

# Determinants of Probability Neglect and Risk Attitudes for Disaster Risk: An Online Experimental Study of Flood Insurance Demand among Homeowners

Peter John Robinson <sup>1,\*</sup> and W. J. Wouter Botzen<sup>1,2,3</sup>

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Little is known about why individuals place either a high or a very low value on mitigating risks of disaster-type events, like floods. This study uses panel data methods to explore the psychological factors affecting probability neglect of flood risk relevant to the zero end-point of the probability weighting function in Prospect Theory, and willingness-to-pay for flood insurance. In particular, we focus on explanatory variables of anticipatory and anticipated emotions, as well as the threshold of concern. Moreover, results obtained under real and hypothetical incentives are compared in an experiment with high experimental outcomes. Based on our findings, we suggest several policy recommendations to overcome individual decision processes, which may hinder flood protection efforts.

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**KEY WORDS:** Flood insurance demand; incentives; probability neglect; prospect theory; risk preferences

## 1. INTRODUCTION

Low-probability/high-impact (LPHI) risks, such as floods, are increasing due to socioeconomic developments like population and economic growth in disaster-prone areas, as well as climate change (IPCC, 2012). Individuals possess cognitive limitations when making protection decisions against these risks (Browne, Knoller, & Richter, 2015; Meyer, Baker, Broad, Czajkowski, & Orlove, 2014). They often have difficulties assessing their likelihoods and fail to insure against them, even when premiums

are subsidized (Dixon, Clancy, Seabury, & Overton, 2006; Kunreuther & Pauly, 2004; Petrolia, Landry, & Coble, 2013). One explanation for this behavior is that individuals are boundedly rational and have difficulties assessing costs and benefits of insurance in a rational expected utility maximization (Conlisk, 1996). This can be the case for LPHI risks, with which individuals have little experience and opportunities for learning, such as learning about the benefits of insurance.

Regarding low probabilities and probability weighting in Prospect Theory, Tversky and Kahneman (1992, p. 303) remark that, “the (probability weighting) function is not well-behaved near the endpoints, and very small probabilities can be either greatly over-weighted or neglected.” Barberis (2013) reviews the literature about LPHI risks and highlights the absence of research in understanding why individuals either place a high or an extremely low weight on these types of events, which may be consistent with individual differences in probability weighting.

<sup>1</sup>Department of Environmental Economics, Institute for Environmental Studies, VU University Amsterdam, De Boelelaan, Amsterdam, The Netherlands.

<sup>2</sup>Utrecht University School of Economics (U.S.E.), Utrecht University, Utrecht, The Netherlands.

<sup>3</sup>Risk Management and Decision Processes Center, The Wharton School, University of Pennsylvania, PA, USA.

\*Address correspondence to Peter John Robinson, Institute for Environmental Studies, VU University Amsterdam, De Boelelaan 1087, 1081 HV Amsterdam, The Netherlands; peter.robinson@vu.nl.

A number of emotion-based models have been proposed to govern risk judgments (Samuelson & Zeckhauser, 1988; Tversky & Kahneman, 1974). Loewenstein and Lerner (2003) suggest that anticipated emotion (regret) and immediate emotion (worry and mood) impact decisions. Moreover, Slovic, Fischhoff, Lichtenstein, Corrigan, and Combs (1977) proposed that risks are ignored when the perceived probability of that risk is below a threshold of concern. It has, to our knowledge, not been examined yet how flood insurance demand relates to these factors in an experiment with stated flood probabilities that resemble realistic flood risks for homeowners. This research aims to explain risk-taking behavior under low-probability flood risks to improve risk management policy by suggesting ways to overcome the components of individual emotion that hinder flood protection efforts.

An economic experiment was conducted with 1,041 Dutch homeowners. The experiment elicited maximum willingness-to-pay for insurance for prospects of probability and loss combinations framed in the flooding context. We included survey questions to elicit psychological variables, as well as socioeconomic factors. A secondary objective of this article is to compare risky behavior under real incentives based on the random problem selection mechanism (RPSM) and the Becker, DeGroot, and Marschak (1964) method to a hypothetical condition. Based on the data, we estimate panel data models of probability neglect of flood risk (a willingness-to-pay of zero for flood insurance), and of willingness-to-pay for flood insurance.

The article is structured as follows: Section 2 provides motivation for variables included in the analysis and hypotheses of their expected effects. Section 3 describes the experiment implementation and design. Section 4 presents the method and main results related to the panel data models to establish determinants of probability neglect of flood risk and willingness-to-pay for flood insurance. This is followed by a discussion and policy recommendations in Section 5. Section 6 concludes the article.

## 2. MOTIVATION AND HYPOTHESES

### 2.1. Psychological Factors

The objective of this article is to explain risk-taking behavior under low-probability flood risks. A bimodal pattern of risk attitudes has been shown

to prevail in previous insurance experiments that simulate LPHI risk (e.g., McClelland, Schulze, & Coursey, 1993; Papon, 2008; Schade, Kunreuther, & Koellinger, 2012). On the one hand, individuals may perceive the probability of loss to be below their threshold of concern and remain uninsured. In practice, this behavior has been documented by the refusal to purchase subsidized insurance policies against natural disasters (Kunreuther & Pauly, 2004; Kunreuther et al., 1978). While on the other hand, individuals may attach a subjective probability to the loss, which is far in excess of the objective one. This subgroup will have very high demand for insurance against low-probability risks (e.g., Brouwer, Tinh, Tuan, Magnussen, & Navrud, 2013).

One might come up with a suitable metric for probability neglect analogous to Tversky and Kahneman's (1992) quotation in Section 1. A possible candidate in the context of flood insurance demand is a willingness-to-pay of zero for insurance. Probability neglect, which we assume is the rounding of very low probabilities to zero, is difficult to explain by Expected Utility Theory (von Neumann & Morgenstern, 1944) due to its linear processing of probabilities. Under Expected Utility Theory, zero willingness-to-pay for flood insurance is explained by extreme convexity of the utility function. It seems unlikely that individuals would process losses that are large in magnitude as close to zero. Our conjecture is similar to Rabin (2000), who provides evidence that utility curvature as a sole determinant of risk attitudes can imply implausible risk preferences over large stakes. Moreover, individuals placing either a large or a small value on mitigating LPHI risks is difficult to explain with utility curvature alone (Botzen & van den Bergh, 2012b). Therefore, we define zero willingness-to-pay for flood insurance as probability neglect of flood risk. Probability neglect has also been cited as a standard explanation for the refusal to protect oneself against disaster risks (e.g., Kunreuther & Michel-Kerjan, 2015). In addition, we will investigate factors influencing individuals' risk preferences according to their maximum willingness-to-pay for flood insurance values, while we recognize that these values do not separate risk attitudes due to either probability weighting or outcome sensitivity.

Loewenstein and Lerner (2003) suggested two ways emotion can impact decisions. The first is *anticipated emotion*, which relates to how individuals expect to feel under different outcomes. This could materialize as regret if individuals feel that they did not make an *ex ante* optimal decision (Loomes & Sugden,

1982).<sup>4</sup> Individuals may purchase insurance against potential large losses to avoid feeling regret (Braun & Muermann, 2004). Insured individuals may also view insurance as an investment and expect financial return on their policy (Krantz & Kunreuther, 2007). If losses do not occur, then they may regret paying for insurance.

- H1:** Individuals with more anticipated regret about uninsured flood losses will have higher flood insurance demand.
- H2:** Individuals with more anticipated regret about insurance payments in the event of no flood will have lower flood insurance demand.

The second type of emotion discussed by Loewenstein and Lerner (2003) is *immediate emotion*, present at the moment of the decision. Immediate emotion can be subcategorized into *incidental emotions* induced by factors unrelated to the decision, and *anticipatory emotions* arising from consequences of the decision itself. A number of studies have explored incidental emotion and probability weighting (Fehr-Duda, Epper, Bruhin, & Schubert, 2011; Schulreich et al., 2014; Traczyk & Fulawka, 2016). These studies find that a better mood increases risk-seeking behavior.

- H3:** Individuals in a better mood will have lower flood insurance demand.

Anticipatory emotion may relate to worry about flooding. For example, there is often a significant relation between worry about flood risk and demand for flood risk mitigation measures (Bubeck, Botzen, & Aerts, 2012). Furthermore, Botzen, Kunreuther, and Michel-Kerjan (2015) showed that worry about flooding is associated with greater anticipated flood damage and higher perceived flood probabilities.

- H4:** Individuals with more worry about flooding will have higher flood insurance demand.

<sup>4</sup>Loomes and Sugden's (1982) Regret Theory captures risk preferences due to regret and rejoicing, however, the theory allows equal probability distributions over outcomes to not be equivalent, leading to violations of the equivalence axiom (Loomes & Sugden, 1982, table 6). Regret Theory also abandons the transitivity axiom. However, the aim of our study is to investigate whether anticipated regret elicited on an attitudinal response scale relates to risk preferences (measured according to flood insurance demand) for the low probabilities that typify flood risks. The objective of our article is therefore unrelated to examining the predictive power of Regret Theory, and measuring risk preferences according to the Regret Theory model.

Individuals may also dismiss low-probability events judged to be below a subjective *threshold of concern* (Slovic et al., 1977). Kunreuther and Pauly (2004) hypothesized that people are reluctant to purchase flood insurance because of search costs regarding the collection of accurate information on the value of insurance. If the perceived flood probability is not high enough (to surpass the threshold of concern), individuals will not account for the probability, and make minimal effort to gather insurance information. Botzen et al. (2015) showed that flood risk awareness, as well as perceived probability and damage amounts, are lower for individuals who believe flood risks are below their threshold of concern.

- H5:** Individuals who are more likely to believe flood probabilities are below their threshold of concern will have lower flood insurance demand.

## 2.2. Incentives

Our investigation of incentives is secondary to the psychological and subjective factors highlighted in Section 2.1, although we find it an important topic due to the growing number of insurance demand studies using similar experiment procedures to ours (e.g., Kunreuther & Michel-Kerjan, 2015; Schade et al., 2012; Zimmer, Gründl, Schade, & Glenzer, 2018). Common practice in experimental economics is to provide incentives that align experimental choices with incentives faced in actual market decisions (Camerer & Hogarth, 1999). Without incentives, individuals may become risk seeking due to a *hypothetical bias*.

A general challenge for high loss experiments is finding a way to incentivize decisions, because individuals require significant endowments (Etchart-Vincent, 2009). One method that mitigates this complication somewhat is the RPSM. The RPSM selects one experiment task at the end of the experiment with a randomization device, and individuals are paid according to the outcome of the selected task. The procedure is attractive if individuals treat tasks independently (Cubitt, Starmer, & Sugden, 1998). Kunreuther and Michel-Kerjan (2015) incorporated the RPSM in an experiment involving sizable experimental losses. Their payoffs were exchanged into lower amounts paid to a small number of individuals. However, the study did not aim to explore the impact this procedure has on decision making. Nevertheless, Bolle (1990) recommends paying one randomly

Table I. Hypotheses

Hypothesis	Topic	Hypothesized Effect
H1	More regret about uninsured flood losses	Higher flood insurance demand
H2	More regret about flood insurance payment	Lower flood insurance demand
H3	Better mood	Lower flood insurance demand
H4	More worry about flooding	Higher flood insurance demand
H5	Flood risk is judged below the threshold of concern	Lower flood insurance demand
H6	Hypothetical incentives	Lower flood insurance demand

selected subject the sum of the experimenter’s budget under low decision costs and anonymous choices, based on a theoretical and empirical investigation in ultimatum bargaining experiments.

Etchart-Vincent and l’Haridon (2011) compared the effect of three payment schemes on risk preferences: hypothetical losses, losses from an endowment, and real losses based on the RPSM. They found no significant differences between the three conditions regarding probability weighting. We investigate how the RPSM with larger experimental outcomes exchanged into lower amounts affects decision making compared to hypothetical losses.

**H6:** Individuals are more willing to take risks under hypothetical incentives, which will be reflected in their lower flood insurance demand.

Table I summarizes the hypothesized effects of our variables of interest on flood insurance demand. Note that it is unclear from the previous literature whether the variables of interest will influence flood insurance demand through levels of willingness-to-pay for insurance or through probability neglect of flood risk. Therefore, we state the hypothesized effect of each variable on flood insurance demand in general.

### 3. IMPLEMENTATION AND EXPERIMENT DESIGN

#### 3.1. Implementation

An online experiment was conducted with a sample of Dutch homeowners, primarily located within

dike-ring areas that face flood risk, which may be important for eliciting feelings related to flood risk. Online experiments obtain a large and diverse sample at low cost. Moreover, the method prevents participant communication, competitive behavior, and experimenter effects (Horton, Rand, & Zeckhauser, 2011). We acknowledge that individuals participating in online experiments may be less attentive and motivated than individuals in a laboratory in the presence of an experimenter (Oppenheimer, Meyvis, & Davidenko, 2009). We try to minimize these concerns by omitting individuals from the analysis who commit violations of stochastic dominance.<sup>5</sup>

All individuals were initially contacted via email, and were rewarded “Social Points” for participating, which can be exchanged into gifts via the survey company’s website ([www.multiscope.nl](http://www.multiscope.nl)).<sup>6</sup> Respondents are distributed over dike-ring areas with a low and relatively high flood risk.<sup>7</sup>

From the total sample of 1,041 individuals, 624 were randomly assigned to face real incentives (see Section 3.2), while no performance-based payment was provided to 417; 52.4% are male and median income is between €3,000 and €3,499; 61.7% had completed higher education; 13.1% are aged less than 35 years, 36.6% between 35 and 49 years, and 50.3% are 50 years and older. Older individuals were perhaps more likely to participate because we targeted homeowners. Renters do not pay for structural flood damage to their home, so this subgroup was excluded from the study.

#### 3.2. Insurance Decision Tasks and Variable Elicitation

Individuals were asked to imagine purchasing a property worth €240,000 in a flood prone area.<sup>8</sup>

<sup>5</sup>These are individuals who were willing to pay more for flood insurance under a given flood risk than under another flood risk with a higher flooding probability.

<sup>6</sup>The email did not state the nature of the experiment to prevent selection bias.

<sup>7</sup>In all, 48.2% of the sample live in dike-ring areas designed at standards 1/1,250, implying that dikes can withstand a 1 in 1,250 years flood event; 3.8% of the sample live in 1/2,000 areas, 7.8% live in 1/4,000 areas, and 18.3% reside in 1/10,000 areas. Moreover, 19.4% live outside dike-ring areas in land that cannot be flooded by rivers, therefore the probability of river flooding is zero; 0.8% live outside dike-ring areas in a river bed, therefore the probability of flooding is high although there is no official safety standard. The remaining 1.7% could not be classified because they provided invalid postcodes.

<sup>8</sup>€240,000 = approximate average purchase price for a home in the Netherlands in year 2016 (Statistics Netherlands, 2017).

Additional text stated that government compensation will not be granted for uninsured flood damages. We obtained maximum willingness-to-pay for insurance values for prospects of probability and loss combinations framed as flood risks. This article will focus on flood insurance demand for four realistic flooding probabilities in the Netherlands. Cities of high economic importance, such as Amsterdam and The Hague, are protected by dikes with an annual exceedance probability of 1 in 10,000. For dike-ring areas in the River Rhine delta, this likelihood is 1 in 1,250, although 1 in 1,000 may be less cognitively challenging for individuals to imagine. For homeowners located in less-protected areas, the annual probability of flooding can exceed 1 in 100 (Ermolieva et al., 2017). Overall, we elicited insurance demand under flood probabilities 1 in 10,000, 1 in 1,000, 1 in 100, and 1 in 20.<sup>9</sup>

Changes to flood risks were attributed to different water levels in rivers. Flood insurance decisions took place from an endowed bank balance of €60,000, and flood losses were also fixed at this value. This can bias behavior toward risk seeking if the individual views the endowment as a windfall gain (Thaler & Johnson, 1990), or risk aversion if the individual integrates the endowment into potential losses. However, Etchart-Vincent and l'Haridon (2011) found no such effects in an experiment similar to ours.

To elicit willingness-to-pay values, we used a two-stage procedure where individuals faced a payment card task and then a willingness-to-pay task. First, individuals were presented a yearly flood risk as well as 16 ascending insurance premium values between €1 and €60,000, with an additional option to remain uninsured. The values were logarithmically spaced to include risk-seeking/neutral/averse options into the elicitation task, which is not possible with equal spacing for large outcomes. According to these values, individuals were asked their maximum willingness-to-pay for flood insurance to fully cover the cost of property damages. Second, to obtain a more refined valuation, individuals were asked what they were at most willing to pay for flood insurance between the value chosen previously and the next highest value.<sup>10</sup>

<sup>9</sup>We also elicited demand under a number of other higher flooding probabilities, but this article will focus on these four flooding probabilities presented first to individuals.

<sup>10</sup>Given the online nature of our experiment, there is a risk that individuals would be tempted to give up on the experiment after a

Decisions were ordered ascending in the probability of flood loss. This method may induce order effects, but individuals should find this procedure cognitively easier than if decisions were to be randomized. We see this as an issue of counterbalancing the drawback of more random decision making and higher incidence of stochastic dominance violations, if individuals were to be given the decisions in a randomized order. Although randomizing the order would prevent order effects, evidence from our pretest and other studies (Etchart-Vincent & l'Haridon, 2011) suggested that individuals find it easy to deal with increasing probabilities, so this is why we adopted this method. This is particularly relevant because respondents were unsupervised in our experiment, and therefore may have been prone to stochastic dominance violations.

We paid one individual according to one flood insurance decision (selected at random) under real incentives. A 1% exchange rate was applied to these earnings, so the selected individual could earn €600 should he or she not experience a loss in the chosen decision. For payment, we applied the Becker et al. (1964) mechanism: A premium for which flood insurance is sold is selected at random between the upper and lower bounds of the potential flood loss.<sup>11</sup> If the individual is willing to pay a value equal to or greater than the premium, then he or she has purchased insurance at the price of the premium, otherwise he or she faces the flood risk uninsured. Individuals should make decisions consistent with true preferences according to the Becker, DeGroot, and Marschak (BDM) procedure, and this was explicitly stated.

The randomly selected player could not lose money from her/his own pocket in the experiment

short time if they perceived the tasks as too difficult. Therefore, we favor the two-stage procedure over more complex methods for determining risk preferences like the price list format, where participants make a series of discrete choices. The latter would require a sizable number of decisions, which may lower response rates. While more theoretically appealing risk preference elicitation procedures exist, collecting valuations directly has advantages (see Zeisberger, Vrecco, & Langer, 2012, pp. 364–365, for a discussion). However, it can be argued that the two-stage procedure may be cognitively demanding for individuals with high valuations because they were asked to provide their valuation between a wide interval. We opt to include these individuals in the analysis (apart from those who stated they would be willing to pay €60,000), but reduce the impact of these potential outliers by applying ln-transformations to the valuations.

<sup>11</sup>We left the bounds unspecified because respondents may anchor on the bounds, which can bias outcomes (Bohm, Lindén, & Sonnegård, 1997).

given that flood insurance decisions took place from an endowed bank balance of €60,000, and flood losses did not exceed this value. We note that respondents were unaware of whether or not a flood would occur during the experiment itself and did not know the randomly determined insurance premium selling price, therefore it is in their best interest to reveal their maximum willingness-to-pay for flood insurance. In theory, the payment mechanism satisfies the conditions of being salient because incentives are proportional to the good and bad outcomes of the experiment (Smith, 1982), and incentive compatibility because incentives are structured in a way that aims to reveal respondents' true preferences (Jaspersen, 2016). Due to the potentially complex nature of the BDM mechanism for some individuals, we illustrated the method graphically alongside written instructions.<sup>12</sup>

A series of Likert scale survey questions were presented following the flood insurance decisions. We measured anticipated regret using similar single-item measures to Robinson and Botzen (2018) and Keller, Harlam, Loewenstein, and Volpp (2011). Moreover, we adapted the incidental immediate emotion variable according to a question in Fehr-Duda et al. (2011). The question was asked prior to flood insurance decisions to minimize the impact of the insurance decisions on individual mood. Worry and threshold of concern were elicited using similar items to Botzen et al. (2015).

## 4. METHOD AND MAIN RESULTS

### 4.1. Method

We will perform two types of panel data regression analysis to explore the determinants of a willingness-to-pay of zero for flood insurance (probability neglect of flood risk), as well as variables that impact levels of willingness-to-pay for individuals who are willing to pay a positive amount. First, probability neglect is regressed on variables of interest and socioeconomic controls in random-effects Probit models. Second, we perform ln-level random-effects generalized least-squares (GLS) regressions using ln-transformed maximum willingness-to-pay for flood insurance values.<sup>13</sup> Random-effects models are used to account for between-respondent individual char-

acteristics and the within-respondent variation in flood risks. Fixed effects would not allow us to observe individual-specific characteristics because these are differenced out in the estimation procedure.

Results are displayed for flood probabilities, 1 in 10,000, 1 in 1,000, 1 in 100, and 1 in 20, because they span the annual probabilities of flooding for all dike-ring areas and some unprotected areas in the Netherlands. We control for gender, education, income, age, and individual location.<sup>14</sup> We control for income, not wealth, because there is a lot of missing data with regard to respondents' stated home values, which is an important determinant of wealth in the Netherlands. Respondents are perhaps less likely to know the value of their homes than their monthly incomes.

We omit 99 respondents who violated stochastic dominance in at least one of the four questions relating to their flood insurance decisions. These responses may confound our results either due to a lack of attentiveness, or because these individuals were still coming to grips with the format of questions. We omit an additional 2, 3, 6, and 10 responses for flood probabilities 1 in 10,000, 1 in 1,000, 1 in 100, and 1 in 20, respectively, where maximum willingness-to-pay for flood insurance was €60,000.

Table II provides an overview of the variables included in the analysis in the next section, including the way in which they were measured and how they are coded as well as their mean and standard deviation values. Although we do not transform variables of interest into dummy variables, which ensures we do not throw away potentially useful data, the acceptance/rejection of hypotheses is not influenced by whether we dichotomize these variables.

### 4.2. Results

Table III displays regression results for the random-effects Probit models of probability neglect (Models I and II) and the random-effects GLS models of willingness-to-pay for flood insurance for individuals who are willing to pay a positive amount (Models III and IV).<sup>15</sup> Models I and II show that

<sup>14</sup>It is important to note that individuals who live in higher flood risk areas display more worry about flooding (Spearman's  $\rho = 0.122$ ,  $p$ -value  $\leq 0.0001$ ), so it appears that subjective and objective risks correlate to some extent. The impact of worry on flood insurance demand may be sensitive to individual location; however, we find that including interactions between the risk and worry variables results in insignificant coefficient estimates on the interacting terms in the regression models ( $p$ -values  $> 0.05$ ).

<sup>15</sup>The analysis assumes that there is a discontinuity between probability neglect of flood risk and individuals who exhibit strong

<sup>12</sup>See the Appendix for the experiment instructions in English.

<sup>13</sup>Qualitative conclusions are also robust to random-effects Logit and Tobit model specifications.

Table II. Variables Included in the Analysis

Dependent Variables	Measurement	Coding	Mean	Std. Dev.	N
Probability neglect of flood risk	Willingness-to-pay of zero for flood insurance	Willing to pay zero for flood insurance = 1 and 0 otherwise	0.14		3,747
Willingness-to-pay	Maximum willingness-to-pay for flood insurance	Ln(maximum willingness-to-pay for flood insurance)	5.23	1.83	3,211
Independent Variables					
Regret uninsured loss	I would feel regret about not purchasing flood insurance if a flood occurs	Strongly disagree = 1 to strongly agree = 5	3.15	1.12	3,747
Regret insurance	I would feel regret about paying an insurance premium if no flood occurs	Strongly disagree = 1 to strongly agree = 5	2.90	1.21	3,747
Better mood	How has your day been going?	Badly = 1 to promising = 5	3.18	0.65	3,747
Worry	I am worried about the danger of flooding at my current residence	Strongly disagree = 1 to strongly agree = 5	1.70	0.87	3,747
Threshold of concern	The probability of flooding is too low to be concerned about	Strongly disagree = 1 to strongly agree = 5	3.62	1.07	3,747
Hypothetical	Dummy variable measure of incentives	Hypothetical = 1 and incentivized = 0	0.40		3,747
$P = 1$ in 1,000	Dummy variable measure of 1 in 1,000 flood probability	Flood probability 1 in 1,000 = 1 and 0 otherwise	0.25		3,747
$P = 1$ in 100	Dummy variable measure of 1 in 100 flood probability	Flood probability 1 in 100 = 1 and 0 otherwise	0.25		3,747
$P = 1$ in 20	Dummy variable measure of 1 in 20 flood probability	Flood probability 1 in 20 = 1 and 0 otherwise	0.25		3,747
Male	Dummy variable measure of gender	Male = 1 and female = 0	0.52		3,647
Education	Ordinal variable measure of education	Primary school = 1 to PhD = 6	3.67	1.18	3,647
Income	Ordinal variable measure of net monthly household income	Less than €1,000 = 1 to €5,500 or more = 9	5.67	2.15	3,647
Age	Ordinal variable measure of age	Less than 35 years = 1 to 50 years or older = 3	2.37	0.70	3,647
Risk	Ordinal variable measure of individual location	Zero river flooding risk = 1 to outside dike-ring in river bed = 6	3.44	1.69	3,647

Note: The statements and questions are translated from Dutch. Willingness-to-pay is only measured for individuals who are willing to pay a positive amount.  $P = 1$  in 10,000 is used as a reference category in the regression analysis. Interior education categories are high school to lower secondary education = 2 and higher secondary education = 3, bachelor's degree = 4, and master's degree = 5. Interior income categories are between €1,000 and €1,499 = 2, between €1,500 and €1,999 = 3, between €2,000 and €2,499 = 4, between €2,500 and €2,999 = 5, between €3,000 and €3,499 = 6, between €3,500 and €3,999 = 7, and between €4,000 and €5,499 = 8. The interior age category is between 35 and 49 years = 2. Interior risk categories are river flooding risk 1 in 10,000 = 2, river flooding risk 1 in 4,000 = 3, river flooding risk 1 in 2,000 = 4, and river flooding risk 1 in 1,250 = 5.

individuals who anticipate more regret for uninsured losses have a lower likelihood of probability neglect of flood risks. There is also an interac-

risk seeking. Nevertheless, our results are robust to considering probability neglect of flood risk as a boundary expression of extreme risk seeking rather than as a discontinuous phenomenon. That is, adding individuals who were willing to pay at most €1 and €2 to the category of individuals neglecting the probability of flood risk does not qualitatively change our results.

tion effect between this type of regret and the flood probability. That is, for higher flooding probabilities, individuals with more anticipated regret for uninsured losses are even less likely to neglect flood risks (random-effects Probit model  $p$ -values  $\leq 0.05$ ). We conjecture that this may be due to an increase in the saliency of this type of regret for higher probabilities, because uninsured losses are more likely. According to Model IV, this regret has only a level

Table III. Regression Results of the Influence of Variables of Interest on Flood Insurance Demand

Variable	Random-Effects Probit Model Results		Random-Effects GLS Model Results	
	Model I	Model II	Model III	Model IV
$P = 1$ in 1,000	0.063 (2.44)	-0.960 (2.79)	0.963** (0.31)	1.014** (0.32)
$P = 1$ in 100	-1.900 (2.56)	-3.489 (3.13)	1.691*** (0.31)	1.809*** (0.32)
$P = 1$ in 20	0.116 (2.58)	-1.503 (3.35)	2.256*** (0.31)	2.417*** (0.32)
Regret uninsured loss	-0.998*** (0.16)	-0.816*** (0.17)	0.139* (0.06)	0.134* (0.06)
Regret uninsured loss $\times P = 1$ in 1,000	-0.844** (0.28)	-0.902** (0.32)	0.020 (0.04)	0.010 (0.04)
Regret uninsured loss $\times P = 1$ in 100	-0.840** (0.31)	-0.889* (0.38)	0.030 (0.04)	0.016 (0.04)
Regret uninsured loss $\times P = 1$ in 20	-1.020** (0.32)	-1.065** (0.40)	0.081* (0.04)	0.065 (0.04)
Regret insurance	0.606*** (0.14)	0.520** (0.16)	0.006 (0.05)	0.022 (0.05)
Regret insurance $\times P = 1$ in 1,000	0.017 (0.25)	0.061 (0.29)	-0.109* (0.04)	-0.105** (0.04)
Regret insurance $\times P = 1$ in 100	0.020 (0.26)	0.076 (0.35)	-0.125*** (0.04)	-0.121*** (0.04)
Regret insurance $\times P = 1$ in 20	-0.083 (0.26)	-0.046 (0.37)	-0.163*** (0.04)	-0.159*** (0.04)
Better mood	-0.059 (0.25)	-0.044 (0.27)	0.136 (0.09)	0.097 (0.09)
Better mood $\times P = 1$ in 1,000	-0.394 (0.51)	-0.219 (0.58)	-0.014 (0.06)	-0.013 (0.06)
Better mood $\times P = 1$ in 100	-0.184 (0.58)	0.049 (0.69)	-0.026 (0.06)	-0.038 (0.06)
Better mood $\times P = 1$ in 20	-0.725 (0.59)	-0.505 (0.77)	-0.052 (0.06)	-0.071 (0.06)
Worry	-0.868*** (0.23)	-0.885*** (0.24)	0.153* (0.07)	0.163* (0.07)
Worry $\times P = 1$ in 1,000	0.400 (0.43)	0.419 (0.49)	-0.050 (0.05)	-0.048 (0.05)
Worry $\times P = 1$ in 100	-0.225 (0.46)	-0.230 (0.60)	-0.103* (0.05)	-0.102* (0.05)
Worry $\times P = 1$ in 20	0.360 (0.47)	0.397 (0.61)	-0.138** (0.05)	-0.138** (0.05)
Threshold of concern	0.599*** (0.16)	0.580*** (0.17)	-0.106 (0.06)	-0.114 (0.06)
Threshold of concern $\times P = 1$ in 1,000	-0.252 (0.29)	-0.183 (0.35)	0.006 (0.04)	-0.001 (0.04)
Threshold of concern $\times P = 1$ in 100	-0.324 (0.30)	-0.212 (0.40)	0.059 (0.04)	0.051 (0.04)
Threshold of concern $\times P = 1$ in 20	-0.702* (0.30)	-0.603 (0.42)	0.093* (0.04)	0.081 (0.04)
Hypothetical	-0.046 (0.32)	0.277 (0.37)	-0.311* (0.12)	-0.330* (0.13)
Hypothetical $\times P = 1$ in 1,000	-0.503 (0.61)	-0.368 (0.72)	-0.000 (0.08)	-0.018 (0.09)
Hypothetical $\times P = 1$ in 100	0.717 (0.67)	0.978 (0.88)	-0.006 (0.08)	-0.015 (0.09)
Hypothetical $\times P = 1$ in 20	0.585 (0.68)	0.859 (0.94)	0.094 (0.08)	0.089 (0.09)
Male		-0.643 (0.34)		-0.108 (0.11)
Education		-0.038 (0.15)		0.108* (0.05)
Income		-0.031 (0.08)		0.062* (0.03)
Age		0.317 (0.26)		-0.086 (0.08)
Risk		-0.069 (0.10)		0.004 (0.03)
Constant	-5.163*** (1.24)	-5.235** (1.68)	3.476*** (0.46)	3.082*** (0.55)
$N$	3,747	3,647	3,211	3,129
Number of respondents	940	915	866	845
Log likelihood	-768.011	-754.492		
Pseudo- $R^2$	0.306	0.318		
$R^2$			0.181	0.196

Note: Dependent variables are probability neglect of flood risk in Models I and II, and willingness-to-pay in Models III and IV. Only individuals who were willing to pay a positive flood insurance amount are retained in Models III and IV.  $P = 1$  in 10,000 is used as a reference category. Unstandardized coefficients are reported with standard errors in parentheses. Observations are lower for regression results with control variables because some individuals provided invalid postcode addresses and/or listed their education attainment as "Other."

\*\*\*, \*\*, and \* indicate significance at 0.1%, 1%, and 5% levels, respectively.

effect on levels of flood insurance individuals are willing to pay once socioeconomic characteristics have been controlled for (random-effects GLS model  $p$ -value  $\leq 0.05$ ).

In addition, Models I and II show that there is also a level effect of more anticipated regret about paying for insurance in the event of no flood, which relates to an increased likelihood of probability ne-

glect of flood risk (random-effects Probit model  $p$ -values  $\leq 0.01$ ). According to Models III and IV, there is an interaction effect as well between regret about paying for insurance and the flood probability regarding levels of willingness-to-pay. Only for flood probabilities greater than 1 in 10,000 are individuals who have more anticipated regret about paying for insurance willing to pay less for flood insurance



(random-effects GLS model  $p$ -value  $\leq 0.01$ ). There is no obvious explanation for this interaction effect with probability, although it suggests that individuals may simply neglect flood risk at the lowest flood probability if they are prone to this type of regret instead of thinking about how much less they are willing to pay.

More worry about flooding decreases the likelihood of probability neglect of flood risk in Models I and II as expected (random-effects Probit model  $p$ -values  $\leq 0.001$ ). Moreover, whereas there is a relatively large positive effect of worry on levels of willingness-to-pay at flood probability 1 in 10,000 and 1 in 1,000, this positive relation becomes lower in magnitude at probability 1 in 100 and 1 in 20 in Models III and IV (random-effects GLS model  $p$ -values  $\leq 0.05$ ). From our point of view, it is logical that individuals would employ risk perceptions (like worry) to a greater extent for lower probabilities that most individuals in our sample also face in practice.

The influence of incidental better mood is insignificant across all model specifications. Overall, our results suggest that context-specific anticipated and anticipatory emotion are more important determinants of probability neglect of flood risk and levels of overall willingness-to-pay than incidental emotion.

Moreover, Model II shows that individuals who are more likely to believe the probability of flooding is below their threshold of concern are more likely to neglect the probability of flood risk (random-effects Probit model  $p$ -values  $\leq 0.001$ ). However, there is no significant relation between threshold of concern and levels of willingness-to-pay once socioeconomic factors have been controlled for (see Model IV). This result demonstrates that individuals may simply round flood probabilities to zero if they are not concerned about them.

We find some evidence in favor of a hypothetical bias in the results, in that, hypothetical incentives are related to lower flood insurance demand, and the influence is apparent through levels of willingness-to-pay (see Models III and IV; random-effects GLS model  $p$ -values  $\leq 0.05$ ).

Apart from the variables of interest, we find a positive effect of higher education levels and incomes on willingness-to-pay for flood insurance in Model IV. One might be concerned that the influence of the psychological variables may, in part, be explained by respondents' home value. For example, an individual with a higher home value may worry more about flooding or be less likely to judge flood probabilities as falling below their threshold

of concern, and the influence of these variables on flood insurance demand could be partly explained by these relations. Nevertheless, we find that worry and threshold of concern are unrelated to property value (Spearman's rho  $p$ -values  $> 0.05$ ). We do find a rather weak negative relationship between the two regret variables and property value (Spearman's rho =  $-0.076$  for regret uninsured loss and  $-0.107$  for regret insurance,  $p$ -values  $< 0.05$ ). The former relation is quite difficult to explain, given that one might imagine more expensive property values to be positively related to the degree individuals anticipate regret about uninsured flood losses. In any case, as a robustness check we estimated the regressions with property value instead of income and find that the influence of regret across Models I, II, III, and IV is robust to this change (detailed results not shown here).

## 5. DISCUSSION

### 5.1. Discussion of Main Results

The first objective of this research was to explain risk-taking behavior under low-probability flood risks. Climate change will increase the probability of flood risks in many areas around the world, so the latter is important for defining subgroups who are less able to prepare for these events. The second goal was to compare decisions between a real incentives condition based on the RPSM and BDM mechanism to a hypothetical condition. Concerning the first objective, we find that emotions specific to flood risk (anticipated regret and anticipatory worry) better explain flood insurance demand than incidental emotion. Namely, an individual who is more likely to anticipate regret for uninsured flood losses has higher flood insurance demand, and an individual who is more likely to feel anticipated regret about paying for insurance in the event of no flood will demand less insurance. Moreover, worry about flooding relates to higher flood insurance demand. These outcomes support H1, H2, and H4. We reject H3 because no systematic mood influences were found regarding flood insurance demand.

Kunreuther and Pauly (2018) showed in a dynamic experiment involving a sequence of hurricane risks, that individuals who state high levels of unhappiness after experiencing a hurricane-related loss are more likely to purchase insurance against the next hurricane risk. Our results relating to

anticipated negative emotion if a flood occurs are consistent with Kunreuther and Pauly (2018), who examined emotions at the moment a loss is experienced, rather than anticipated emotions before an event.

Our study adds to the previous literature regarding the affect heuristic, according to which individuals make judgments and perceive risks based on their affective response to a given risk (Slovic, Finucane, Peters, & MacGregor, 2007). In a review study of flood risk perceptions by Kellens, Terpstra, and De Maeyer (2013), it was found that affect is an important ingredient for successful risk communication and in formulating flood risk perceptions.

In a hypothetically incentivized willingness-to-pay study by Botzen and van den Bergh (2012b) as well as in a choice experiment by Botzen and van den Bergh (2012a), it was found that a range of risk perception measures, like a homeowner's perceived risk of suffering flood damages and expected damage amounts, relate to demand for flood insurance in the Netherlands. Our article focuses on risk perceptions elicited through stated levels of anticipatory worry about flooding, which provides the same qualitative conclusions to that of the latter two studies. A novel element of our findings here is that we show that risk perceptions in terms of worry or potential utilization of the affect heuristic influence flood insurance demand, at least for probabilities that individuals face in practice and can perhaps better imagine. Hence, communicating about actual flood risk in a way that includes affect, can be effective in increasing demand for flood insurance among people who currently lack flood coverage, like in the Netherlands.

Individuals who believe the probability of flooding is below their threshold of concern are less likely to demand flood insurance, supporting H5, and the influence is through probability neglect. This supports Kunreuther's (1996) conjecture that individuals who use a threshold model treat probabilities that fall below threshold levels as having a zero chance of occurrence.

Concerning the second goal, individuals exposed to hypothetical incentives are willing to pay less for flood insurance, providing support for H6 and the hypothetical bias. Contrary to the results about psychological factors, hypothetical incentives impacted the levels of flood insurance individuals were willing to pay, rather than whether or not they were willing to pay a positive amount.

## 5.2. Policy Recommendations

Home and contents insurance does not cover flood damage from river-dike failure or by sea water in the Netherlands. The government can provide compensation for flood damage, but the decision to grant as well as the extent of relief relies on political decision making (Botzen & van den Bergh, 2008). Developing a workable flood insurance system is a challenge, given the potential for extreme losses, and the private sector is reluctant to offer coverage because of this. There also exists considerable uncertainty with regard to predicting floods, which tends to increase the cost of insurance (Kunreuther, 1996). Nevertheless, a profitable flood insurance market might be a feasible way to tackle flood risks in the Netherlands according to estimates in Botzen and van den Bergh (2012b). Although due to capital constraints, government involvement as a reinsurer may also be necessary (Botzen & van den Bergh, 2008). An important precondition for a well-functioning flood insurance arrangement is sufficient demand.

Comparing maximum willingness-to-pay for flood insurance,  $WTP(X)$ , to expected flood damage,  $EV(X)$ , we can obtain risk premiums that individuals are willing to pay for flood insurance:  $RP(X) = WTP(X) - EV(X)$ , where  $RP > 0 \leftrightarrow$  risk aversion,  $RP = 0 \leftrightarrow$  risk neutrality,  $RP < 0 \leftrightarrow$  risk seeking. Mean risk premiums for individuals who are willing to pay for flood insurance are €207, €398, €437, and €-948 under flood probabilities 1 in 10,000, 1 in 1,000, 1 in 100, and 1 in 20, respectively. Therefore, for the low flood probabilities that cover most of the sample area, individuals who are willing to pay for flood insurance, are willing to pay a significant mark-up over expected damages. The percentage of the sample willing to pay zero for flood insurance, corresponds to 26%, 13%, 10%, and 8%, respectively. Overall, these results show that there is a subgroup of the Dutch population for which the willingness-to-pay is sufficient to cover insurance costs, while there is also an important share of people among which demand is insufficient. Therefore, the results are broadly in line with the bimodal pattern of risk attitudes, which has been shown to prevail in previous insurance experiments involving low probabilities.

Additional policies can aid in the development of an efficient flood insurance arrangement to decrease reliance on *ad hoc* government compensation. The policies can be separated into those that aid in risk

communication, those that educate and provide information as well as those related to the design of flood insurance.

Individuals who are unwilling to insure regardless of the flood probability may benefit from better risk communication. Botzen and van den Bergh (2012b) find that risk ladders showing flood risks with more common risks, like fire or theft, increase risk comprehension, as well as the level of demand for flood insurance and its sensitivity to probability changes. Individuals typically have a difficult time understanding probability information (Kunreuther, Novemsky, & Kahneman, 2001), and risk ladders provide a practical way of signaling flood risks. Moreover, Keller, Siegrist, and Gutscher (2006) found that flood risks described for one year, are perceived as lower than the same risk reframed for a longer time period. Individuals may be less likely to judge flood risks as below a threshold of concern if the risk is described in a multiyear context (Botzen et al., 2015). Schwarcz (2010) describes possible risk communication strategies for disaster type risks consistent with what Thaler and Sunstein (2003) defined as “libertarian-paternalism” or nudge strategies, such as framing the risk for more than one time period, like the period during which someone on average lives in a flood-prone area (e.g., 25 years). Such a strategy is attractive in the short run given its low implementation costs.

Homeowners may regret paying for flood insurance when flood losses are not experienced, and finding ways to convince policyholders that “no return on an insurance policy is the best return” poses challenges (Krantz & Kunreuther, 2007). Information campaigns about the importance of insurance against flood risks may overcome these difficulties. For instance, the German Insurance Association has implemented risk awareness campaigns to increase flood insurance penetration, the first of which was launched in Bavaria in 2009 following the destructive flood that hit the region in 2005 (Surminski & Thieken, 2017).

With respect to the design of flood insurance, individuals may prefer policies that cover risks for a longer period of time (Kunreuther & Michel-Kerjan, 2015). Multiyear insurance with penalty costs applied to early cancellation may prevent short-sighted behavior in subgroups of individuals that regret paying for insurance should they not suffer losses. Moreover, LPHI risk insurance bundled with other more likely potential losses has been also shown to increase insurance demand (Slovic et al., 1977). In

this setting, the combined probability of loss from all (bundled) insurable events may exceed subjective thresholds of concern (Kunreuther & Pauly, 2004).

## 6. CONCLUSION

Given the absence of research in understanding why individuals either place a high or an extremely low weight on LPHI risks, in this article, we examine the psychological factors affecting probability neglect of flood risk and willingness-to-pay for flood insurance. We suggest several policies to overcome psychological factors related to the potential low demand for flood insurance to improve flood preparations, of which the effectiveness can be examined by further research. These include policies that promote better risk communication to enhance insurance decisions for individuals with a high threshold of concern, and education and information provision to change the behavior of people who see insurance as an investment. Moreover, future research could study multiyear flood insurance, which may prevent short-sighted behavior of people who have a tendency to regret paying for insurance, as well as bundling LPHI risks with more immediate risks which may achieve an overall covered risk which is less likely to be judged as falling below thresholds of concern. These policy measures could aid the development of a flood insurance market in the Netherlands for which we find there to be demand.

## ACKNOWLEDGMENTS

This study received financial support from the Netherlands Organisation for Scientific Research (NWO) VIDI Grant 452.14.005. We thank Tim Polaszek for helping to implement the pretest. Michael Siegrist and two anonymous referees provided valuable suggestions for the article. We are grateful to Thomas Epper and IVM colleagues for their comments on the experiment design.

## APPENDIX: INSTRUCTIONS

*Incentivized flood insurance experiment instructions are translated from Dutch.*

### A1. First Screen

Welcome to this questionnaire. This is an investigation that is part of a research project undertaken by the Institute for Environmental Issues (IVM),

Vrije Universiteit (VU) Amsterdam, and funded by the Netherlands Organization for Scientific Research (NWO).

The questionnaire is about your views about flood safety and flood insurance.

**A2. Flood Insurance Instructions**

Here is a brief explanation of the next questions. Read this carefully.

Your current insurance policy for your house and contents does not cover damage caused by

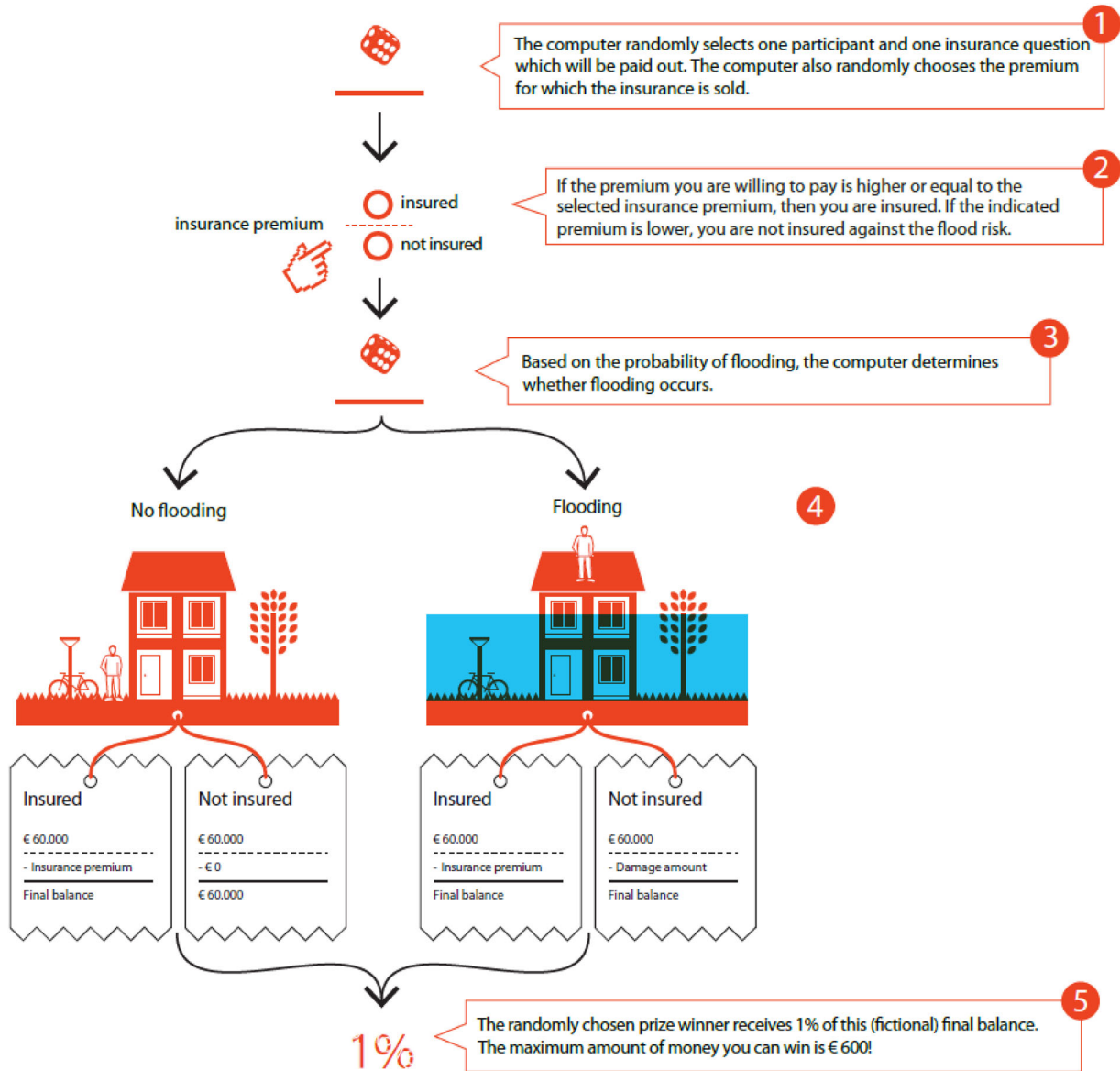


Fig. A1. Payment illustration.

flooding. Imagine you recently purchased a property worth €240,000 in an area that can flood and that it is possible to buy flood insurance.

You will get 14 questions about how much you are willing to pay for flood insurance for this property. With each question, the government will not reimburse your flood damage if you are not insured. Every question is about another year with a different risk due to different water levels. Each year you have €60,000 in your bank account from which insurance premiums or flood damage can be paid.

There are no correct or incorrect answers. We are only interested in your opinion!

### A3. Payment

*The hypothetical condition is identical to the incentivized version with the following instructions omitted.*

We randomly choose one individual to be paid.

Fig. A1 explains a lottery that will be used to determine whether you will be paid based on your answers in the insurance questions.

It is therefore in your best interest to answer your real willingness to pay. For example, if you state a willingness to pay higher than your real willingness, you may pay too much, while if you state a willingness to pay lower than your real willingness, you may end up without insurance and regret not stating a higher willingness.

Again, the prize winner of this research is randomly chosen by the computer.

Each participant has an equal chance of winning!

### A4. Flood Insurance Decisions

Year 1

Imagine that this year the chance of a flood is 1 in 10,000 causing €60,000 damage to your property.

What is the maximum premium this year that you would be willing to pay for flood insurance to fully cover the cost of damages?

[Response options, displayed top to bottom:

I accept this risk and I won't insure myself; €1; €2; €4; €9; €20; €40; €80; €170; €350; €740; €1,500; €3,200; €6,600; €13,800; €28,800; €60,000]

### A5. Follow-Up Flood Insurance Decisions

You indicated that you would be willing to purchase flood insurance for [maximum willingness to pay in the previous decision] but not for [next high-

est value]. What is the maximum premium you are willing to pay this year in this interval?

Please enter an amount within the interval, so between the two amounts mentioned above.

*Subsequent flood insurance decisions were presented analogously.*

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