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**Valuation of Self-Insurance and Self-Protection under Ambiguity: Experimental Evidence**

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**Abstract**

This experimental study, first, compares the individual valuations of two risk reduction mechanisms: self-insurance and self-protection. Second, it investigates these valuations when the loss amount is ambiguous, and compare these values with valuations when loss amounts are known. results confirm that there exists no “framing effect” due to the two risk reduction mechanisms. Ambiguity in the loss amount has a weak impact on the valuation, and using different representations of ambiguity does not change the valuation. Moreover, the mean ratios of ambiguous to risky bids are greater than one for low loss amounts indicating ambiguity aversion. These ratios are not significantly different from one for high loss amounts regardless of the probability of loss levels. Finally, 28 percent of the sample behaved consistent with the predictions of “anchoring and adjustment”, while only 6 percent supported the “maximin” predictions.

**Keywords:** self-insurance, self-protection, risk, uncertainty

**JEL:** C91, D81

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## 1. Introduction

Self-insurance and self-protection are defined as two risk reduction mechanisms in Ehrlich and Becker (1972). Self-insurance applies to the case in which human precautionary actions do not affect the probability of the occurrence of a loss event, but can influence the size of the loss. Self-protection reduces the probability of the occurrence of the loss event. Eating less beef is an example for self-protection in that one can lower the probability of getting mad cow disease, but not the intensity of the disease (Immordino, 2000) and any precaution against natural disasters can only lower the size of the loss but not the probability of the occurrence of the hazard.

Contrary to the Expected Utility Theory (hereafter, EUT) that assumes both self-insurance and self-protection to be equally desirable (because of their equal marginal contribution to EU function as it is explained by Chang and Ehrlich (1985), differences may exist between the impact of self-insurance and self-protection on individual response to risk. In Ehrlich and Becker's (1972) theoretical work, while self-insurance and market-insurance were shown to be substitutes, self-protection and market-insurance were conceptualized as complements (also supported by Courbage, 2001). Their argument that, "the incentive to self-protection... is not so dependent on attitude toward risk" was supported by later theoretical studies which concluded that a more risk-averse person would always invest more in self-insurance, but not necessarily more in self-protection (Boyer and Dionne, 1983; Dionne and Eechoudt, 1985; Briys and Schesinger, 1990; Briys, Sckensinger, and Schulenburg, 1991).

Although there are many theoretical works (e.g., Lee, 2005), there exists only two experimental studies we are aware of that compared the impacts of these risk reduction mechanisms on individual responses to risk. Shogren (1990) argued that a risk-averse or risk-neutral individual would value self-protection more highly than self-insurance. A more recent study by Di Mauro and Maffioletti (1996) found no difference (no framing effect) between

the two mechanisms.<sup>1</sup> This contradiction indicates the need for further research. In addition, the majority of the experiments have focused on the impact of probabilistic ambiguity on the individual reactions (e.g., Camerer and Kunreuther, 1989; Cohen, Jaffray, and Said, 1985), and not much research effort has been devoted to analyze the effect of outcome ambiguity. Findings concerning the effects of ambiguous probability and ambiguous outcome on choices are also unequivocal (Camerer and Weber, 1992; Ho, Keller, and Keltyka, 2002).

For the above reasons, the present experimental study, first, attempts to investigate how individuals value risk reduction through self-protection and self-insurance. Particularly, it tests the difference between valuation of these mechanisms (“pure framing effect”<sup>2</sup>) in a risky situation (where probability and the loss size is known) by using a loss situation in one state and no gain in the other state of the world. Second, the study detects how individuals value self-protection and self-insurance risk management tools when the size of the loss is unambiguous, and compares these values to those given when the loss size is ambiguous<sup>3</sup>. This enables comparison of this study’s results with those in Di Mauro and Maffioletti’s (1996) probabilistic ambiguity study, which revealed a weak effect of ambiguity on the valuation of the two risk-management tools. In addition, we further check the consistency of the individuals’ behaviors with Einhorn and Hogarth’s (1985) Anchoring and Adjustment model and Gardenfors and Sahlin’s (1982, 1983) Maximin model.<sup>4</sup> Third, individual risk and uncertainty attitudes are determined and compared with the results of Di Mauro and Maffioletti (2004). In their study, through series of experiments using probabilistic ambiguity, they supported the well-known fourfold pattern of risk attitude: risk/ambiguity seeking

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<sup>1</sup> According to Di Mauro and Maffioletti (1996, pg 54), any rational individual would value self-protection more, according to the lottery structure used in Shogen (1990) study.

<sup>2</sup> “Self-insurance that reduces the size of the loss to zero is perfectly equivalent to self-protection that reduces the probability of the loss to zero. Any difference in the valuation of the two risk-management tools can only be ascribed to the frame”

<sup>3</sup> For example, an individual that prefers buying a smoke detector (self-protection) rather than decorating the house with unburned materials (self-insurance) may change his/her mind in the case where the exact loss amount of a possible fire is known and unknown.

<sup>4</sup> See Di Mauro and Maffioletti (1996, pg 55-57).

attitude towards high probability events, and risk/ambiguity averse attitude towards low probability events. The same results should hold for our study if the effect of ambiguity on probability and outcome for choices or pricing are the same.

The next section reviews the previous studies and explains the hypotheses related to the current research questions. Next, the experimental design is described, followed by the results and discussions.

## **2. Outcome Ambiguity, Self-Insurance, and Self-Protection**

Since Ellsberg's work (1961), it is quite accepted through the results of theoretical and experimental studies (e.g., Tvesky and Kahneman, 1992; Camerer and Weber, 1992; Tvesky and Fox, 1995) that there exists differences in individual responses to risky versus ambiguity situations, although it is contrary to EUT. Most of the recent experimental studies report that individuals tend to avoid ambiguity (e.g., Hogarth and Kunreuther, 1985; Gonzalez-Vallejo, Bonazzi, Shapiro, 1996; Kuhn and Budescu, 1996; Kunreuther, Hogarth, and Spranca, 1995; Camerer and Kunreuther, 1989; Sarin and Weber, 1993), except for the studies of Kahn and Sarin (1988) and Ho et al. (2002).<sup>5</sup> Moreover, amongst the probabilistic ambiguity studies that investigated the relation between risk attitudes and uncertainty attitudes, while some suggest no correlation between risk attitudes and ambiguity attitudes (Cohen et al., 1985; Hogarth and Einhorn, 1990), Di Mauro and Maffioletti (2004) revealed that people are risk/ambiguity averse for gains and risk/ambiguity seeking for losses in high probability events, and risk/ambiguity averse for losses and risk/ambiguity seekers for gains in low probability events. Further, they found increasing patterns in both risk and uncertainty aversion when probability of loss decreases and when probability of gain increases.

While many experimental studies have been done in order to compare individual reactions in different domains and for different probability levels under ambiguous

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<sup>5</sup> Consistent with Kahn and Sarin (1988), they found that most managers were ambiguity seeking in loss domain for both outcome and probabilistic ambiguity situations.

probabilities, not much work is devoted to analyze the impact of outcome ambiguity on reactions to uncertainty. Although some scholars claim that the effect of ambiguity on probability and outcome on choices (e.g., Camerer and Weber, 1992; Schoemaker, 1989;1991;Gonzalez-Vallejo et al., 1996) and pricing (Kunreuther et. al. 1995) are indifferent, others suggest that differences exist (e.g., Ho et. al., 2002; Shapira, 1993). One possible reason of this contradiction could be based on the fact that in Camerer and Weber (1992) outcome ambiguity is represented as an unknown probability distribution over the potential range of outcomes, whereas in Ho et. al. (2002) it is taken as the range of outcomes without explicitly invoking probabilistic reasoning<sup>6</sup>. Note also that, whereas Prospect theory (Kahneman and Tvesky, 1979) portrays outcomes in the loss domain as having a steeper slope for the value function than do outcomes in the gain domain (loss aversion), Gonzalez-Vallejo, Bonazzi and Shapiro's (1996) gain domain study found ambiguity avoidance for gambling choice decisions.

Few experimental studies examined the effect of outcome ambiguity in the domain of losses. Consistent with the results of Kuhn and Budescu (1996) environmental and health hazards study, Oliver (1972) found bankers' loan decisions to be ambiguity averse. In Ho et. al.'s (2002) managerial decision making experiment, however, it is concluded that people are ambiguity seeking in the loss domain and ambiguity averse in the gain domain. It appears that any rational person would try to avoid ambiguity in their gain domain setting not to give up the opportunity to gain, more than in the loss domain.<sup>7</sup>

Accordingly, the main objectives of the current study are to (1) examine and compare the individual valuations of the two risk reduction mechanisms in risky situations and test whether there exists a "framing effect", (2) investigate how these valuations differ between ambiguous versus unambiguous loss size conditions, (3) compare our results with the results

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<sup>6</sup> The later one is more appropriate for our research questions, since independence of probability and outcome is a given assumption with self-insurance and self-protection concepts.

<sup>7</sup> The actual return on investment (ROI) is given as 16% where in the loss domain they use the lottery; 14% for sure for risky versus 10%-18% for ambiguity and in the gain domain they use the lottery; 18% for sure for risky versus 9%-27% for ambiguity.

of Mauro and Maffioletti (1996; 2004) to see whether the effects of probabilistic and outcome ambiguity situations on the valuation of risk reduction mechanisms are somewhat different.

Following Di Mauro and Maffioletti (1996), we used the following lottery structure when we ask subjects to evaluate the risk-reduction mechanisms:  $(p, W-L; (1-p), W)$  where  $p$  is the probability of loss,  $L$  is the loss amount, and  $W$  is the initial endowment. Hence, if there exists any valuation difference between probability reduction to zero and loss amount reduction to zero, it is not because they generate different expected values, it is because people perceive these mechanisms differently i.e. because of the “pure framing effect”. With using the same lottery structure, we expect no framing effect for the valuations.

In addition, Di Mauro and Maffioletti (1996) checked whether the individuals’s behavior is consistent with Einhorn and Hogarth’s (1985) model of Anchoring and Adjustment and Gardenfors and Sahlin’s (1982, 1983) Maximin model. The Anchoring and Adjustment model states that “when the probability of loss increases, individuals move from ambiguity aversion to ambiguity preference”. However, Maximin model implies that, individuals always be ambiguity averse no matter what the probability of loss is. They found no strong evidence of consistency for both models. The current study enables to test this conclusion by using outcome ambiguity.

In Di Mauro and Maffioletti (2004) probabilistic ambiguity study, they conclude that people are risk/ambiguity seekers for losses in high probability events, and risk/ambiguity averse for losses in low probability events. This should hold if the effects of ambiguous probability of loss and ambiguous amount of loss (outcome) on choices are the same (e.g., Camerer and Weber, 1992; Gonzalez-Vallejo, Bonazzi and Shapiro, 1996), and should not hold if their effects are somewhat different (e.g., Ho et. al., 2002; Schoemaker 1989; 1991; Shapiro, 1993).

In order to examine the above hypotheses, in our experiment, we ask individuals to indicate their willingness-to-pay for risky lotteries (with known probability of loss and known loss amount) and ambiguous lotteries (with known probability of loss and unknown loss amount) with the same expected loss size for an expected utility maximizer. We use three probabilities (3%,50%,80%) and two loss amounts (3 Euro and 8 Euro out of 10 Euro). We operationalized ambiguous outcome cases in two different ways: best estimate<sup>8</sup> (the point estimate which is exactly the same as the risky case, except through the wording used in the scenario, is made unprecise to the subjects) and an interval of loss size (where the mean of the interval equals to the “best estimate”). Individual valuations were elicited using a market institution, specifically a computerized second price auction<sup>9</sup>.

### 3. Experimental Design

Table 1 summarizes the experimental design. The experiment consists of four sessions with 20 students each. Two sessions included 12 scenarios for self-insurance and the other two sessions included 12 scenarios for self-protection (6 risky, 6 ambiguous scenarios)<sup>10</sup>. Risk and ambiguity were manipulated as a within-subject treatment, and the two representations of loss amount ambiguity (best estimate and interval of loss amounts) were treated between subjects (through different sessions). The loss amounts of 3 Euro and 8 Euro out of 10 Euro with probabilities of the occurrence of the loss event being 3%, 50%, and 80% are used for the sake of remaining compatible with prior experiments in the literature (Di Mauro and Maffioletti,1996; 2004).

#### Insert Table 1

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<sup>8</sup> By using the point estimate representation for outcome ambiguity, we intent to test whether Einhorn and Hogarth (1985) “anchoring and adjustment model” for the probabilistic ambiguity holds for the outcome ambiguity in the loss domain through the decision making processes of self-insurance and self-protection.

<sup>9</sup> See Mauro and Maffioletti (2004, page 358) for a detailed explanation about the second price auction.

<sup>10</sup> The scenarios within each situation were arranged in random order. Ambiguous scenarios were presented before the risky ones.

Subjects are asked to indicate their willingness to pay (WTP) to reduce the probability of loss (the amount of loss) for self-protection (self-insurance) sessions. A computerized second price auction is used to elicit the willingness to pay values. More precisely, subjects indicated their willingness to pay by pressing any key when the price reaches the most that they are willing to pay (the closing price when they want to leave the auction). The last person to drop out had the right to reduce the amount of money loss to zero after paying the price at which the second-to-last person dropped out. Others played the randomly selected scenario if the event had occurred, they faced a money loss; if the event did not occur, they kept their initial endowment. The computer determined whether the event would occur or not through a random mechanism (with respect to the probability stated in the scenario).

For the risky scenarios, exact probabilities and loss amounts are stated. For the ambiguous scenarios, only the probabilities were exactly known by the subjects. For the loss amounts, two representations of ambiguity are used<sup>11</sup>. The best estimate definition of ambiguity is stated in the instructions as “ An expert, hired by a governmental agency, estimates the money loss to be 10 Euro if a loss event occurs. However, this is the first investigation ever carried out, so you experience considerable uncertainty about the precision of this estimate.” As for the interval definition of ambiguity, the ranges are taken where the mean of the interval equals to the “best estimate”. For example, both Scenario A and Scenario B are examples of self-insurance scenarios, however, Scenario A is an example of a “best estimate” representation type of ambiguity and Scenario B is an example of an “interval” representation type of ambiguity for the situation that the probability of loss being 50% and the amount of loss is 8 euro.

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<sup>11</sup> For more examples and explanations on best estimate and interval definitions of ambiguity see Mauro and Maffioletti (2004, page 359).

**SCENARIO A:** Assume that you have 10€ and you are concerned about the occurrence of some event. The probability of the occurrence of such an event is 50% and if this event does occur, you will lose some money. An expert, hired by a governmental agency, estimates the amount of money loss to be 8€ if the event occurs. However, this is the first investigation ever carried out, so you experience considerable uncertainty about the precision of this estimate. You are now asked to state the maximum amount of money that you would be willing to pay to reduce the amount of money loss to zero.

**SCENARIO B:** Assume that you have 10€ and you are concerned about the occurrence of some event. The probability of the occurrence of such an event is 50% and if this event does occur, you will lose some money. An expert, hired by a governmental agency, estimates the amount of money loss to be anywhere between 6€ and 10€ if the event occurs. You are now asked to state the maximum amount of money that you would be willing to pay to reduce the amount of money loss to zero.

After all of the subjects have completed their decisions for all 12 scenarios, the computer randomly selected one of the scenarios to play out for real.

#### 4. Experimental Evidence

The experiment was run in January 2006 at the experimental economics laboratory of The Strategic Interaction Group at the Max Planck Institute of Economics in Jena. The software of the computerized experiment has been developed in z-Tree (Fischbacher, 1999). 80 students from Jena University were recruited to participate in the experiment using the ORSEE software (Greiner, 2004). Participants received written instructions after being seated at a computer terminal<sup>12</sup>. A sample of the instructions in English is available in the Appendix.

The information on the demographic characteristics of the sample was collected through a very short questionnaire asked just before the experiment. Accordingly, the sample consisted of 49% female with average age of 24 and average monthly income of 404 Euro. All of the subjects, except for one, were single.

##### 4.1. Differences in the risk reduction mechanisms

Means, medians, and standard deviations for each risk reduction mechanism (self-insurance and self-protection) at each probability and loss amount level, and for each representation of ambiguity (best-estimate and interval) are presented in Table 2. Based on the observed differences in means, it is difficult to conclude that a “framing effect” exists due to the usage of the two different risk reduction mechanisms.

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<sup>12</sup> The original instructions were in German.

**Insert Table 2**

In fact, the Mann-Whitney U-test for independent samples show that the distribution of WTP values to reduce the probability (self-protection) and WTP values to reduce the loss amount (self-insurance) are not statistically different from each other.

**Insert Table 3**

**4.2. Valuation under risky and ambiguous loss situations**

To determine individual risk attitudes, the mean values of the ratios of risky bids to expected values (BID/EV) of each risky loss situation are calculated. Similarly, individual ambiguity attitudes are calculated as the mean values of the ratios of ambiguous to risky bids for each of the two mechanisms and for each representation of ambiguity. For both, a ratio greater than one indicates risk aversion, smaller than one stands for risk preference, and equal to one indicates risk neutrality.<sup>13</sup>

Table 4 shows that the risk ratios are statistically greater from one (according to one-sample t-tests) indicating an overall risk aversion behavior of individuals regardless of the probabilities and loss amount change. Further, at the probability 3%, subjects behave relatively more risk averse.<sup>14</sup> Also provided in the table are individual ambiguity attitudes. Using these figures, one can test the Einhorn and Hogarth model with respect to loss amount ambiguity rather than probability of loss ambiguity. The mean values of ambiguity ratios indicate that subjects are ambiguity averse (the average of the ratio is greater than one and significantly different from one by one sample t-test) for low loss amounts. For high loss amounts, however, the ratio is not significantly different from one indicating risk neutrality.

**Insert Table 4**

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<sup>13</sup> Risk Ratio= Bid for the risky situation/ Expected Value. Ambiguity Ratio= Bid for the ambiguous situation/ Bid for the risky situation. Di Mauro and Maffioletti's study (2004, pg. 361) can be seen for further information about risk and uncertainty attitudes.

<sup>14</sup> Scheffe test that is used for grouping the means in homogeneous subsets displays the bids for 50% and 80% probabilities in the same group, while bids for 3% probability belongs to a separate group.

Wilcoxon rank-sum test is used in order to test whether individual valuations of self-insurance and self-protection differ between ambiguous and known (risky) loss amount situations. According to the test results summarized in Table 5, the Z values indicate that in the majority of the loss situations ambiguous and risky bids were derived from the same parental distribution. This result is consistent with Camerer and Kunreuther (1989) and Cohen, Jaffray, and Said (1985).

**Insert Table 5**

**4.3. Representation of loss amount (outcome) ambiguity**

In the current experiment, two different representations of ambiguity have been adopted following Di Mauro and Maffioletti (1996; 2004) and Hogarth and Kunreuther (1989). Although both “best estimate” and “interval of loss amounts” has the same expected value, they differ in their variances, indicating that individuals perceive interval of loss amounts representation more ambiguous than the best estimate one.<sup>15</sup> In order to test this hypothesis, Mann-Whitney U-test (for each probability of loss and amount of loss) was conducted. The results that are summarized in Table 6 reveal no significant differences, indicating that subjects perceived the best estimate and the interval of loss amounts representations of ambiguity in the same fashion<sup>16</sup>.

**Insert Table 6**

**4.4. Consistency of the valuations with the theoretical models**

Table 7 summarizes the numbers of the subjects that behaved consistent with the predictions of each of the ambiguity models. Note that in the prior analysis of these models, probability of loss is taken to be ambiguous, whereas, for the present study, it is the loss amount that is ambiguous. With respect to this, approximately 28% of the subjects behaved consistent with

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<sup>15</sup> See Di Mauro and Maffioletti (2004, page 365) for detailed discussion.

<sup>16</sup> The same result is supported by Kruskal-Wallis test for homogeneity of the ambiguity representations.

the predictions of Anchoring and adjustment model, while only 6% of the responses supported the Maximin model.

## **5. Conclusion and Discussion**

This paper provides experimental evidence to examine the individual valuations of two risk reduction mechanisms; self-insurance and self-protection, in risky situations, and test whether there exists a “framing effect”. The study also investigates how individual valuations differ between ambiguous versus unambiguous loss amount situations. The results are in line with Di Mauro and Maffioletti’s (1996) probabilistic ambiguity study in that individuals are found to respond self-insurance and self-protection as the same. In addition, the impact of ambiguous loss amounts on the valuation of these two risk reduction mechanisms are found to be considerably small (also in the line with the results of Cohen et al., 1985 and Camerer and Kunreuther, 1989). This also supports the claim that the effect of ambiguity on probability and outcome on choices are indifferent (e.g., Camerer and Weber, 1992; Shoemaker, 1991; Gonzalez-Vallejo, Bonazzi and Shapiro, 1996).

Concerning the relative impacts of using “best estimate” and “interval of loss amount” as two alternative representations of ambiguity, no evidence is found to conclude that the valuations alter due to the change in the type of the ambiguity representation. Consistent with Shoemaker (1991), there exists no relation between attitudes to risk and attitudes to ambiguity. The mean values of ambiguity ratios indicate that subjects are ambiguity averse for low loss amounts, yet, the ratio is not significantly different from one for high loss amounts. Finally, as Di Mauro and Maffioletti (1996) concluded for the valuations under ambiguity on probability of loss, the analysis for individual responses under ambiguity on the loss amount did not strongly support one specific theoretical model.

As for the further research, the differences between self-insurance and self-protection should be investigated and compared for different kinds of risky events such as environmental risks, terrorism, and work place risk. Series of experiments should be designed using alternative representations of ambiguity (see Morone and Ozdemir, 2005) and other incentive mechanisms to test theoretical models such as Segal (1987) and Tvesky and Kahneman (1992).

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## APPENDIX- Sample instructions for self-protection experiment

You are about to participate in an experiment concerning gaining some information on certain economic behaviour. If you follow the instructions carefully you can earn money, but you may end up not earning anything, other than the 2 Euro participation fee. You will be paid in cash at the end of the experiment.

During the experiment, you are not allowed to communicate with the other participants.

You will be presented eight different scenarios with different probabilities of occurrence of an event. If event occurs, you would face a loss of money. However, you have an opportunity to take some action at some monetary cost. If you take this action you will be able to reduce the probability of the occurrence of such an event to zero.

For each scenario you will be asked to state the maximum amount you are willing to pay to reduce the probability of the occurrence of such an event to zero. There will be an auction mechanism to indicate your willingness to pay as follows:

On the screen you will see a description of the scenario. Below the description, at the bottom of the screen, will be displayed a price which will steadily increase. You will indicate your willingness to pay by pressing any key when the price reaches the most that you are willing to pay (the closing price when you want to leave the auction). The last person to drop out will have the right to reduce the probability of the occurrence of the event to zero and will pay the price at which the second-to-last person dropped out.

For each scenario, your endowment is 10 Euro, meaning that you can spend up to 10 Euro in each scenario to reduce the probability of the occurrence of the event to zero.

After you have indicated your willingness to pay for all eight scenarios, the computer will randomly select one of the scenarios to play out for real.

**Example 1:** Assume for the scenario that is randomly chosen out of eight, you are the last person who dropped out last (highest price). The second-to-last person (second highest price) is 3 Euro. Then you will have the right to reduce the probability of losing money to zero and will pay the price 3 Euro.

You earn                      Endowment- Price = 10 Euro- 3 Euro = 7 Euro

**Example 2:** Assume for the scenario that is randomly chosen out of eight, you are not the 1st person who dropped out. Then you will play the selected scenario out that is if the event occurs, you face a money loss, if the event does not occur, you will keep your endowment, 10 Euro.

If event occurs:                      You earn=Endowment- Money Amount stated in the scenario

If event does not occur:                      You earn= Endowment

**Step1:** At the beginning of the experiment, you will be given an example in order to get familiar with the procedure of the experiment.

**Step 2:** You will see the first scenario on the screen and will be given a few minutes to think about it and when you are ready, please press OK.

**Step 3:** The auction will take place. You will be asked to press a key when the price reaches the most that you are willing to pay (that is when you want to leave the auction).

**Step 4:** You will be presented the other seven scenarios and will repeat the same procedure.

**Step 5:** At the end of the eight scenarios, the computer will select a number from 1 to 8 (each number corresponds to one of the scenarios). The selected scenario will be displayed with all the prices at which each participant dropped out from the auction.

**Step 6:** The last person to have dropped out will pay the price at which the second-to-last person dropped out (second highest price).

The other participants will play the explained scenario for real and be paid according to the outcome: The computer will determine whether the event occurs or not through a random mechanism. If the event occurs, then you will lose the amount of money mentioned in the scenario. If the event does not occur, then you will keep your endowment.

On the next page there are practice questions. With these questions, how each different scenario is played will be explained in greater detail.

### **Examples of self-protection scenarios**

**Best Estimate:** Assume that you have 10€ and you are concerned about the occurrence of some event. The probability of the occurrence of such an event is 80% and if this event does occur, you will lose some money. An expert, hired by a governmental agency, estimates the amount of money loss to be 8€ if the event occurs. However, this is the first investigation ever carried out, so you experience considerable uncertainty about the precision of this estimate. You are now asked to state the maximum amount of money that you would be willing to pay to reduce the probability of the occurrence of the event.

**Interval of Probability:** Assume that you have 10€ and you are concerned about the occurrence of some event. The probability of the occurrence of such an event is 50% and if this event does occur, you will lose some money. An expert, hired by a governmental agency, estimates the amount of money loss to be anywhere between 6€ and 10€ if the event occurs. You are now asked to state the maximum amount of money that you would be willing to pay to reduce the probability of the occurrence of the event.

*Table 1. Summary of experimental design*

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Do individuals perceive self-insurance and self-protection differently? (Framing effect) ( <i>Between subject factor</i> )	
<ul style="list-style-type: none"><li>• Self-insurance reduces the amount of loss</li><li>• Self-protection reduces the probability of occurrence of loss</li></ul>	
What is the impact of different representation of ambiguity? ( <i>Between subject factor</i> )	
<ul style="list-style-type: none"><li>• Best estimate</li><li>• Interval of loss amount</li></ul>	
How much does valuation under ambiguity differ from valuation under risk? ( <i>Within subject factor</i> )	
<ul style="list-style-type: none"><li>• Risky scenarios (probability and loss amount are exactly known)</li><li>• Ambiguous scenarios (probability is known, but loss amount is not known exactly)</li></ul>	
Does ambiguity reaction depend on the size of probability and loss amount? ( <i>Within subject factor</i> )	
<ul style="list-style-type: none"><li>• Three probability levels: 3%, 50%, 80%</li><li>• Two loss amounts: 3 Euro and 8 Euro out of 10 Euro.</li></ul>	

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Table 2. Summary statistics of individual bids

	Probability of loss- Loss amount	Mean	Standard deviation	Number of subjects
Self-protection (risky bids)	50%-8Euro	6,000	2,112	40
	50%-3 Euro	2,175	1,824	
	80%-8 Euro	6,875	2,197	
	80%-3Euro	2,450	1,535	
	3%-8 Euro	2,270	2,574	
	3%-3 Euro	1,175	1,662	
Self-insurance (risky bids)	50%-8Euro	6,025	1,954	40
	50%-3 Euro	1,950	1,395	
	80%-8 Euro	7,300	2,138	
	80%-3Euro	2,825	1,599	
	3%-8 Euro	1,975	2,010	
	3%-3 Euro	1,075	1,542	
Self-protection (Best estimate)	50%-8Euro	5,550	2,163	20
	50%-3 Euro	2,500	1,791	
	80%-8 Euro	7,200	1,852	
	80%-3Euro	3,650	2,345	
	3%-8 Euro	2,350	2,960	
	3%-3 Euro	1,500	1,820	
Self-insurance (Best estimate)	50%-8Euro	5,000	2,026	20
	50%-3 Euro	2,700	2,515	
	80%-8 Euro	5,750	2,826	
	80%-3Euro	2,900	1,372	
	3%-8 Euro	2,300	2,657	
	3%-3 Euro	1,900	2,712	
Self-protection (Interval of loss amount)	50%- 6-10 Euro	5,250	1,970	20
	50%-1-5 Euro	2,400	1,875	
	80%- 6-10 Euro	7,050	2,188	
	80%-1-5 Euro	4,000	1,685	
	3%-6-10 Euro	1,700	2,028	
	3%-1-5 Euro	0,800	0,951	
Self-insurance (Interval of loss amount)	50%- 6-10 Euro	5,400	1,875	20
	50%-1-5 Euro	2,250	1,618	
	80%- 6-10 Euro	7,300	1,380	
	80%-1-5 Euro	3,650	2,007	
	3%-6-10 Euro	1,100	1,165	
	3%-1-5 Euro	0,900	0,852	

Table 3. Mann-Whitney test between risk-reduction mechanisms (one-tail test): values of U\*\*

	50%-8	50%-3	80%-8	80%-3	3%-8	3%-3
<b>Risky Bids*</b>	-0,191	-0,192	-1,133	-1,159	-1,319	-0,351
<b>Ambiguous Bids</b>						
-Best estimate	170	199	154	167	194	196
-Interval of loss amount	191	192	198	176	178	183

\* For risky bids, the standardized normal variable Z is given instead of U, since the sampling distribution of U for large samples approaches the normal distribution.

\*\* None of them are found significant at the 95% level in that self-insurance is stochastically larger than self-protection.

Table 4. The mean values of risk and ambiguity ratios to determine individual risk and ambiguity attitudes

	Probability of loss- Amount of loss out of 10 Euro					
	50%-8	50%-3	80%-8	80%-3	3%-8	3%-3
<b>Risk ratios*</b>	1.325	1.642	1.066	1.479	7.7604	14.165
<b>Ambiguity ratios**</b>						
<i>Self-insurance</i>						
-Best Estimate	0.975***	1.360	0.964***	1.078***	1.236***	1.732
-Interval of loss amount	0.873	1.325	0.945***	1.486	1.265***	1.483
<i>Self-protection</i>						
-Best estimate	0.848***	1.342	1.058***	1.471	0.731***	1.474
-Interval of loss amount	1.126***	1.425	1.086***	1.485	1.104***	1.550

\* The risk ratio is calculated as BID/EV. A risk ratio that is greater than one implies risk aversion, while a risk ratio smaller than one means risk loving (seeking) behavior.

\*\* The ambiguity ratio is calculated as the bid under ambiguous situation divided by the corresponding bid under risky situation.

\*\*\*The mean values of the ratios are not significantly different from one at 95% confidence interval level according to one-sample t-test results.

Table 5. Wilcoxon rank-sum test between risky and ambiguous bids

	Probability of loss- Amount of loss out of 10 Euro					
	50%-8	50%-3	80%-8	80%-3	3%-8	3%-3
<b>Self-insurance</b>						
Best estimate	-1.592	-1.502	-2.137*	-0.280	-0.086	-2.354*
Interval of loss amount	-2.226*	-1.252	-2.164*	-1.685	-1.347	-0.577
<b>Self-protection</b>						
Best estimate	-2.303*	-0.360	-0.431	-2.974*	-2.230*	-0.060
Interval of loss amount	-0.045	-1.114	-0.855	-3.675*	-1.095	-1.134

Z values are the subtraction of ambiguous bids from risky bids.

\*Significant at 95% confidence level in that the risky and ambiguous bids differ in distribution.

*Table 6. Mann-Whitney U-test for independent samples between the two representations of ambiguity*

	<b>Probability of loss-amount of loss out of 10 Euro</b>					
	50%-8	50%-3	80%-8	80%-3	3%-8	3%-3
<b>Self-protection</b>	184	188.5	187	162.5	185.5	161.5
<b>Self-insurance</b>	172.5	194.5	137.5	145.5	155	170

U-values are given in the table that concludes distributions of two representations of ambiguity being the same, since none are found to be significant at 95% confidence level.

*Table 7. Number of individual responses that are consistent with the predictions of the ambiguity models*

<i>MODEL</i>	<i>NUMBER OF SUBJECTS</i>
Expected Utility	15
Anchoring and Adjustment	22
Maximin	5
Ambiguity Preference	2
Ambiguity Aversion	10
Other Behaviors	25
TOTAL	80