experimental results on the demand for insurance

Result R4: Differences in the demand for insurance coverage between strict liability and negligence rule under risk. The experimental data confirm our theoretical prediction. We do find a higher demand for liability insurance under strict liability than under the negligence rule in risk context.

First, table C.9 provides summary statistics on the propensity to buy insurance coverage for ambiguity-averters and ambiguity-lovers. This table shows than under risk, both types of subjects have a propensity to buy insurance significantly superior to 50% under SL-RK-I and significantly lower than 50% under NR-RK-I. Therefore the propensity to buy insurance coverage is higher under strict liability than under negligence rule in a risk context.

Similarly, the level of the demand for insurance is shown to be higher under SL-RK-I than under NR-RK-I by the results of Dunn's test displayed in table C.8. Both ambiguity-averters and ambiguity-lovers have a distribution of the demand for insurance which is different between SL-RK-I and NR-RK-I, with a higher demand under SL-RK-I. Indeed, the z-test statistic is positive and significant at a 1% level for this pairwise comparison for both types of subjects.

Result R5: Demand for insurance coverage under negligence rule. Our data confirm our theoretical prediction. Indeed, as indicated previously, table C.9 provides summary statistics on the propensity to buy insurance coverage for ambiguity-averters and ambiguity-lovers. This table shows that both ambiguity-averters and ambiguity-lovers have a propensity to buy insurance significantly lower than 50% under NR-RK-I. Hence, a majority of subjects does not buy insurance coverage under negligence in a risk context.

Result A4: Ambiguity-averse individual's demand for insurance. The data partially confirm our theoretical prediction. First, our experimental data do not confirm the predicted increase in the demand for insurance when ambiguity is introduced in a strict liability regime. In other words, there is no significant difference in the insurance demand of ambiguity-averters when the treatments SL-RK-I and SL-AM-I are compared. This is shown in the Dunn's test result displayed in table C.8: the z-test statistic of -1.09 for the pairwise comparison of SL-RK-I and SL-AM-I is not significant at a 10% confidence level.
Second, the experimental results confirm that the demand for insurance is null under negligence rule in an ambiguity context for ambiguity-averters. Indeed, table C.9 shows that the propensity to buy insurance is significantly inferior to 50% for the ambiguity-averters (NR-AM-I).

Result A5: Ambiguity-loving individual's demand for insurance. The experimental data do not confirm our theoretical prediction. There is no decrease in the insurance demand of ambiguity averters when ambiguity is introduced in a strict liability regime. Indeed, the Dunn's test result displayed in table C.8, for the comparison of SL-RK-I and SL-AM-I shows a z-test statistic of -0.228, which is not significant at a 10% confidence level. Hence there is no statistically significant difference in the distribution of the demand between these two treatments.
Despite the lack of theoretical results for the insurance demand of ambiguity-lovers under ambiguity and negligence rule, the experimental data show that similarly to the ambiguity-averters, the ambiguity-lovers' demand for insurance is null under negligence rule in an ambiguity context (NR-AM-I). Indeed, table C.9 shows that the propensity to buy insurance is significantly inferior to 50% for the ambiguity-averters.

4.5. Robustness checks

4.5.1. Self-insurance decisions

To get another perspective on the effects of liability rules, degree of ambiguity and availability of insurance on precaution and insurance behavior, we run a random-effects ordered logistic regression on our data. The dependent variable is either the demand for self-insurance or the demand for insurance. The independent variables in this regression are the treatment variables (SL,I,AM), other characteristics of the context of decision (number of accident, period of decision), the socio-demographic characteristics of the individual and the attitudes towards ambiguity. Tables E.10 and E.11 provide the marginal effects at means of these regressions.
Regarding the treatment variables (SL,I,AM), table E.10 shows that other things being equal, strict liability induce an increase in the demand for self-insurance. This result is robust to the introduction of context variables and individual controls. Indeed, the marginal effect at means of SL is positive and significant at a 1% level of confidence. This result corroborates our finding that strict liability and negligence rule are not equivalent in their deterrent effects. Table E.10 also indicates that ambiguity increases the demand for self-insurance, other things being equal. The marginal effect at means of AM is positive and significant at a 1% level of confidence. Besides, this table confirms the substitution property between insurance and self-insurance. Indeed, we observe a negative marginal effect at means, significant at a 1% level of confidence, in our three different specifications.
Regarding the variables describing the decision context, we find that the cumulated number of accidents and the decision period (value between 1 and 24) both have no significant effect on the self-insurance decision.
Now, concerning the individual control variables, we do not find a significant effect of attitudes towards ambiguity on self-insurance decision. This result is easily explained by the fact that ambiguity-lovers and averters do not differ in their self-insurance choices both under risk and ambiguity contexts, as explained in subsection 4.3.

4.5.2. Insurance decisions

Table E.11 corroborates our findings described in subsection 4.4. We find that strict liability induces an increase in the demand for insurance, other things being equal. Indeed, for our three different specifications,

we have a positive marginal effect at means, significant at a 1% level of confidence.
The degree of ambiguity does not affect the demand for insurance, other things being equal. This is not surprising given what we observe on figure D.10. Given one liability rule, introducing ambiguity does not lead to a significantly different level of insurance demand.
Attitudes towards ambiguity does not have a significant effect on the demand for insurance. This result is in line with the findings described in subsection 4.4.

5. Concluding remarks

The purpose of this article is to compare negligence rule and strict liability under one-sided ambiguity. Particularly, the paper focus on the deterrent effect of those liability regimes under one-sided ambiguity compared to contexts characterized by the presence of precisely known risks on the one hand; on the other hand, the paper also inquires into the effect of the availability of insurance. Under risk, the model predicts that, if insurance is available, strict liability and negligence rule are equivalent in their deterrence effect. Our experimental data cast into doubt this standard result of the Economics of tort law. Indeed, the likelihood of observing the level of self-insurance which minimizes the joint cost of precaution and accident is higher under the negligence rule than under the strict liability regime.

Under ambiguity, in line with our theoretical predictions, we find that the strict liability regime induces an increase in the demand for self-insurance by ambiguity-averse subjects, but only if insurance is not available. If insurance is available, contrary to our predictions, the demand of ambiguity-averse subjects under strict liability is not modified by the introduction of ambiguity. Moreover, we find that the negligence rule induces a majority of ambiguity-averters to provide level of self-insurance which minimizes the joint cost of precaution and accident, both under risk and ambiguity, and both in presence or absence of insurance opportunities. Thus, concerning ambiguity-averters, whether there is precision or imprecision of the knowledge of the accident risks, the negligence rule conveys better incentives to provide self-insurance. Besides, the experimental data show that the ambiguity-lovers have a behavior similar to the ambiguity-averters under ambiguity, regarding their demand for self-insurance and insurance, both under strict liability and negligence rule. Therefore, there is an inconsistency between the ambiguity attitudes of the ambiguity-lovers and their observed behavior in a civil liability setting.

Our experimental observations do not completely fit our theoretical predictions and contradict a major result of the standard analysis of civil liability under the assumption of perfect knowledge of the probability distribution. According to our experimental sample, strict liability and negligence rule are not equivalent in their deterrence effect, both under risk and one-sided ambiguity. Hence, our experiment contributes to the L&E literature on the analysis of tort law. This paper plea in favour of the negligence rule, since it provides better incentives to minimize the expected joint cost of precaution and accident. Nevertheless, the tort law is also designed to compensate and remedy potential damages. Strict liability, even if it does not provide optimal incentives to provide self-insurance, guarantees the compensation of potentially catastrophic accidents. The trade-off between deterrence and compensation is a matter of public policy.

Further experimental research needs to be done on ambiguity and liability regimes. Especially, this paper does not include the possibility for the insurer to charge a premium above the actuarial price when there is ambiguity. Moreover, our operational definition of the social cost only includes the cost of preventing and remedying damages. It can be argued that the social cost may include the cost of risk allocation via the purchase of insurance coverage or the psychological costs of ambiguity. Despite these drawbacks, this paper sets a framework for the experimental study of tort rules under ambiguity, which can be improved to deepen our understanding of individual behavior depending on his decision context.

Acknowledgements

This work was supported by a public grant overseen by the French National Research Agency (ANR) as part of the "Investissements d'Avenir" program, through the "iCODE Institute project" funded by the IDEX Paris-Saclay, ANR-11-IDEX-0003-02.

References

[1] Mohammed Abdellaoui, Aurelien Baillon, Laetitia Placido, and Peter Wakker. The rich domain of uncertainty: Source functions and their experimental implementation. *American Economic Review*, 101(2):695–723, 2011.

[2] David Alary, Christian Gollier, and Nicolas Treich. The effect of ambiguity aversion on insurance and self-protection. *The Economic Journal*, 123(573):1188–1202, 2013.

[3] Vera Angelova, Olivier Armantier, Giuseppe Attanasi, and Yolande Hiriart. Relative performance of liability rules: experimental evidence. *Theory and Decision*, 77(4):531–556, December 2014.

[4] John Prather Brown. Toward an economic theory of liability. *The Journal of Legal Studies*, 2(2):pp. 323–349, 1973.

[5] Laure Cabantous and Denis Hilton. De l'aversion à l'ambiguïté aux attitudes face à l'ambiguïté: Les apports d'une perspective psychologique en économie. *Revue économique*, 57(2):259, 2006.

[6] Colin Camerer and Martin Weber. Recent developments in modeling preferences: Uncertainty and ambiguity. *Journal of Risk and Uncertainty*, 5(4):325 – 370, 1992.

[7] J. Carson, K. McCullough, and D. Poose. Deciding whether to invest in mitigation measures: Evidence from florida. *The Journal of Risk and Insurance*, 80(2):309–327, 2013.

[8] Sujoy Chakravarty and Jaideep Roy. Recursive expected utility and the separation of attitudes towards risk and ambiguity: an experimental study. *Theory and Decision*, 66(3):199–228, 2009.

[9] Surajeet Chakravarty and David Kelsey. Ambiguity and Accident Law1. 2011.

[10] C. Courbage. Self-insurance, self-protection and market insurance within the dual theory of choice. *The Geneva Papers on Risk and Insurance*, 26(1):43–56, 2001.

[11] Nicholas Dopuch, Daniel E. Ingberman, and Ronald R. King. An experimental investigation of multi-defendant bargaining in 'joint and several' and proportionate liability regimes. *Journal of Accounting and Economics*, 23(2):189 – 221, 1997.

[12] Nicholas Dopuch and Ronald R. King. Negligence versus strict liability regimes in auditing: An experimental investigation. *Accounting Review*, 67(1):97 – 120, 1992.

[13] Isaac Ehrlich and Gary S. Becker. Market insurance, self-insurance, and self-protection. *Journal of political Economy*, 80(4):623–648, 1972.

[14] Daniel Ellsberg. Risk, Ambiguity, and the Savage Axioms. *The Quarterly Journal of Economics*, 75(4):643, November 1961.

[15] Luigi A. Franzoni. Liability Law and Uncertainty Spreading. *Available at SSRN 2432861*, 2014.

[16] Deborah Frisch and Jonathan Baron. Ambiguity and rationality. *Journal of Behavioral Decision Making*, 1(3):149 – 157, 1988.

[17] Scott E. Harrington and Patricia M. Danzon. The economics of liability insurance. In Georges Dionne, editor, *Handbook of Insurance*, number 22 in Huebner International Series on Risk, Insurance, and Economic Security, pages 277–313. Springer Netherlands, 2000.

[18] Glenn W. Harrison, Eric Johnson, Melayne M. McInnes, and E. Elisabet Rutström. Risk aversion and incentive effects: Comment. *American Economic Review*, 95(3):897 – 901, 2005.

[19] Charles A Holt and Susan K Laury. Risk aversion and incentive effects. *American economic review*, 92(5):1644–1655, 2002.

[20] Robert H. Jerry and Douglas R. Richmond. *Understanding Insurance Law*. LexisNexis, 2012.

[21] Robert E. Keeton. Basic text on insurance law. 1971.

[22] W. Page Keeton, Dan B. Dobbs, Robert E. Keeton, and David G. Owen. *Prosser and Keeton on the Law of Torts*. St Paul, Minn: West Publishing Co, 1984.

[23] Ronald R. King and Rachel Schwartz. Legal penalties and audit quality: An experimental investigation. *Contemporary Accounting Research*, 16(4):685 – 710, 1999.

[24] Ronald R. King and Rachel Schwartz. An experimental investigation of auditors' liability: Implications for social welfare and exploration of deviations from theoretical predictions. *Accounting Review*, 75(4):429, 2000.

[25] Peter Klibanoff, Massimo Marinacci, and Sujoy Mukerji. A smooth model of decision making under ambiguity. *Econometrica*, 73(6):1849–1892, 2005.

[26] K. Konrad and S. Skaperdas. Self-insurance and self-protection: A non-expected utility analysis. *The Geneva Papers on Risk and Insurance Theory*, 18:131–146, 1993.

[27] Lewis Kornhauser and Andrew Schotter. An experimental study of single-actor accidents. *The Journal of Legal Studies*, 19(1):pp. 203–233, 1990.

[28] N. Lampach and S. Spaeter. The efficiency of (strict) liability revised in risk and ambiguity. BETA Working Paper 2016-29, 2016.

[29] Nicolas Lampach, K. Boun My, and S. Spaeter. Risk, ambiguity and efficient liability rules. an experiment. BETA Working Paper 2016-30, 2016.

[30] Mary Coate McNeely. Illegality as a factor in liability insurance. *Columbia Law Review*, 41(1):26–60, January 1941.

[31] Taciano L. Milfont and John Duckitt. The environmental attitudes inventory: A valid and reliable measure to assess the structure of environmental attitudes. *Journal of Environmental Psychology*, 30(1):80 – 94, 2010.

[32] F. Pannequin, A. Corcos, and C. Montmarquette. Insurance and self-insurance: Beyond substitutability, the mental accounting of losses? *ARIA 2014 Annual Meeting, Seattle.*

[33] Michael Rothschild and Joseph E Stiglitz. Increasing risk: I. a definition. *Journal of Economic theory*, 2(3):225–243, 1970.

[34] Leonard J. Savage. The foundations of statistics, 1954.

[35] Steven Shavell. Strict liability versus negligence. *The Journal of Legal Studies*, 9(1):pp. 1–25, 1980.

[36] Steven Shavell. On the social function and the regulation of liability insurance. *The Geneva Papers on Risk and Insurance. Issues and Practice*, 25(2):166–179, April 2000.
[37] Steven Shavell. Chapter 2 Liability for Accidents. In *Handbook of Law and Economics*, volume 1, pages 139–182. Elsevier, 2007.
[38] Arthur Snow. Ambiguity aversion and the propensities for self-insurance and self-protection. *Journal of Risk and Uncertainty*, 42(1):27–43, December 2010.
[39] Joshua C. Teitelbaum. A unilateral accident model under ambiguity. *The Journal of Legal Studies*, 36(2):431–477, 2007.
[40] André Tunc. *Fault a common name for different misdeeds.* [S.l.], 1975. Repr. from Tulane law Review. Vol. 49, No 2, january 1975, pp. 279-294.

AppendixA. Theoretical analysis

AppendixA.1. Demand for self-insurance and liability insurance under risk

AppendixA.1.1. Strict liability

If an accident occurs, the agent is held liable whatever the level of safety measures that have been taken. Therefore $h(-x(a)+I) = -x(a)+I$. The expected utility can be written $EU(a,I) = (1-q)U(W_0 - a - pI) + qU(W_0 - a - pI - x(a) + I)$. The optimal choice is described by the first order conditions[6]

$$\frac{\partial EU}{\partial a} = -(1-q)U'(W_N) + q(-1-x'(a))U'(W_A) = 0$$

$$\frac{\partial EU}{\partial I} = (1-q)(-p)U'(W_N) + q(1-p)U'(W_A) = 0$$

Therefore, at the optimum of the agent, we have the equality of the marginal benefit and cost of insurance on the one hand and the equality of the marginal benefit and cost of self-insurance on the other hand. Indeed, the first-order conditions can be rewritten[7]

$$-qx'(a)U'(W_A) = EU'$$

$$qU'(W_A) = pEU'$$

The optimal level of self-insurance is characterized by the following equation

$$\frac{1}{q} = -x'(a^*)$$

Indeed, the first order condition $\frac{\partial EU}{\partial a} = 0$ and $U''(W) = 0$ imply $\frac{1}{q} = -x'(a^*)$. Hence, the risk neutral agent provides the socially optimal level a^s, with $\frac{1}{q} = -x'(a^s)$.

Moreover, the unavailability of liability insurance would have no effect on the demand for self-insurance of the risk-neutral agent as $\frac{\partial^2 EU}{\partial a \partial I} = 0$.

Concerning the demand for insurance, for $p = q$, we have $\forall I$, $\frac{\partial EU}{\partial I} = 0$. Consequently, the agent is indifferent to her level of insurance coverage, and $I \in [0; x(a)]$.

[6]The second order conditions are

$$\frac{\partial^2 EU}{\partial a^2} = (1-q)U''(W_N) + (-1-x'(a))^2 qU''(W_A) < 0$$

$$\frac{\partial^2 EU}{\partial I^2} = p^2(1-q)U''(W_N) + (1-p)^2 qU''(W_A) < 0$$

[7]with $EU' = (1-q)U'(W_N) + qU'(W_A)$

Risk-averse agent. The optimal level of self-insurance a^* of the risk-averse agent equalizes the marginal returns of insurance and self-insurance. Indeed, $\frac{\partial EU}{\partial a} = 0$ and $\frac{\partial EU}{\partial I} = 0$ induce an interior solution such that

$$\frac{1}{p} = -x'(a^*)$$

with $\frac{-x'(a^*)}{1}$ expressing the marginal decrease in harm generated by prevention at the optimal level of self-insurance a^* when buying an additional unit of self-insurance on the one hand, and $\frac{1}{p}$ expressing the increase in insurance coverage when buying an additional unit of insurance at price p. For an actuarial price of insurance $p = q$, the risk-averse agent provides the socially optimal level a^s, with $\frac{1}{q} = -x'(a^s)$.

Concerning the demand for insurance coverage, the risk-averse agent has a full coverage for an actuarial price of insurance, with $I^* = x(a^*)$.

Indeed, the first order condition on insurance demand states $(1-q)(-p)U'(W_N) + q(1-p)U'(W_A) = 0$. Thus, for $p = q$, this implies $I = x(a)$.

Insurance and self-insurance are substitutes. Indeed, the marginal value of self-insurance is decreasing in I, indeed

$$\frac{\partial^2 EU}{\partial a \partial I} = p(1-q)U''(W_N) + (-1 - x'(a))(1-p)qU''(W_A) < 0$$

An increase in the insurance coverage I will decrease the demand for self-insurance a. Consequently, unavailability of liability-insurance would increase the level of care exercised by the risk-averse agent under the strict liability rule.

AppendixA.1.2. Negligence rule

Under the negligence rule, when an accident occurs, the agent is held liable if the investment in prevention a is below a given legal standard $\bar{a}$. Therefore the decrease in wealth in case of an accident is $h(-x(a)+I) = -x(a) + I$ if $a < \bar{a}$ and $h(-x(a) + I) = 0$ if $a \geqslant \bar{a}$. Thus, the expected utility can be written

$$EU(a, I) = \begin{cases} U(W_0 - a - pI) & \text{if } a \geqslant \bar{a} \\ (1-q)U(W_0 - a - pI) + qU(W_0 - a - pI - x(a) + I) & \text{if } a < \bar{a} \end{cases}$$

The purchase of liability coverage under the negligence rule could be problematic. Indeed, the possibility for the potential injurer to get an indemnity if held liable could induce an under-provision of care (Tunc, 1974). The standard model of civil liability shows that under reasonable hypothesis, potential injurers do not purchase insurance coverage under the negligence rule. Therefore, the opportunity to purchase liability coverage does not affect the deterrence function of this liability regime, and it is not problematic to assume the existence of insurance under this liability regime in a risky context.

For the record, under the negligence rule the agent is held liable if the investment in prevention a is below a given legal standard $\bar{a}$. Therefore, the expected utility can be written

$$EU(a, I) = \begin{cases} U(W_0 - a - pI) & \text{if } a \geqslant \bar{a} \\ (1-q)U(W_0 - a - pI) + qU(W_0 - a - pI - x(a) + I) & \text{if } a < \bar{a} \end{cases}$$

Risk neutral agent. A risk-neutral agent adopts a level of self-insurance $\bar{a}$ and has a null insurance coverage $I^* = 0$. Indeed, when maximizing the expression $(1-q)U(W_0 - a - pI) + qU(W_0 - a - pI - x(a) + I)$, we obtain $\forall I$, $\frac{1}{q} = -x'(\bar{a})$, which corresponds to a level of self-insurance $\bar{a}$. Once again, when maximizing $U(W_0 - a - pI)$, the utility is maximum for $I = 0$.

Risk averse agent. For $p = q$, the risk averse agent chooses respectively $\bar{a}$ and $I = 0$ as levels of self-insurance and insurance under the negligence rule.

Indeed, when maximizing the expression $(1-q)U(W_0 - a - pI) + qU(W_0 - a - pI - x(a) + I)$, for $p = q$, the agent is willing to invest in a level a^* *s.t.* $\frac{1}{p} = -x'(a^*)$. Now, the legal standard is $\bar{a}$ *s.t.*$\frac{1}{q} = -x'(\bar{a})$. It is straightforward to see that when maximizing $U(W_0 - a - pI)$, the agent is also willing to invest in a level of self-insurance $\bar{a}$. Therefore, the agent's expected utility is maximum at $\bar{a}$.

When maximizing $U(W_0 - a - pI)$, the level of expected utility for an amount of self insurance $a \geqslant \bar{a}$, the utility is maximum for $I = 0$.

AppendixA.2. Strict liability under ambiguity

AppendixA.2.1. Demand for self-insurance

Ambiguity-neutral agent. Given a strict liability rule, the ambiguity-neutral agent invests in the same amount of self-insurance a and insurance I under risk and ambiguity.

Ambiguity-averse demand for self-insurance and availability of insurance. The individual chooses a and I to maximize $E_F[\phi(EU(a,I;\pi))]$ with

$$EU(a,I;\pi) = (1-\pi)U(W_0 - a - pI) + \pi U(W_0 - a - pI - x(a) + I)$$

Moreover, in the experimental setting the insurer is assumed to be risk-and-ambiguity neutral and to charge actuarial prices, hence $p = E_F(\pi) = q$.

Under this condition, the first derivative of the EU respective to a is

$$\frac{\partial EU}{\partial a} = (1-\pi)(-1)U'(W_0 - a - qI) + \pi(-1 - x'(a)U'(W_0 - a - qI - x(a) + I)$$

The second derivative of the EU respective to a and π is

$$\frac{\partial^2 EU}{\partial a \partial \pi} = U'(W_0 - a - qI) + (-1 - x'(a))U'(W_0 - a - qI - x(a) + I)$$

We can see that $\forall \pi$, $\frac{\partial^2 EU}{\partial a \partial \pi}|_{(a^*,I^*)} > 0$. As a reminder, the notation (a^*, I^*) refers to the optimal decision of the agent under risk. Under the assumption $p = q$, we have for the risk-averse agent

$$(a^*, I^*)\, s.t. \begin{cases} \dfrac{1}{q} = -x'(a^*) \\ I^* = x(a^*) \end{cases}$$

For the record, we have for the risk-neutral agent

$$(a^*, I^*)\, s.t. \begin{cases} \dfrac{1}{q} = -x'(a^*) \\ I^* \in [0; x(a^*)] \end{cases}$$

As $\forall \pi$, $\frac{\partial^2 EU}{\partial a \partial \pi}|_{(a^*,I^*)} > 0$, an increase in a at point (a^*, I^*) results in a mean-preserving contraction in the distribution of the EU. This result holds both for the risk averse and the risk neutral agent. Therefore, $E_F[\phi\,(EU(a,I;\pi)))]$ increases in a at point (a^*, I^*) both for the risk averse and risk neutral agents. The agent is willing to increase her demand in self-insurance under ambiguity, compared to the risk context.

Ambiguity-loving demand for self-insurance and availability of insurance. As previously, $\forall \pi$, $\frac{\partial^2 EU}{\partial a \partial \pi}|_{(a^*,I^*)} > 0$, an increase in a at point (a^*, I^*) results in a mean-preserving contraction in the distribution of the EU. This result holds both for the risk averse and the risk neutral agent. Therefore, $E_F[\phi\,(EU(a,I;\pi)))]$ decreases in a at point (a^*, I^*) both for the risk averse and risk neutral agents. The agent is willing to decrease her demand in self-insurance under ambiguity, compared to the risk context.

Ambiguity-averse demand for self-insurance and unavailability of insurance . When the insurance is unavailable, the agent chooses a to maximize $E_F[\phi(EU(a;\pi))]$ with

$$EU(a;\pi) = (1-\pi)U(W_0 - a) + \pi U(W_0 - a - x(a))$$

The first derivative of the EU respective to a is

$$\frac{\partial EU}{\partial a} = (1-\pi)(-1)U'(W_0 - a) + \pi(-1 - x'(a)U'(W_0 - a - x(a))$$

The second derivative of the EU respective to a and π is

$$\frac{\partial^2 EU}{\partial a \partial \pi} = U'(W_0 - a) + (-1 - x'(a))U'(W_0 - a - x(a))$$

We can see that $\forall \pi$, $\frac{\partial^2 EU}{\partial a \partial \pi}|_{(a^*)} > 0$. Under this condition, $E_F[\phi(EU(a;\pi)))]$ increases in a at point (a^*) both for the risk averse and risk neutral agents. The agent is willing to increase her demand in self-insurance under ambiguity, compared to the risk context.

Ambiguity-loving demand for self-insurance and unavailability of insurance. As $\forall \pi$, $\frac{\partial^2 EU}{\partial a \partial \pi}|_{(a^*)} > 0$, $E_F[\phi(EU(a;\pi)))]$ increases in a at point (a^*) both for the risk averse and risk neutral agents. The agent is willing to decrease her demand in self-insurance under ambiguity, compared to the risk context.

AppendixA.2.2. Demand for liability insurance

Ambiguity-neutral agent. The same results than under risk hold.

Ambiguity-averse agent. Under the assumption of a risk-and-ambiguity neutral insurer who charges an actuarial price of insurance $p = q$, we have

$$\frac{\partial^2 EU}{\partial I \partial \pi} = qU'(W_N) + (1 - q)U'(W_A) > 0$$

We know that under this condition, for $\pi = q$ the mean EU is unchanged and $\frac{\partial EU}{\partial I} = 0$. For high values of the EU ($\pi < q$), an increase in I evaluated at point I^* decreases the EU. For low values of the EU ($\pi > q$), an increase in I evaluated at point I^* increases the EU. Thus, we have mean-preserving contraction in the distribution of the EU. Consequently, the marginal value of insurance under ambiguity is

$$E_F[\phi'(EU(a, I; \pi))\, EU'_I(a, I; \pi)] > 0$$

The agent is willing to increase her demand for insurance coverage under ambiguity. This result holds both for the risk averse and the risk neutral agent.

Ambiguity-loving agent. As previously shown, an increase in I evaluated at point I^* results in a mean-preserving contraction in the distribution of the EU. The agent is willing to decrease her demand for insurance coverage under ambiguity. This result holds both for the risk averse and the risk neutral agent.

AppendixA.3. Negligence rule under ambiguity

Let $\bar{a}$ be the legal standard such that $-x'(\bar{a}) = \frac{1}{E_F[\pi]} = \frac{1}{q}$. We assume that the legal standard under ambiguity is set in order to minimize the expected value of the social cost given the second-order probability $F(\pi)$ and under the assumption that the social planner has unbiased beliefs $E_F[\pi] = q$. Nevertheless, it can be argued that the social planner or the judge has biased beliefs or ambiguity aversion, which would modify the setting of the legal standard. However, an identical $\bar{a}$ under risk and ambiguity allows to analyze the behavior of the potential injurer ceteris paribus.

Ambiguity neutral agent. Given the negligence rule, the ambiguity-neutral agent invests in the same amount of self-insurance a and insurance I under risk and ambiguity.

Ambiguity averse agent and availability of insurance. For any price of insurance, a risk-neutral agent invests in a amount of self-insurance $\bar{a}$ and a null insurance coverage $I = 0$ if they are ambiguity averse.

For an ambiguity averse agent, the expected utility evaluated under ambiguity is

$$\begin{cases} U(W_0 - a - pI) & \text{if } a \geqslant \bar{a} \\ E_F[\phi(EU(a, I; \pi))] & \text{if } a < \bar{a} \end{cases}$$

And we have

$$\frac{\partial^2 EU}{\partial a \partial \pi} = U'(W_0 - a - qI) + (-1 - x'(a))U'(W_0 - a - qI - x(a) + I) > 0$$

Therefore, when maximizing $E_F[\phi(EU(a, I; \pi))]$, the ambiguity averse agent is willing to invest in a level of self-insurance superior to a^* with $\frac{1}{q} = -x'(a^*) = -x'(\bar{a})$.[8] Thus, the utility is at the highest for a level of self-insurance $\bar{a}$ and a null insurance coverage. This result holds both for risk averse and risk neutral agent.

Ambiguity-loving agent and availability of insurance. When maximizing $E_F[\phi(EU(a, I; \pi))]$, the ambiguity-loving agent is willing to invest in a level of self-insurance lower than $a^* = \bar{a}$. Therefore, the demand for self-insurance is undetermined for the ambiguity-loving agent. Similarly, we cannot conclude on the demand for liability insurance.

Ambiguity averse agent and unavailability of insurance. For an ambiguity averse agent, the expected utility evaluated under ambiguity is

$$\begin{cases} U(W_0 - a) & \text{if } a \geqslant \bar{a} \\ E_F[\phi(EU(a; \pi))] & \text{if } a < \bar{a} \end{cases}$$

We have

$$\frac{\partial^2 EU}{\partial a \partial \pi} = U'(W_0 - a) + (-1 - x'(a))U'(W_0 - a - x(a)) > 0$$

Hence, it is straightforward to see that the agent is willing to invest in an amount $\bar{a}$.

Ambiguity-loving agent and unavailability of insurance. When maximizing $E_F[\phi(EU(a; \pi))]$, the ambiguity-loving agent is willing to invest in a level of self-insurance lower than $a^* = \bar{a}$. Therefore, the demand for self-insurance is undetermined for the ambiguity-loving agent.

AppendixB. Experimental protocol

[8] See Appendix AppendixA.2.1.

Figure B.1: Multiple price list procedure *à la* Holt and Laury (2002; 2005)

Question	Option A				Option B				Choice	
	Proba A1	Loss A1	Proba A2	Loss A2	Proba B1	Loss B1	Proba B2	Loss B2	Option A	Option B
1	50%	-3 €	50%	-7 €	0%	-0 €	100%	-10 €		
2	50%	-3 €	50%	-7 €	10%	-0 €	90%	-10 €		
3	50%	-3 €	50%	-7 €	20%	-0 €	80%	-10 €		
4	50%	-3 €	50%	-7 €	30%	-0 €	70%	-10 €		
5	50%	-3 €	50%	-7 €	40%	-0 €	60%	-10 €		
6	50%	-3 €	50%	-7 €	50%	-0 €	50%	-10 €		
7	50%	-3 €	50%	-7 €	60%	-0 €	40%	-10 €		
8	50%	-3 €	50%	-7 €	70%	-0 €	30%	-10 €		
9	50%	-3 €	50%	-7 €	80%	-0 €	20%	-10 €		
10	50%	-3 €	50%	-7 €	90%	-0 €	10%	-10 €		
11	50%	-3 €	50%	-7 €	100%	-0 €	0%	-10 €		

Figure B.2: Multiple price list procedure *à la* Chakravarty and Roy (2009)

Question	Option A				Option B Either loose €0 with 0% and €5 with 100%, Either loose €0 with 100% and €5 with 0%				Choice	
	Proba A1	Loss A1	Proba A2	Loss A2	Proba B1	Loss B1	Proba B2	Loss B2	Option A	Option B
1	50%	-0 €	50%	-0,50 €	?%	-0 €	?%	-5 €		
2	50%	-0 €	50%	-1 €	?%	-0 €	?%	-5 €		
3	50%	-0 €	50%	-2 €	?%	-0 €	?%	-5 €		
4	50%	-0 €	50%	-3 €	?%	-0 €	?%	-5 €		
5	50%	-0 €	50%	-4 €	?%	-0 €	?%	-5 €		
6	50%	-0 €	50%	-5 €	?%	-0 €	?%	-5 €		
7	50%	-0 €	50%	-6 €	?%	-0 €	?%	-5 €		
8	50%	-0 €	50%	-7 €	?%	-0 €	?%	-5 €		
9	50%	-0 €	50%	-8 €	?%	-0 €	?%	-5 €		
10	50%	-0 €	50%	-9 €	?%	-0 €	?%	-5 €		
11	50%	-0 €	50%	-10 €	?%	-0 €	?%	-5 €		

Figure B.3: Urn containing 10 balls with 7 yellow balls, 1 red ball and 2 unknown balls

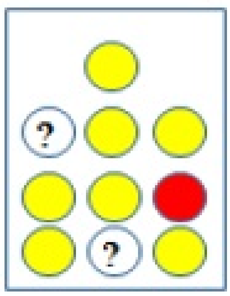


Figure B.4: Description of the different possible urns for ambiguity treatments

Possible urns	Urn A	Urn B	Urn C
Composition	1 Red	1 Red	1 Red
	7 Yellow	7 Yellow	7 Yellow
	2 Blue	1 Blue and 1 Black	2 Red
Probability of accident if choice Blue	20%	10%	0%
Probability of accident if choice Black	0%	10%	20%

Color choice	Blue	Dark

Figure B.5: Self-insurance and insurance choices in a strict liability treatment

Investment «A»	Losses if accident	Protected amount of wealth	Additional protected amount of wealth for 1 ECU of prevention	Decision
0	10000	0	-	
100	8000	2000	20	
200	6400	3600	16	
300	5200	4800	12	
400	4200	5800	10	
500	3400	6600	8	
600	2800	7200	6	
700	2400	7600	4	
800	2100	7900	3	
900	1900	8100	2	
1000	1800	8200	1	

Choice	Premium: P*I	Indemnity: I	Additional Indemnity per ECU of premium	Insurance choice
0	0	0	-	
1	100	1000	10	
2	200	2000	10	
3	300	3000	10	
4	400	4000	10	
5	500	5000	10	
6	600	6000	10	
7	700	7000	10	
8	800	8000	10	
9	900	9000	10	
10	1000	10000	10	

AppendixC. Descriptive statistics

Table C.5: Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Female	72	0.375	0.488	0	1
Age	72	22.167	4.553	18	56
Ambiguity-lovers	72	0.417	0.496	0	1
Universalism	72	0	0.69	-2.32	0.772
Benevolence	72	0	0.801	-2.003	0.843
Ecocentrism	72	0	0.822	-2.234	1.115
Payoff	72	26.101	3.424	12.6	29.8
Field of study					
Econ./Management	47	65.28			
IT/Maths/Engineer.	15	20.83			
Natural sciences	4	5.56			
Other	6	8.33			

Table C.6: Dunn's test for the self-insurance demand

Ambiguity-averters Col Mean- Row Mean	SL-RK-NI	SL-AM-NI	SL-RK-I	SL-AM-I	NR-RK-NI	NR-AM-NI	NR-RK-I
SL-AM-NI	-3.869***						
SL-RK-I	3.216***	7.085***					
SL-AM-I	2.331***	6.2***	-0.885				
NR-RK-NI	4.217***	8.085***	1.000	1.885**			
NR-AM-NI	4.229***	8.098***	1.013	1.898**	0.013		
NR-RK-I	5.232***	9.101***	2.016**	2.901***	1.016	1.003	
NR-AM-I	5.285***	9.154***	2.069**	2.954***	1.069	1.056	0.053
Ambiguity-lovers Col Mean- Row Mean	SL-RK-NI	SL-AM-NI	SL-RK-I	SL-AM-I	NR-RK-NI	NR-AM-NI	NR-RK-I
SL-AM-NI	-2.092**						
SL-RK-I	4.442***	6.534***					
SL-AM-I	4.410***	6.502***	-0.031				
NR-RK-NI	2.63***	4.722***	-1.812**	-1.781**			
NR-AM-NI	1.739**	3.831***	-2.702***	-2.671***	-0.891		
NR-RK-I	2.580***	4.672***	-1.861**	-1.830**	-0.05	0.841	
NR-AM-I	2.246**	4.338***	-2.196**	-2.165**	-0.384	0.507	-0.334

The table displays the Dunn's z-test statistics. *** p<0.01, ** p<0.05, * p<0.1.

Table C.7: Self-insurance decisions equal to the reference level 400 ECU

	Mean	Std. Err.	[95% Conf. Interval]
SL-RK-NI	0.130	0.023	[0.085 0.175]
SL-AM-NI	0.079	0.018	[0.043 0.115]
SL-RK-I	0.213	0.028	[0.158 0.268]
SL-AM-I	0.241	0.029	[0.184 0.298]
NR-RK-NI	0.778	0.028	[0.722 0.833]
NR-AM-NI	0.769	0.029	[0.712 0.825]
NR-RK-I	0.704	0.031	[0.643 0.765]
NR-AM-I	0.699	0.031	[0.638 0.760]

Table C.8: Dunn's test for the insurance demand

Ambiguity-averters Col Mean- Row Mean	SL-RK-I	SL-AM-I	NR-RK-I
SL-AM-I	-1.09		
NR-RK-I	8.310***	9.400***	
NR-AM-I	8.961***	10.051***	0.651
Ambiguity-lovers Col Mean- Row Mean	SL-RK-I	SL-AM-I	NR-RK-I
SL-AM-I	-0.228		
NR-RK-I	8.4990***	8.727***	
NR-AM-I	7.809***	8.037***	-0.69

The table displays the Dunn's z-test statistics. *** p<0.01, ** p<0.05, * p<0.1.

Table C.9: Propensity to buy insurance

	Mean	Std. Err.	[95% Conf. Interval]
Ambiguity-averters			
SL-RK-I	0.810	0.035	[0.741 0.879]
SL-AM-I	0.857	0.031	[0.796 0.919]
NR-RK-I	0.206	0.036	[0.135 0.277]
NR-AM-I	0.167	0.033	[0.101 0.232]
Ambiguity-lovers			
SL-RK-I	0.756	0.046	[0.666 0.845]
SL-AM-I	0.800	0.042	[0.717 0.883]
NR-RK-I	0.078	0.028	[0.022 0.134]
NR-AM-I	0.144	0.037	[0.071 0.218]

AppendixD. Graphics

Figure D.6: Average self-insurance demand per decision period with 95% confidence interval for SL-RK-NI and SL-AM-NI

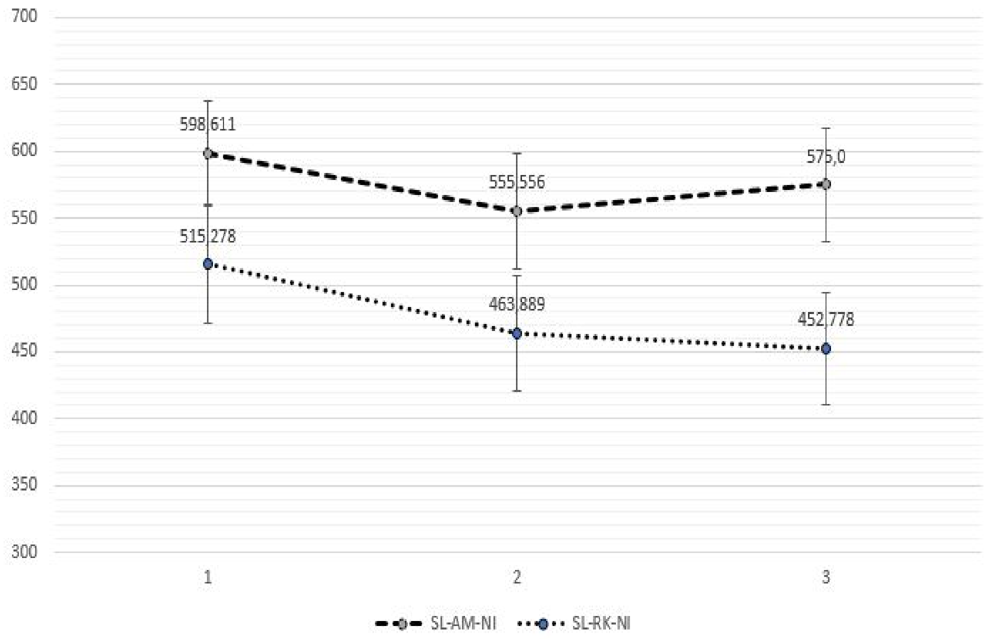


Figure D.7: Average self-insurance demand per decision period with 95% confidence interval for SL-RK-I and SL-AM-I

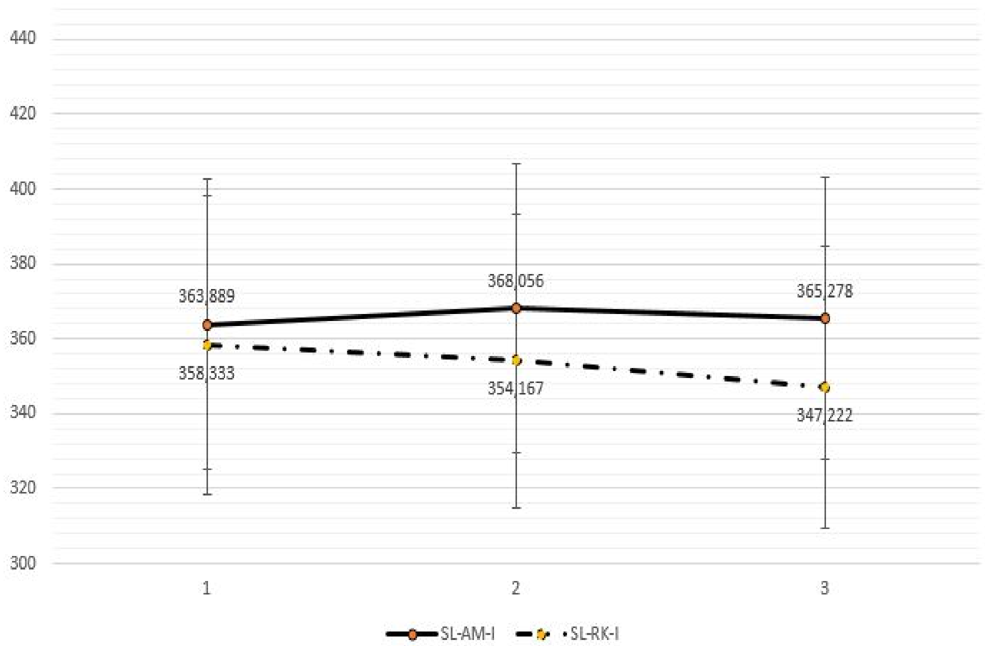


Figure D.8: Average self-insurance demand per decision period with 95% confidence interval for NG-RK-NI and NG-AM-NI

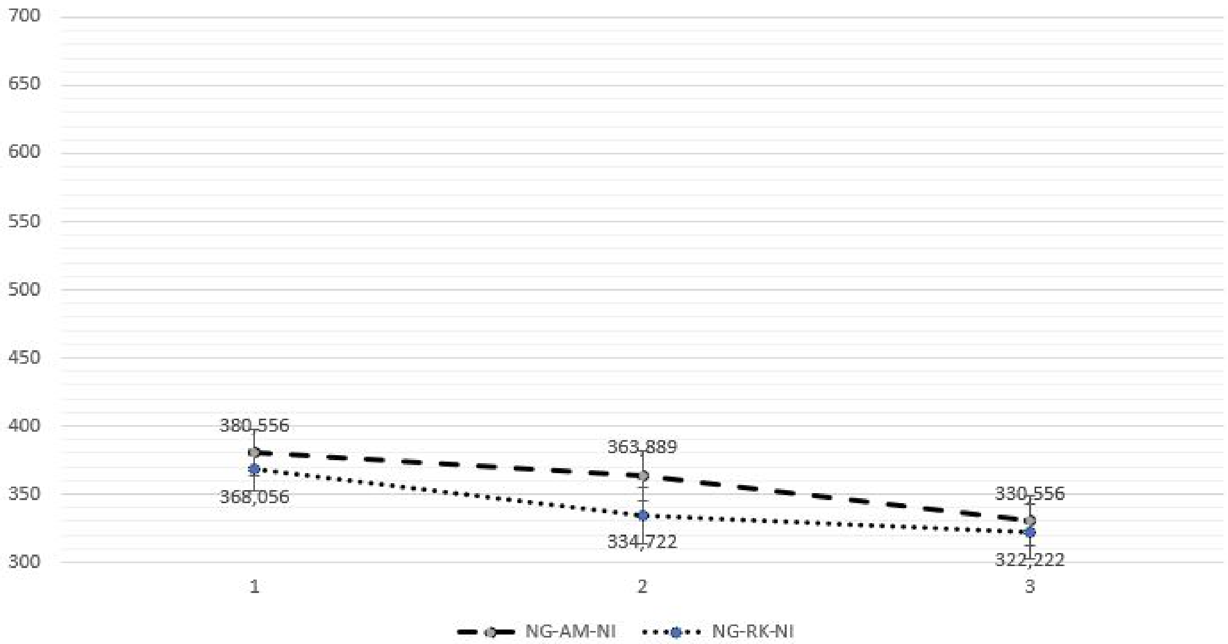


Figure D.9: Average self-insurance demand per decision period with 95% confidence interval for NG-RK-I and NG-AM-I

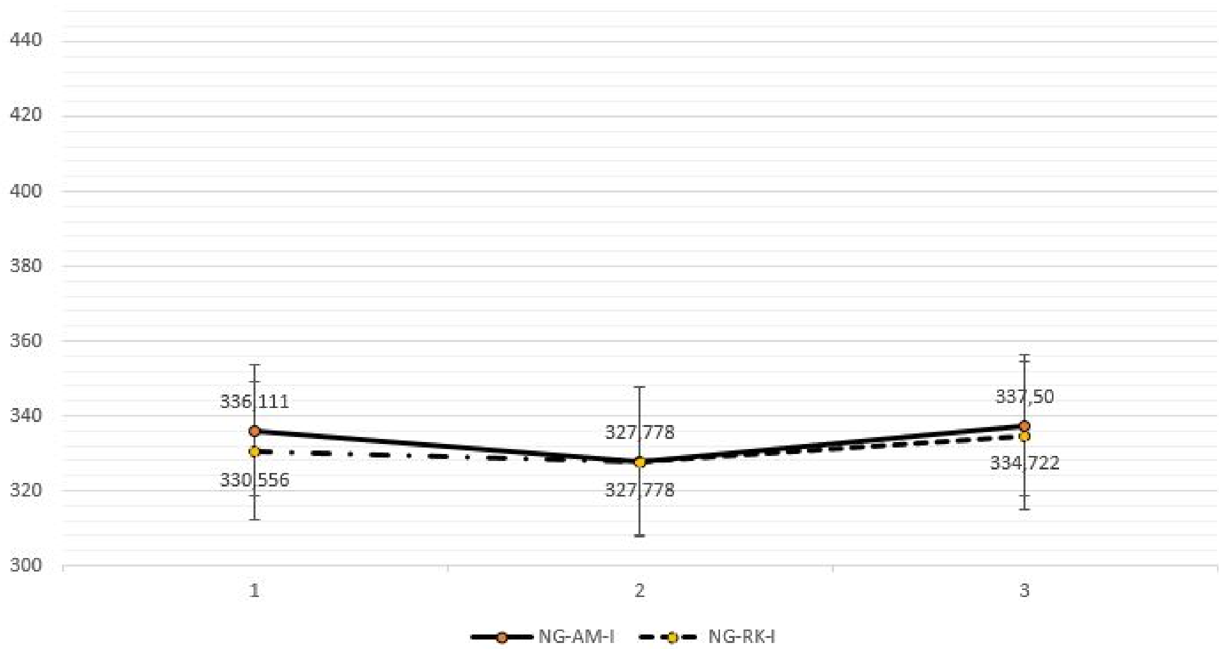
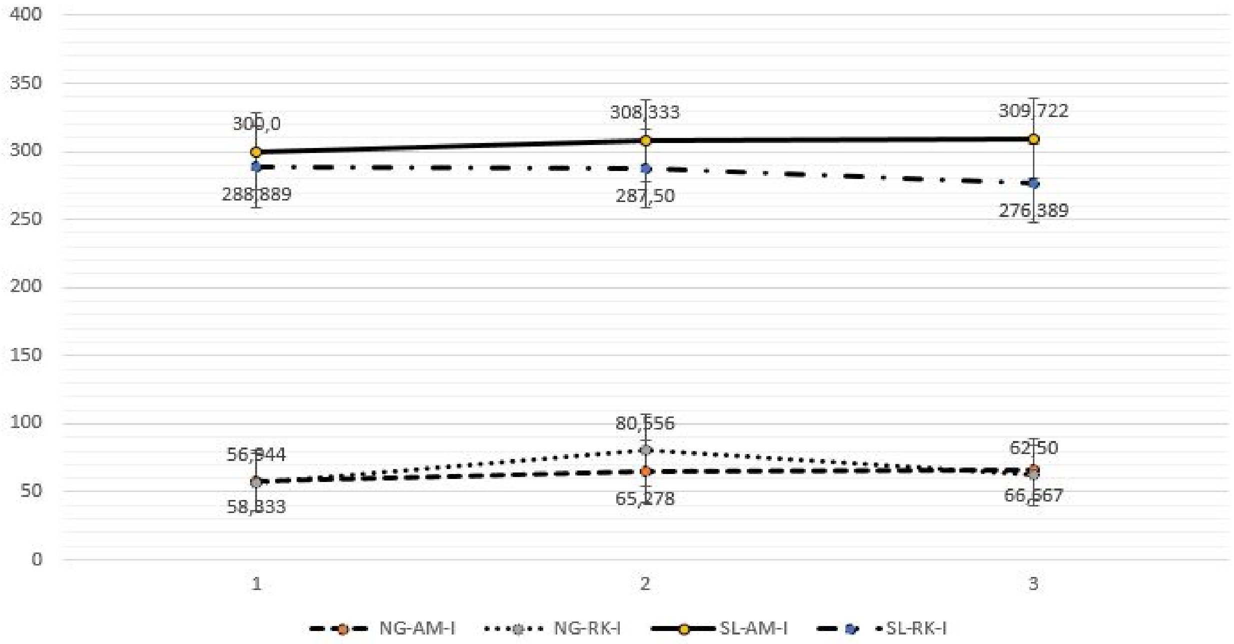


Figure D.10: Average insurance demand per decision period with 95% confidence interval



AppendixE. Regressions

Table E.10: Random-effects ordered logistic regression for self-insurance demand

	(1)	(2)	(3)
SL	0.936***	0.892***	0.892***
	(0.260)	(0.250)	(0.251)
AM	0.374***	0.405***	0.405***
	(0.106)	(0.107)	(0.106)
Insurance	-0.965***	-0.789***	-0.788***
	(0.166)	(0.206)	(0.206)
Cum. nb. accidents		-0.099	-0.095
		(0.146)	(0.143)
Decision period		-0.019	-0.020
		(0.027)	(0.026)
Female			-0.074
			(0.385)
Age			0.048*
			(0.025)
Universalism			-0.080
			(0.297)
Benevolence			-0.508**
			(0.204)
Ecocentrism			-0.631***
			(0.209)
Ambiguity-loving			-0.536
			(0.397)
Observations	1,728	1,728	1,728
k	17	19	27
p	0	0	0
chi2	73.06	84.89	136.2
dfm	3	5	11

Marginal effect at means for regression on 1,728 observations. Cluster robust standard errors in parentheses (72 clusters). Results are significantly different from zero at *** 1%, ** 5% and * 10% .

Table E.11: Random-effects ordered logistic regression for insurance demand

	(4)	(5)	(6)
SL	4.070***	4.071***	4.084***
	(0.738)	(0.740)	(0.742)
AM	0.153	0.137	0.131
	(0.130)	(0.135)	(0.134)
Cum. nb. accidents		0.221	0.240
		(0.266)	(0.258)
Decision period		-0.025	-0.025
		(0.052)	(0.051)
Female			-0.302
			(0.488)
Age			0.117***
			(0.035)
Universalism			-0.117
			(0.380)
Benevolence			-0.818**
			(0.351)
Ecocentrism			0.029
			(0.324)
Ambiguity-loving			0.247
			(0.482)
Observations	864	864	864
k	14	16	24
p	1.27e-07	1.97e-06	3.04e-05
chi2	31.75	31.93	38.55
dfm	2	4	10

Marginal effect at means for regression on 864 observations. Cluster robust standard errors in parentheses (72 clusters). Results are significantly different from zero at *** 1%, ** 5% and * 10% .