IMPACT OF OUTCOME AMBIGUITY ON SELF-INSURANCE AND SELF-PROTECTION: EXPERIMENTAL EVIDENCE

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ABSTRACT

This experimental study examines and compares individual valuations of the two risk reduction mechanisms: self-insurance and self-protection in risky versus ambiguous outcome situations. Results confirm that individuals do not perceive these mechanisms differently under risk. Moreover, ambiguity in the outcome (i.e., size of loss) affects valuations weakly, and changing representations of ambiguity do not alter valuation. In general, individuals are found to be ambiguity averse for low sizes of loss and ambiguity neutral for high sizes of loss, regardless of the probability of loss. Finally, no strong support is found for any particular model of ambiguity.

Keywords: ambiguity, self-insurance, self-protection

I. INTRODUCTION

In all stages of our life, we make decisions under risk and uncertain conditions. For example, we try to invest in a portfolio through checking the return to investment with different degrees of uncertainty. We try to make a car insurance decision with a very limited information about the probability of the occurrence of an accident and the size of the loss it may cause. Since Knight (1921), a risky event is defined as one with the probabilities of multiple possible outcomes that are known and an uncertainty event is defined as one with probabilities of outcomes that are unknown. Yet, actually in real life, it can be the probability and/or the loss/gain size that can be known/unknown when we try to make our decisions. There are two notions here: take the case of the car insurance decision, for risky situations, where we know the exact probability of occurrence and the loss size, how do we decide to take different types of precautions? Do we choose to wear seat belt, purchase insurance, drive carefully and slow, obey the traffic rules etc.? As noticed, while some precautionary actions may reduce the probability of the occurrence of the accident, others only reduce the size of the loss.
Self-insurance and self-protection (SISP hereafter) have been framed as two risk reduction mechanisms by Ehrlich and Becker (1972). Self-insurance applies to the case in which individuals’ taking precautions themselves (rather than buying insurance from a company) influence the size of the loss, whereas 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. On the other hand, any precaution against natural disasters can only lower the size of the loss but not the probability of the occurrence of the hazard.

According to Expected Utility Theory (hereafter, EUT), both self-insurance and self-protection can be equally desirable if they result in an increase in expected utility (by either lowering the probability of an adverse event or making the adverse events outcomes less bad). If both precautionary actions (self-insurance and self-protection) reduce the risk to zero, then according to EUT, rationally individuals should value them same and be indifferent of their choices. Any difference in valuation and/or choice (where both mechanisms decreases the risk to zero) can be considered as ‘framing effect’. In that case, the value assigned to the precautionary action may not depend on how much risk is reduced but also on how risk is reduced.

Literature has shown that differences may exist between the impacts of SISP on individual responses to risk. Ehrlich and Becker (1972), for example, showed that risk can be reduced (also supported by Courbage, 2001) through either mechanism privately or collectively. Moreover, in many theoretical studies, a more risk-averse person was found to always invest more in self-insurance, but not necessarily more in self-protection (Dionne and Eeckhoudt, 1985; Briys and Schlesinger, 1990; Briys et al., 1991; Alary et al., 2013). As about the ambiguity effect on SISP, Snow (2011) shows that ambiguity averse individual value both self-insurance and self-protection higher than the individuals that are not ambiguity averse, in addition, the valuation increases as the ambiguity aversion increases.

Although there are many theoretical works about this issue (e.g., Immordino, 2000; Quiggin, 2002; Lee, 2005; Lohse et al., 2007), we are aware of only two experimental studies that compared the individual valuations of SISP. Shogren (1990), for instance, concluded 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. The first objective of the current study is to examine further how people perceive SISP under risk.\footnote{Since Knight (1921), the risky event is defined as one with the probabilities that is objectively known. Note that for the present study’s purposes, a risky situation is defined as where probability and loss size are known.}

With respect to ambiguity, previous experiments have investigated it in two dimensions: probability versus outcome. Probabilistic ambiguity is defined as the uncertain situation where probability of occurrence of an event is unknown, and outcome ambiguity is defined as the one where the magnitude of the loss/gain is unknown. The current study is based on the domain of loss. The characterization of decision-making situations in the loss domain has been summarized as: (1) $S_1 =$ situation with known probability and known loss size; (2) $S_2 =$ situation with unknown probability and known loss size; (3) $S_3 =$ situation with known probability and unknown loss size; (4) $S_4 =$ situation with unknown probability and unknown loss size (Hogarth and Kunreuther, 1995). Most research effort on ambiguity has been devoted to analysing the differences between $S_1$ and $S_2$ (e.g., Cohen, Jaffray, and Said, 1985; Camerer and Kunreuther, 1989). Yet, Di Mauro, and Maffioletti (1996) is the only experimental study that investigated the effect of probabilistic ambiguity on valuations of SISP and did not find a strong support for any difference in valuations under risky and ambiguous situations.
In aggregate, consistent with intuition, most empirical research show that individuals behave to avoid ambiguity (Hey et al., 2009; Hey et al., 2010; Pace and Hey, 2011; Morone and Ozdemir, 2012). Thus, for example, in the case of a tornado that household certainly knows that it will hit the house according to the warning (with known probability), they will try to find ways to mitigate the loss size. However, in the case of a disease with no cure (certain loss of life), a person will tend to take precautions to reduce the probability of getting caught the disease. Thus, the probability and/or outcome ambiguity may lead individuals to favour one risk reduction mechanism over another.

The present study is the first attempt to examine and compare the valuations of SISP in S1 and S3. In real life, the role of outcome ambiguity (S3) is very important for the risk-reducing decisions. For example, an individual may prefer buying a smoke detector (self-protection) rather than decorating the house with non-flammable materials (self-insurance), however, would he/she still value the smoke detector more in two different cases: when the exact loss amount of a possible fire is known versus unknown?

To compare individual valuations of SISP in probabilistic ambiguity versus outcome ambiguity situations, we follow Di Mauro and Mafiolletti’s (1996) experiment design that they used for probabilistic ambiguity to represent ambiguous loss amounts (outcomes) in our experiment. The similarity of our experimental setting with theirs allows us to compare the results of our study with theirs. Although some scholars claim that the effects of ambiguity in probability and outcome on choices (e.g., Schoemaker, 1991; Camerer and Weber, 1992; Gonzalez-Vallejo and Shapiro, 1996) and pricing (Kunreuther et al., 1995) are the same, others suggest that ambiguity in probability versus ambiguity in outcome may yield different behavioural orientations (e.g., Ho et al., 2002). We hope our comparison in the SISP context enhances our understanding of these conflicting results in the literature.

With our experiment design, we explore the distinction between risk and ambiguity in the SISP context also through comparing individual attitudes to risk and ambiguity. The majority of the studies done on probabilistic ambiguity conclude four different risk and ambiguity attitudes that are prevalent in loss situations: risk seeking/ambiguity seeking attitudes under high probability of loss conditions and risk averse/ambiguity averse attitudes under low probability of loss conditions. We provide evidence that a similar pattern of attitudes emerges also in our outcome ambiguity manipulations. Finally, we also check the consistency of individual responses to outcome ambiguity with Einhorn and Hogarth’s (1985) Anchoring and Adjustment model and Gardenfors and Sahlin’s (1982; 1983) Maximin model.

The results show that (1) individuals are found to perceive SISP as the same risk reduction mechanisms, (2) ambiguity in outcome has insignificant impact on the valuations of SISP, (3) individual reactions to loss size ambiguity are not strongly consistent with the predictions of any single one of the theoretical frameworks. Practical implications of these conclusions might be that individuals, in general, do not have strong preference between self-protection and self-insurance. For example, an individual who wants to reduce the risk of burglary is indifferent between installing a burglar alarm (self-protection) and putting valuable items in a safe (self-insurance). Further, this behaviour does not relevantly change under uncertainty. Finally, more theoretical studies are needed to figure out how to predict the 31 percent of the subjects’ behaviours that cannot be explained by any of the ambiguity models used in this study.

The paper is organized as follows. Section I reviews prior research and develops related hypotheses concerning the current research questions, while Section II describes the experimental

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Footnote: We fully realize that a gamble framed with precise probabilities and ambiguous outcome as a 50 percent chance of no loss and a 50 percent chance of a loss of an ambiguous amount can be theoretically reframed as one with ambiguous probabilities of precise monetary amount. But we believe that two frames are psychologically quite different.
II. VALUATION OF SELF-INSURANCE AND SELF-PROTECTION

Little attention has been paid to compare SISP in previous experiments. The two studies we are aware of have had contradictory conclusions. Shogren (1990) finds higher valuation for self-protection, yet, as we agree, Di Mauro and Maffioletti (1996) claims that with the lottery type Shogren uses, any rational person will choose self-protection over self-insurance. Hence his lottery setting allows the individuals that choose self-protection to earn with certainty, while investing in self-insurance will provide an expected payoff with a probability; that does not allow the isolation of a framing effect due to the risk reduction mechanism.

The framework used to compare SISP in the current study is based on EUT (i.e., willingness to pay is the same for reducing either the loss or the probability of the loss to zero). Hence, supposing an individual faces a loss, \( L \), in one state of the world with a probability of \( p \), and no gain in the other state with a probability of \( 1-p \) and taking \( W \) as the initial endowment, the maximum willingness to pay to reduce the risk, \( P \), either through insurance or protection can be expressed as:

\[
EU(W - P) = pU(W - L) + (1 - p)U(W)
\]  

Hence, ‘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 described to the frame’ Di Mauro and Maffioletti (1996, p. 2). According to EUT, this framing effect should not exist.

**Hypothesis 1**: Consistent with EUT, there exists no difference in mean valuations between the self-protection and self-insurance framing conditions under the risky situations.

Empirical findings by Cohen et al. (1985) and Camerer and Kunreuther (1989) indicate that nonexistence of the framing effect does not differ between ambiguous and risky situations.

**Hypothesis 2**: Individual mean valuations of self-insurance and self-protection do not differ between ambiguous outcome and risky situations.

Most theoretical studies on ambiguity have focused on modelling the impact of imprecise probabilities on decision making. Ambiguity is usually assumed to be adding a second order probability distribution on the top of uncertain probabilities in a decision under risk, in that case, decisions under outcome ambiguity are not different from the decisions under risk or probabilistic ambiguity (e.g., Camerer and Weber, 1992; Gonzales-Vallejo and Shapiro, 1996; Kuhn and Budescu, 1996). However, Ho et al. (2002, p. 49)\(^3\) claim that ‘when outcomes are ambiguous, people may or may not think of such ambiguity as consisting of a probability distribution over possible outcomes’ and the effect of ambiguous probability versus ambiguous outcome on choices may differ (e.g., Schoemaker, 1991).

The prior studies about the distinction between outcome and probabilistic ambiguity necessitates for further research. In fact, one of the main objectives of the current study is to explore this distinction in the SISP context. More specifically, we aim to compare our results for individual valuations when loss size is ambiguous with the results when the probability of loss

\(^3\)Note that they portray outcome probability as ‘the range of outcomes without explicitly invoking probabilistic reasoning’ (Ho et al., 2002, p. 51).
is ambiguous. We expect one of their main findings, of a weak effect of ambiguity on SISP valuations, should hold in our study following the prior results that concluded outcome and probabilistic ambiguity to be similar.

In a similar vein, amongst the few experimental studies examining the effects of outcome ambiguity in the domain of losses, Kuhn and Budescu (1996) in the environmental and health hazards context report that people are generally ambiguity averse. In Ho et al. (2002) managerial decision making experiment; however, it was found that people are ambiguity seeking in the loss domain and ambiguity averse in the gain domain. Yet, it appears that any rational person would try to avoid ambiguity more in a gain domain setting in comparison to a loss domain setting, simply not to give up the opportunity to gain.\(^4\)

For further investigation, our experimental design enables us to check whether individual behaviours are 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 says that ‘when the probability of loss increases, individuals move from ambiguity aversion to ambiguity preference’. However, the Maximin model implies that individuals are always ambiguity averse regardless of the level of probability. In the Di Mauro and Maffioletti (1996) study, no strong evidence of consistency was found for any one of the two models in differing probabilistic ambiguity situations. The present study explores the viability of both models using outcome ambiguity manipulations. Therefore,

\[ \text{Hypothesis 3 (Anchoring and Adjustment model): Individuals are ambiguity averse with low loss sizes and ambiguity seeking with high loss sizes.} \]

\[ \text{Hypothesis 4 (Maximin model): Individuals are ambiguity averse regardless of the level of loss size.} \]

III. THE EXPERIMENT

Table 1 summarizes the experimental design. In total, 80 students participate in the experiment. The students are grouped in four as 20 students each. The first two groups are asked 12 scenarios about self-insurance and the other two are asked 12 scenarios about self-protection (six risky, six ambiguous scenarios).\(^5\) Risk and ambiguity are manipulated as a within-subject treatment. More specifically, each group of students are asked first the risk situation where the probability of occurrence of the event and the monetary loss amount are given as exact numbers. Then the same students are asked scenarios with ambiguous event. In this case the probabilities are still exact numbers however this time the loss amounts are given either as best estimate of an expert or as an interval. Hence, the two representations of loss amount ambiguity (best estimate and interval of loss amounts) are treated between subjects (through different sessions).

In details, the loss amounts of 3 Euro and 8 Euro out of 10 Euro with probabilities of the occurrence of the loss event being 3 percent, 50 percent, and 80 percent are used for the sake of remaining compatible with prior experiments in the literature. For the risky scenarios, exact probabilities and loss amounts are stated. For the ambiguous scenarios, only the probabilities are exactly known by the subjects, the loss amounts are operationalized as ‘ambiguous’ in two

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\(^4\)The actual return on investment (ROI) is given as 16% where in the loss domain they use the lottery; 14 percent for sure for risky versus 10 percent-18 percent for ambiguity and in the gain domain they use the lottery; 18 percent for sure for risky versus 9 percent-27 percent for ambiguity.

\(^5\)The scenarios within each situation are arranged in random order. Ambiguous scenarios are presented before the risky ones.
TABLE 1
Summary of experimental design

Do individuals perceive self-insurance and self-protection differently? (Framing effect)
(Between subject factor)
- Self-insurance reduces the amount of loss
- Self-protection reduces the probability of occurrence of loss

How much does valuation under ambiguity differ from valuation under risk? (Within subject factor)
- Risky scenarios (probability and loss amount are exactly known)
- Ambiguous scenarios (probability is known, but loss amount is not known exactly)

What is the impact of different representation of ambiguity? (Between subject factor)
- Best estimate
- Interval of loss amount

different ways: best estimate⁶ (the point estimate which is exactly the same as the risky case but through the wording used in the scenario is made imprecise to the subjects) and an interval of loss size (where the mean of the two extremes in the interval equals to the ‘best estimate’). 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, for the situation where the probability of loss being 50 percent and the amount of loss is 8 euro: both Scenario A and Scenario B are examples of self-insurance scenarios for ambiguity, however, Scenario A is an example of ‘best estimate’ representation type of ambiguity and Scenario B is an example of ‘interval’ representation type of ambiguity.

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 percent 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 percent 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.

⁶By using the point estimate representation for outcome ambiguity, we intent to test whether Einhorn and Hogarth’s (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.
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 indicate 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 has 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 play the randomly selected scenario. If the event occurs, they face a money loss and if the event does not occur, they keep their initial endowment. After all of the subjects complete their decisions for all twelve scenarios, the computer randomly selects one of the scenarios to play out for real, so it determines whether the event would occur or not through a random mechanism (with respect to the probability stated in the scenario).7

IV. EMPIRICAL RESULTS

80 students from Jena University are recruited randomly, using the ORSEE software (Greiner, 2004) to participate in the experiment and the design is computerized through using z-Tree (Fischbacher, 2007). Participants receive written instructions after being seated at a computer terminal.8 A sample of the instructions is available in the Appendix. Information regarding the demographic characteristics of the participants are collected through a very short questionnaire just before the experiment. The sample contains 49 percent females. The average age level is 24 years and the average monthly income level is 404 Euros. All of the subjects, except for one, are single.

The results of the analyses will be represented as follows: first, the differences between self-insurance and self-protection under risky situations (known probability and loss amount) will be examined, then we will test whether subjects give different willingness-to-pay values for these mechanisms in risky versus ambiguous loss amount situations. Third, the two different representations of loss amount ambiguity are examined, following the investigation of the existing theoretical models’ fitness to our data.

IV.1 Differences in the risk reduction mechanisms

Means, medians, and standard deviations of WTP 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. When we look at the mean values, we can easily conclude that, consistent with intuition, as the probability of the occurrence of the event and the loss amount increase, the individuals willingness-to-pay to take precautions both as self-insurance (to reduce the loss amount to zero) and the self-protection (to reduce the probability of the occurrence of the event to zero) increase. Further, there seems to be no extreme difference between the mean values of the willingness-to-pay values for these two precautions. Yet, a more detailed statistical nonparametric analysis is needed for more precise conclusion.

As shown in Table 3, the Mann-Whitney U-test for independent samples is used to test the difference between the mean values of the willingness-to-pay values for self-insurance and self-protection. This test shows that, based on the differences in mean values, it is difficult to conclude that a ‘framing effect’ exists due to the usage of the two different risk reduction mechanisms. More specifically, the distribution of WTP values to reduce the probability

7It is important to note that participants are paid real money they earned from the experiment. See Starmer and Sugden (1991) for eliciting true preferences through randomly selecting one scenario.

8The original instructions were in German.
### Summary statistics of individual WTP values

| Probability of loss-Loss amount | Mean       | Standard deviation | Number of subjects |
|--------------------------------|------------|--------------------|--------------------|
| **Self-protection (risky situation)** |            |                    |                    |
| 50%-8 Euro                    | 6.000      | 2.112              | 40                 |
| 50%-3 Euro                    | 2.175      | 1.824              |                    |
| 80%-8 Euro                    | 6.875      | 2.197              |                    |
| 80%-3 Euro                    | 2.450      | 1.535              |                    |
| 3%-8 Euro                     | 2.270      | 2.574              |                    |
| 3%-3 Euro                     | 1.175      | 1.662              |                    |
| 50%-8 Euro                    | 6.025      | 1.954              | 40                 |
| **Self-insurance (risky situation)** |            |                    |                    |
| 50%-3 Euro                    | 1.950      | 1.395              |                    |
| 80%-8 Euro                    | 7.300      | 2.138              |                    |
| 80%-3 Euro                    | 2.825      | 1.599              |                    |
| 3%-8 Euro                     | 1.975      | 2.010              |                    |
| 3%-3 Euro                     | 1.075      | 1.542              |                    |
| 50%-8 Euro                    | 5.550      | 2.163              | 20                 |
| **Self-protection (Best estimate)** |            |                    |                    |
| 50%-3 Euro                    | 2.500      | 1.791              |                    |
| 80%-8 Euro                    | 7.200      | 1.852              |                    |
| 80%-3 Euro                    | 3.650      | 2.345              |                    |
| 3%-8 Euro                     | 2.350      | 2.960              |                    |
| 3%-3 Euro                     | 1.500      | 1.820              |                    |
| 50%-8 Euro                    | 5.000      | 2.026              | 20                 |
| **Self-insurance (Best estimate)** |            |                    |                    |
| 50%-3 Euro                    | 2.700      | 2.515              |                    |
| 80%-8 Euro                    | 5.750      | 2.826              |                    |
| 80%-3 Euro                    | 2.900      | 1.372              |                    |
| 3%-8 Euro                     | 2.300      | 2.657              |                    |
| 3%-3 Euro                     | 1.900      | 2.712              |                    |
| 50%- 6–10 Euro                | 5.250      | 1.970              | 20                 |
| **Self-protection (Interval of loss amount)** |            |                    |                    |
| 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              |                    |
| 50%- 6–10 Euro                | 5.400      | 1.875              | 20                 |
| **Self-insurance (Interval of loss amount)** |            |                    |                    |
| 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              |                    |

(self-protection) and WTP values to reduce the loss amount (self-insurance) are not statistically different from each other (supporting Hypothesis 1 of this study) under risk.\(^9\)

### IV.2 Valuation under risky and ambiguous loss situations

To test whether individual valuations of SISP differ between ambiguous loss amount situations and risky situations, the Wilcoxon rank-sum test is used. According to the test results summarized

\(^9\)The results did not change when the potential loss is all the endowment, 10€.
TABLE 3
Mann-Whitney test between risk-reduction mechanisms (one-tail test): values of U**

| Risky WTP* | 50%-8 | 50%-3 | 80%-8 | 80%-3 | 3%-8 | 3%-3 |
|------------|-------|-------|-------|-------|------|------|
| Ambiguous WTP |       |       |       |       |      |      |
| - Best estimate | 170 | 199 | 154 | 167 | 194 | 196 |
| - Interval of loss amount | 191 | 192 | 198 | 176 | 178 | 183 |

Notes: *For risky WTP values, 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
Wilcoxon rank-sum test between risky and ambiguous WTP values (Z values)

| Probability of loss- Amount of loss out of 10 Euro | 50%-8 | 50%-3 | 80%-8 | 80%-3 | 3%-8 | 3%-3 |
|---------------------------------------------------|-------|-------|-------|-------|------|------|
| Self-insurance                                    |       |       |       |       |      |      |
| - 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 |
| Self-protection                                   |       |       |       |       |      |      |
| - 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 |

Note: *Significant at 95% confidence level in that the risky and ambiguous willingness-to-pay (WTP) values differ in distribution.

in Table 4, the Z values indicate that in the majority of the loss situations ambiguous and risky WTP values were derived from the same parent distribution. Supporting Hypothesis 2, this result is consistent with Cohen et al. (1985) and Camerer and Kunreuther (1989).

IV.3 Representation of loss amount (outcome) ambiguity

It has been argued that, while ‘best estimate’ and ‘interval of loss amounts’ representations of ambiguity have the same expected values, because they differ in their variances, individuals perceive the interval of loss amounts representation to be more ambiguous than the best estimate one. However, our analysis suggests that this may not be the case because a Mann-Whitney U-test (for probability of loss and amount of loss separately) reveal no significant differences between valuations of the two representations (Table 5). That is, subjects seem to perceive the best estimate and the interval of loss amounts representations of ambiguity in the same fashion.10

IV.4 Consistency of the valuations with the theoretical models

Most theoretical models for ambiguity is based on risk and ambiguity attitudes. For that, the individual risk and ambiguity attitudes are calculated. To determine individual risk attitudes, we calculated the mean values of the risk ratios and to determine individual ambiguity attitudes we calculated the mean values of the ambiguity ratios. The risk ratio equals to WTP for the

10The same result is supported by Kruskall-Wallis test for homogeneity of the ambiguity representations.
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**TABLE 5**
Mann-Whitney U-test for independent samples between the two representations of ambiguity

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

**Note:** 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 6**
The mean values of risk and ambiguity ratios to determine individual attitudes to risk and ambiguity

| Probability of loss- Amount of loss out of 10 Euro | 50%–8 | 50%–3 | 80%–8 | 80%–3 | 3%–8 | 3%–3 |
|---------------------------------------------------|-------|-------|-------|-------|------|------|
| **Risk ratios**                                   | 1.325 | 1.642 | 1.066 | 1.479 | 7.7604| 14.165|
| **Ambiguity ratios**                              | **1.325** | **1.642** | **1.066** | **1.479** | **7.7604** | **14.165** |
| **Self-insurance**                                | 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 |
| **Self-protection**                               | 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 |

**Notes:** *The risk ratio is calculated as WTP/EV. A risk ratio that is greater than one implies risk aversion, while a risk ratio smaller than one means risk loving (seeking) behaviour.
**The ambiguity ratio is calculated as the WTP value under ambiguous situation divided by the corresponding WTP value 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 6 shows that the average level of risk ratios are statistically greater than one (according to one-sample t-tests), indicating a general risk aversion behaviour. Further, at the probability level of 3 percent, subjects behave substantially more risk averse.\(^{11}\) Also provided in Table 6 are individual ambiguity attitudes. Using these figures, one can evaluate the Einhorn and Hogarth model with respect to loss amount ambiguity. The mean values of ambiguity ratios indicate that subjects are ambiguity averse (the average of the ratio is significantly greater than one based on a one sample t-test) for low loss amounts (3 Euros). For high loss amounts (8 Euros), however, the ratio is not significantly different from one, indicating risk neutrality. Therefore, these results

\(^{11}\) Scheffe test that is used for grouping the means in homogeneous subsets displays the WTP values for 50 percent and 80 percent probabilities in the same group, while WTP values for 3 percent probability belongs to a separate group.

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are somewhat in line with Einhorn and Hogarth model predictions (supporting Hypothesis 3). No evidence is found to support Hypothesis 4, however.

Table 7 summarizes the number of the subjects that behaved consistent with the predictions of each of several 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, 20 percent of the subjects were consistent with the predictions of EUT, while approximately 28 percent of the subjects were consistent with the Anchoring and Adjustment model, while only 6 percent of the responses supported the Maximin model predictions. More important, more than 31 percent of the subjects did not behave consistent with any of the models (expected utility, anchoring and adjustment, maximin, ambiguity preference, or ambiguity aversion) considered.

V. CONCLUSIONS

This paper does not only provide experimental evidence to compare the individual valuations of two risk reduction mechanisms; self-insurance and self-protection, in risky situations, but also is the first attempt to investigate how individual valuations for these mechanisms in ambiguous versus unambiguous outcome (loss size) situations. The results are in line with the ones for the probabilistic ambiguity, in that individuals are found to respond to self-insurance and self-protection framing conditions similarly.

In addition, findings indicate that individuals’ valuations of these two risk reduction mechanisms are only minimally and no significantly different between ambiguous and risky situations (also in line with the results of Cohen et al., 1985 and Camerer and Kunreuther, 1989). This conclusion, consistent with Expected Utility Theory, may indicate that the effects of probabilistic ambiguity and outcome ambiguity on choices are somewhat similar (e.g., Schoemaker, 1991; Camerer and Weber 1992; Gonzalez-Vallejo and Shapiro, 1996). In addition, 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 type of the ambiguity representation. This result supports the conclusions of Di Mauro and Maffioletti’s (2004) study. They examined differences between ‘best estimate’ and ‘interval’ representations of probabilistic ambiguity which also implied that there was a parallelism among the representations of ambiguity.

The results about the individual risk attitudes confirm the presence of the well-known fourfold pattern of risk attitude which is also one of the features of Prospect Theory (e.g., Kahneman and Tversky, 1979; Tversky and Kahneman, 1992). Accordingly, individuals are found to be risk
averse for losses, particularly at the low probability conditions. As for the individual ambiguity attitudes, subjects are found to be ambiguity averse for low loss amounts. For high loss amounts, however, they become ambiguity neutral. This finding provides evidence in favor of an outcome based anchoring and adjustment process, in that individuals appear to shift their attitudes towards a more ambiguity seeking stance as the loss amount increases.

Finally, the analysis in the present study on ambiguity in the loss amount did not strongly support any single one of the theoretical frameworks, namely, expected utility, anchoring and adjustment, maximin. Remarkably, 31 percent of the subjects did not behave consistent with any of the models. This particular finding suggests that more theoretical work needs to be done in this area.

The study has several limitations that also indicate avenues for future research. Specifically, we suggest that a series of experiments should be designed using other incentive mechanisms, different representations of ambiguity (e.g., sets of outcomes) and different settings (that incorporate separate versus joint effects of risk reduction mechanisms). In Lee (1998), SISP is investigated as ‘self-insurance-cum-protection (SICP)’ that represents a risk management tool that reduces both the probability of loss and the size of loss. He claims that there are many actions individuals face in practice, for example, ‘high quality brakes reduce both probability of an automobile accident and the magnitude of a loss if an accident occurs’. Further empirical studies should take into account the SCIP mechanism to contribute to a better understanding. In addition, the risk reduction mechanisms should be investigated and compared for different kinds of risky events such as environmental risks, terrorism, and workplace risks. Given the theoretical and practical relevance of the findings, much research needs to be done in this area in order to advance risk management strategies.

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**SUPPORTING INFORMATION**

Additional Supporting Information may be found in the online version of this article at the publisher's website:

**Appendix S1**