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Dependence of flood risk perceptions on socioeconomic and objective risk factors

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[1] This study examines flood risk perceptions of individuals in the Netherlands using a survey of approximately 1000 homeowners. Perceptions of a range of aspects of flood risk are elicited. Various statistical models are used to estimate the influence of socioeconomic and geographical characteristics, personal experience with flooding, knowledge of flood threats, and individual risk attitudes on shaping risk belief. The study shows that in general, perceptions of flood risk are low. An analysis of the factors determining risk perceptions provides four main insights relevant for policy makers and insurers. First, differences in expected risk are consistently related to actual risk levels, since individuals in the vicinity of a main river and low-lying areas generally have elevated risk perceptions. Second, individuals in areas unprotected by dikes tend to underestimate their risk of flooding. Third, individuals with little knowledge of the causes of flood events have lower perceptions of flood risk. Fourth, there is some evidence that older and more highly educated individuals have a lower flood risk perception. The findings indicate that increasing knowledge of citizens about the causes of flooding may increase flood risk awareness. It is especially important to target individuals who live in areas unprotected by dike infrastructure, since they tend to be unaware of or ignore the high risk exposure faced.

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1. Introduction

[2] Individuals often deviate from rational behavioral principles when they make decisions under risk [*Tversky and Kahneman*, 1986; *Kahneman*, 2003]. In evaluating hazards, people commonly rely on intuitive risk judgments or risk beliefs, which are often called "risk perceptions" [*Slovic*, 1987]. Such perceptions may differ considerably from expert assessments of risk, as individuals find it difficult to evaluate probabilities of infrequent hazards or may lack adequate information about risk. An understanding of risk perceptions and their determinants and allowing for "bounded rationality" or limitations in individuals' perceptual and cognitive capabilities are fundamental in correctly anticipating individual responses to risky events [*Botzen and van den Bergh*, 2009].

[3] Knowledge about risk perceptions of natural hazards may provide important information about individual decisions regarding insurance purchases; decisions to take self-protection measures; and public support for governments' risk reduction policies. Household risk judgments can also support the legitimacy of, and compliance with, land-use planning and other risk reduction policies that are undertaken by governments [*Peacock et al.*, 2005]. Political support by individuals for risk reducing investments is stronger if the risk to be reduced is perceived as great by citizens [*Viscusi and Hamilton*, 1999]. Detailed information about risk perceptions may further improve communication about risk reduction policies to the public. Individual beliefs about hazards are important factors behind individual decision making under risk with respect to insurance purchases and the undertaking of self-protective measures. As an example, W. J. W. Botzen and J. C. J. M. van den Bergh (Risk attitudes to low-probability climate change risk: WTP for flood insurance, working manuscript, Institute for Environmental Studies, Vrije University, Amsterdam, 2008a; Monetary valuation of insurance against climate change risk, working manuscript, Institute for Environmental Studies, Vrije University, Amsterdam, available at www.adaptation.nl, 2008b) empirically analyze demand for flood insurance in the Netherlands using stated preference methods, and their results show that risk perceptions relate significantly and positively to demand for flood insurance. Often natural hazard risks comprise nature- and government- (protection-) related components, which are exogenous to the individual, as well as individual choice components, such as the location decision and the (lack of) implementation of precautionary measures. Examples of precautionary measures are the anchoring of roofs to limit hurricane damage or elevating houses and installing water barriers to limit flood damage. Individuals' risk beliefs affect the undertaking of damage mitigation measures and

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the extent to which losses will be reduced by means of precautionary measures [*Burn*, 1999; *Flynn et al.*, 1999].

[4] Natural hazards have been an important topic for risk perception research, especially in the psychological literature [*Slovic*, 2000]. Nevertheless, there has been little empirical research on the factors shaping individual risk perceptions of specific natural hazards [*Peacock et al.*, 2005]. Most risk perception research has focused on explaining risk perception by prior experience, knowledge, and socioeconomic as well as demographic characteristics [e.g., *Sjöberg*, 2000]. Especially for flood risk, little research has been conducted on the influence on risk perceptions of geographical characteristics, such as proximity to the hazard. The existing evidence relating risk perception to proximity to the risk is mixed. *Palm et al.* [1990] and *Mileti and Darlington* [1997] do not find a relation between proximity to an earthquake fault line and risk perception. On the other hand, risk assessment of volcanic, toxic gas, or radioactive material releases and proximity to the hazard were found to be positively associated [*Lindell*, 1994]. According to *Peacock et al.* [2005], perceptions of hurricane risks are positively related to living in an area with high potential wind speeds. *Brilly and Polic* [2005] observed that flood risk awareness is higher in a flood-prone area in Slovenia than in areas where flooding is less common. According to *Siegrist and Gutscher* [2006], Swiss households' perceptions of flood hazards were related to the riskiness of a location based on flood risk maps. These authors observed a significant and positive relation between risk perceptions and expert assessment of risk, but in certain regions perceived risks were considerably over- or underestimated by individuals. Some studies have used different types of "cognitive mapping" methods to elicit relations between perceptions of natural hazard risk and spatial characteristics derived from geographical maps [see, e.g., *Kaplan*, 1973; *Gaillard et al.*, 2001; *Ruin et al.*, 2007]. For example, *Ruin et al.* [2007] related motorists' perceived risk of flash floods on various routes to actual risk derived from geographical maps and found that drivers were more likely to under- than overestimate the risk of flash floods.

[5] The objective of this study is to examine individual risk perceptions of river flooding in the Netherlands and assess the relationship between actual or objective risk measures and the shaping of risk perceptions. The research method is a survey of approximately 1000 homeowners who live in the Dutch river delta. The specific nature of flood risk means that it is possible to identify the dependence of risk perceptions on the various geographical characteristics of individuals' residential area that affect the likelihood and consequence of the hazard. A Geographical Information System (GIS) is used to obtain information on various indicators of objective exposure to risk derived from the geographical location of households, such as their elevation relative to the potential water level, proximity to a main river, and the degree of protection by dike infrastructure. Particular attention is paid here to how these actual measures of flood exposure based on geographical characteristics shape perceived flood risk, in addition to socioeconomic characteristics and knowledge about, and experiences with, flooding. This approach is supported by dual process theories in psychology that postulate that risk perceptions are shaped by both experiences and analytical reasoning [*Slovic et al.*, 2004]. In contrast to many other studies which often analyze just one indicator of perceived risk, we have elicited several proxies of risk beliefs in order to arrive at a complete understanding of flood risk perceptions. In particular, we examine: the perceived risk relative to an average resident; the perceived probability of flooding (both in relation to other risks and independently); perceptions of whether dike maintenance complies with the safety norm of dike design; and the amount of flood damage individuals expect to suffer. The determinants of these perceptions are analyzed with ordered probit, binary probit, and OLS regression models [e.g., *Wooldridge*, 2002].

[6] The remainder of this paper is structured as follows. Section 2 provides information about flood risk and flood risk perceptions in the Netherlands. Section 3 discusses the psychology of the formation of risk perceptions. Section 4 explains the survey. Section 5 provides a detailed analysis of the answers to the questions on individual flood risk perceptions. Section 6 presents estimation results for a range of statistical models of the factors that shape flood risk perceptions. Section 7 presents conclusions.

2. Flood Risk and Perceptions in the Netherlands

2.1. Flood Risk in the Netherlands

[7] The Netherlands is a relevant case study because the area is very vulnerable to flooding. The country comprises a delta where the rivers Rhine, Meuse and Scheldt flow into the North Sea. About half of the country is situated below sea or river water level, and about two-thirds of the country's GDP is earned in these low-lying regions. Advanced dike infrastructures protect these areas, known as "polders," from flooding. Currently, Dutch flood safety norms are the highest in the world, ranging from a 1 in 10,000 years flood event near the coast up to a 1 in 1,250 years flood event near rivers. Nevertheless, it is realized that absolute safety cannot be achieved, and residual flood risks remain. The consequences of flooding can be catastrophic with potential damage costing up to 100 billion [*Aerts et al.*, 2008]. In other words, floods can be characterized as a low probability, high impact risk. Moreover, climate change is expected to increase future flood risk as a result of more (extreme) precipitation, higher peak flows of rivers, and rise in sea level [*Intergovernmental Panel on Climate Change*, 2007; *Middelkoop et al.*, 2001].

[8] Several adaptation strategies to limit rising risk have been suggested and are currently being implemented: namely, heightening dikes; creating more space for rivers; and designing flood retention areas. In addition, "soft" measures are considered, such as insurance and increasing the preparedness of individuals for disasters [e.g., *Kabat et al.*, 2005]. At present, private insurance for flood damage is not available in the Netherlands, but the government may grant part compensation for damage caused by large flood disasters. The introduction of a public-private partnership for insuring flood damage may be useful to decrease the uncertainty of postdisaster government compensation and provide households with incentives to minimize damage [*Botzen and van den Bergh*, 2008]. Most investments in flood protection are made by the government and are focused on lowering the probability of flooding. Nevertheless, individuals have a certain degree of control over the

Table 1. Comparison of the Experiential and Analytic Systems[a]

Experiential System	Analytic System
Holistic	Analytic
Affective (pleasure –pain oriented)	Logical (reason oriented (what is sensible))
Associationistic connections	Logical connections
Behavior mediated by "vibes" from past experiences	Behavior mediated by conscious appraisal of events
Encodes reality in concrete images, metaphors, and narratives	Encodes reality in abstract symbols, words, and numbers
More rapid processing: oriented toward immediate action	Slower processing (oriented toward delayed action)
Self-evidently valid ("experiencing is believing")	Requires justification via logic and evidence

[a]Source is *Slovic et al.* [2004].

damage caused by floods. *Botzen et al.* [2009a] show that damage-mitigating measures undertaken by Dutch households can be effective in limiting flood damage. Their statistical analysis indicates that households are more likely to invest in self-protection measures, the higher they perceive their risk of flooding. This underpins the need to examine individual risk perceptions and their determinants in more detail. Moreover, insights into individual risk perceptions and their determinants are very relevant for the current discussion of opportunities to develop flood insurance in the Netherlands.

2.2. Studies on Perceived Flood Risk in the Netherlands

[9] Research on flood risk perceptions in the Netherlands is still in its infancy, and considerable research efforts are needed to provide insights for policy. Research on perceptions is rare, as water management studies in the Netherlands have traditionally focused only on technical analyses of flood risk prevention [*Baan*, 2004]. Nevertheless, some studies have been undertaken that provide a relevant starting point and comparison with the present study.

[10] The importance of considering flood risk perceptions in water management in the Netherlands was highlighted by *Baan and Klijn* [2004]. *Terpstra et al.* [2006] conducted a survey (n = 49) and a focus group (n = 14) to examine flood-risk perceptions, and concluded that, overall, individuals found it difficult to imagine a flood really occurring, i.e., the perception of the probability of flooding is low. *Terpstra and Gutteling* [2008] recently undertook an empirical study on flood-risk perceptions in the Netherlands, consisting of a larger sample (n = 658). The authors conducted an Internet survey in the province of Friesland, which is protected by dikes with a safety norm of 1/4,000 years. Respondents were asked to rate: their personal risk of flooding; the likelihood of a flood event in Friesland within the next 10 years; the severity of personal consequences; feelings of fear, perceived control during a flood; and the frequency of flood risk. In addition, respondents rated their trust in the expertise and credibility of the authorities responsible for flood risk management in Friesland. Qualitative response scales were used, ranging from four to six items. The results of *Terpstra and Gutteling* [2008] indicate that, overall, risk perceptions are low, which is reflected in low scores for personal risk, frequency of flooding, and feelings of fear. In contrast, the consequences of flood risks were rated considerably higher than the flood probability, indicating an elevated perceived risk of expected damage compared with the flood probability. Individuals showed confidence in their personal ability to live through a flood event. Trust in the expertise of the authorities responsible for preventing flood damage was generally high, but their credibility was rated somewhat lower.

3. Psychology of the Formation of Risk Perceptions

[11] The thinking, knowing, and information processing of individuals is often presented as a dual-process theory [e.g., *Sloman*, 1996; *Loewenstein et al.*, 2001; *Kahneman and Frederick*, 2002]. This theory postulates that two systems are at work in the human brain to help people apprehend reality; namely, an experiential system and an analytic system, as depicted in Table 1 together with a list of their properties. It should be noted that certain authors have defined these systems somewhat differently. Here, we use the terminology of *Slovic et al.* [2004], who undertook a study indicating the role of the "affect heuristic" in shaping risk perceptions. The experiential and analytical systems work in fundamentally different ways. The experiential system is generally labeled as intuitive, automatic, natural, nonverbal, narrative, and experiential. *Tversky and Kahneman* [1983] show the importance of intuitive reasoning related to the experiential system in making probability judgments. In contrast, the analytical system is characterized by analytical, deliberative, verbal, and rational aspects [*Epstein*, 1994]. The two systems operate in a parallel manner and interact so they simultaneously process information to shape judgments or perceptions.

[12] According to *Slovic et al.* [2004] and *Loewenstein et al.* [2001] affective feelings are important in individual risk judgments. Individuals may have a higher risk perception if flood risk is associated with negative feelings, which may have been caused or reinforced by experiences with flooding or evacuation due to a flooding threat [*Finucane et al.*, 2000; *Keller et al.*, 2006]. This is related to the relevance of the "availability heuristic" in risk perception discussed by *Tversky and Kahneman* [1973, 1974]. Heuristics are simple rules that individuals may use in risk judgments [*Kahneman et al.*, 1982]. Individuals who use the availability heuristic in forming perceptions judge an event as risky if it is easy to imagine or recall. For example, individuals who have experienced a flood may find it easier to imagine that a flood will happen again in the future and, therefore, indicate a higher perceived risk than individuals without flood experience. From a Bayesian learning standpoint, one would also expect that perceived risk increases after the experience of a disaster [*Viscusi and Zeckhauser*, 2006]. In particular, individuals may revise prior risk beliefs upward

after the experience of a disaster if it provides information that risk may be higher than initially anticipated.

[13] Empirical results about the effects of experience on risk perceptions across studies are not entirely consistent. For example, *Peacock et al.* [2005] find that earlier experience with a disaster can even lower the perceived risk associated with future events. A possible explanation of the latter phenomenon is that some people think that if they have experienced one disaster this reduces the likelihood of experiencing another in the future. The specific nature of the experiences is likely to be important in shaping risk perceptions. For example, all residents of a region where flooding has occurred may claim that they have experienced a flood, even when not all of them have actually suffered from water near or inside their house. Research has shown that more intense personal experiences, such as suffering damage, results in elevated perceptions of risk [*Windham et al.*, 1977; *Perry and Lindell*, 1990; *Norris et al.*, 1999; *Riad et al.*, 1999]. The effects of experiences with flooding on perceptions of flood risk by Dutch households will be examined in this study. The dual process theory provides a useful basis for the present study since it highlights the relevance of examining the influence of experience with flooding in shaping perceived risk. It also provides a basis for analyzing rational decisions in relation to objective information, such as proxies for flood exposure based on the geographical properties of the individuals' residential area.

4. Explaining the Survey and Variables Used in Modeling Risk Perception

4.1. Pretests and Implementation of the Survey

[14] During the design of the survey, experienced stated choice practitioners, other economists, natural scientists, water management experts, and psychologists reviewed versions of the questionnaire. After incorporating their comments, three pretests of the questionnaire were conducted between August and October 2007 using face-to-face interviews. Four trained and carefully supervised interviewers (50% male and female) interviewed 88 households. These pretests turned out to be useful in checking the understanding of the survey by the respondents, and resulted in several adjustments in the formulation of explanations and questions. A fourth and final pretest was conducted to test the online questionnaire, which resulted in minor adjustments in layout. Overall, the pretests indicated that the risk perception questions were not too difficult and that respondents were motivated to participate in the survey.

[15] The survey was administered over the Internet using Sawtooth CBC software (www.sawtoothsoftware.com). This computer-based method has the advantage that interviewer effects can be avoided and a large geographically spread sample can be obtained at relatively low costs. Respondents were selected from the consumer panel of Multiscope and contacted by e-mail (www.multiscope.nl). This e-mail did not specify the topic of the survey, to prevent selection bias. The sample consists of random draws of panel members who live in "dike ring" areas in the Netherlands with a safety standard of once in 1,250 years (see *Botzen and van den Bergh* [2009, Figure 1] for a map of the sample area). A so-called dike ring is a geographical unit bounded by a flood protection system of dikes. Only homeowners could participate in the survey. Tenants were excluded since they do not bear the costs of flood damage to their homes. The sample was set up to be representative for the Dutch population up to the age of 60 years. Fewer older individuals are represented in the Internet sample, because seniors are generally less active on the Internet than younger people. The survey was removed from the Internet once the desired number of respondents was reached. The use of the consumer panel of Multiscope does not allow us to calculate the exact response rate to our survey since the survey was removed from the Internet once a prespecified quota of completed questionnaires was reached. On average, response rates of the consumer panel are well above 20% (www.mutiscope.nl). A total of 1140 respondents filled out the questionnaire. Respondents who lived outside the sample area or in apartments higher than the first floor were removed from the data. The resulting total number of completed questionnaires is 982. An extensive description of the pretests, structure and implementation of this survey, and English translation of the complete questionnaire is given by *Botzen et al.* [2008]. Several questions were posed to respondents before those on risk perceptions. These initial questions addressed their experiences with flooding, evacuation and flood damage, as well as their knowledge about the causes of flooding. Such questions introduce the topic to respondents, and the answers serve as explanatory variables in modeling the responses to the risk perception questions (section 6). In addition, a short introductory text was included before the risk perception questions explaining that respondents would be asked several questions on how they estimate the probability and resulting damage of river flooding. In section 5, we will explain in detail the questions used to elicit risk perceptions.

4.2. Sample Characteristics

[16] Our sample has slightly more male (58%) than female respondents, which may be because the Internet survey method attracts more male respondents. Approximately, 50% of the respondents have at least one child who still lives at home and 39% have a bachelor's or master's degree as their highest education level. On average respondents are 46 years old. The proportion of respondents who are older than 60 years is about 11%, which is smaller than is the case in the actual Dutch population. The median and average after-tax household income is the answer category "between €2501 and €3000 per month," which is close to the average after-tax income of a household that owns a house in the Netherlands: namely, €3025 per month (Statistics Netherlands, StatLine Database, www.cbs.nl, Centraal Bureau voor de Statistiek, The Hague, Netherlands, 2008).

5. An Examination of Perceptions of Flood Risk in the Netherlands

[17] Five questions were used to elicit individual perceptions of flood risk. These questions are shown in Appendix A. The first three questions asked respondents to rate the flood probability using qualitative answer categories. The last two questions about flood risk perceptions asked respondents to give quantitative estimates of the expected return period of flood and expected damage. Here, these questions and answers will be discussed in detail.

Table 2. Risk Ratings of Various Hazards[a]

Risk Rating	Hazard							
	Flood	Terrorist Attack	Burglary	House Fire	Car Theft	Car Fire	Traffic Accident	Storm
0	8.6	14.0	0.1	0.2	6.1	6.4	0.1	0.1
1	20.8	24.8	1.1	5.1	2.3	11.3	1.1	1.5
2	16.1	13.5	4.1	7.8	5.1	12.3	3.2	2.2
3	12.3	9.4	6.1	8.6	8.5	9.3	3.6	4.6
4	10.6	5.5	6.7	9.5	6.2	11.6	4.2	4.6
5	15.2	22.8	23.7	35.3	21.7	28.7	28.7	19.9
6	9.0	5.0	21.9	18.0	20.2	11.2	17.6	21.6
7	4.5	3.3	21.4	10.6	18.2	6.2	22.7	24.7
8	2.3	1.3	11.1	3.3	8.7	2.1	13.4	15.0
9	0.4	0.3	3.1	1.1	2.3	0.6	4.5	4.8
10	0.3	0.1	0.7	0.5	0.7	0.2	0.9	1.0

[a]Values given as a percentage of total respondents.

5.1. Perceived Flood Risk Relative to Other Risk

[18] The respondents were asked to rate on a scale from 0 to 10 the probability that their household suffers financial damage to their property as a result of various risks, including flooding (Appendix A). On this scale, 0 represents no probability; five is a neutral option and; 10 is an extremely high probability. Similar scales have been successfully used to assess perceived likelihoods of health risks, such as surviving until a specified age [*Hurd and McGarry*, 1995], as well as nuclear risk [*Kunreuther et al.*, 1988]. This question allows for assessing how individuals perceive the flood risk relative to other risk they face and, therefore, puts the perceptions of flood risk into perspective. The other risks include a terrorist attack, burglary, a house fire, car theft, a car fire, traffic accident, and storm. In some countries storm and flood risk can be very related, such as hurricanes in the USA. In the Netherlands river floods are mostly caused by peak water discharges due to rainfall and meltwater contributions in upstream countries, such as France and Germany, and not so much by storms. Windstorms are very common in the Netherlands and often inflict considerable damage to properties without causing any floods [e.g., *Botzen et al.*, 2009b]. Therefore, it is unlikely that any ambiguity exists between the storm and flood events included in this question.

[19] In practice, the average probability of suffering financial damage caused by flooding is lower than the probability of suffering damage from storm, burglary, a traffic accident, a house fire, and car theft, while it is higher than suffering damage from a car fire and a terrorist attack [*Central Bureau voor de Statistiek*, 2007; *Verbond van Verzekeraars*, 2007]. Approximately, 82% of the respondents rate the flood risk as less likely than the storm risk, 79% rate the flood risk as less likely than burglary, 69% rate flood risk as less likely than a traffic accident, also 69% rate flood risk as less likely than car theft, and 67% rate flood risk as less likely than a house fire. About 50% think that the probability of suffering flood damage is smaller than the probability of suffering damage from a car fire, although this is in fact not true for the average citizen [*Botzen et al.*, 2008]. Moreover, 56% of the respondents think that they are less likely to suffer damage to their property as a result of a flood than from a terrorist attack. In reality, however, the probability of suffering rty damage from flooding is likely to be much larger than suffering property damage because of terrorism in the Netherlands. *Loewenstein and Mather* [1990] find that recent risks often attract considerable concern from individuals (sometimes defined in the literature as "panic"), which may be due to unfamiliarity with the risk. The 2001 attacks by religious extremists on the World Trade Center raised the ranking of terrorism risk on the political agenda and, therefore, individuals may perceive it as a recent threat. This may explain why Dutch households are more concerned with risk related to terrorism than flood risk. Overall, it can be concluded that our respondents judged the level of flood risk to be lower than other types of risks.

[20] Table 2 shows ratings of the flood risk and the other hazards. About 9% of individuals rate the probability of suffering flood damage as 0, and most respondents (20%) rate flood risk with the second lowest category. The percentage of respondents who choose a higher level of risk gradually decreases as the risk level rises, apart from the neutral option (category 5), where a small upward jump in the distribution can be observed. Compared with the distributions of the other risks, the risk levels lower than the neutral point were chosen most often for the flood hazard, apart from the categories 0 and 1 for the terrorist risk and category 4 for the risk of a car fire. This confirms that flood risk perceptions are low compared with the other risks.

5.2. Qualitative Estimate of the Perceived Flood Probability

[21] The aforementioned results concerned the rating of the flood probability, together with other risks. These answers are not, however, used in the statistical analysis of the factors underlying the shaping of flood risk perceptions in section 6. This is because the level of the rating of the flood probability may have been influenced (so-called anchoring) by the rating of the other events in Table A1 (shown in Appendix A). This would imply that the chosen risk level of the perceived flood probability is partly determined by the risk levels assigned by that respondent to the other risks. As a consequence, using the previous question to analyze the factors that determine the rating of the flood risk independently of the other risks would not be very useful. Therefore, we included another question that asked the respondents to rate the flood probability without requiring them to rate other risks, so that the rating of the flood probability itself cannot be biased. The scale differs from the scale of the previous question and has fewer categories so that respondents view the question as being distinct.

[22] This question asked respondents to rate the probability that a flood occurs in their residential area on a qualitative scale with the options: "I do not have any flood risks," "very low," "low," "not low/not high," "high," "very high," and "don't know." Table 3 provides the rating of the flood probability by the respondents. Overall, individuals perceive their risk of flooding as low. About 11% expect that they do not face any flood risk; 31% of the individuals regard their flood risk to be very small; and another 31% thought that they face a small flood risk. Thus, in total, 72% of the respondents rated their flood probability as "small," "very small," or "no flood risk at all." Few respondents chose the "high" and "very high" categories.

Table 3. Respondents' Perceived Flood Probability

Answer Categories	Percent of Responses
No flood risk at all	10.5
Very small	30.7
Small	30.8
Not small/not large	19.3
Large	7.4
Very large	0.7
Don't know	0.6

Only about 0.5% answered the don't know option. The responses to this question are consistent with the results of the previous question, where most individuals rated their probability of suffering damage due to flooding low relative to other risks. A correlation analysis indicates that the perceptions of the probability of suffering flood damage (shown in Table 2) are positively and significantly (at the 1% level) related to the perceived flood probability (shown in Table 3), as would be expected.

5.3. Respondents' Perceived Flood Risk Relative to an Average Citizen

[23] Several studies have elicited individual risk perceptions compared with a national average [e.g., *Viscusi and Zeckhauser*, 2006; A. M. Leiter, The sense of snow: Individuals' perception of fatal avalanche events, working manuscript, Department of Economics and Statistics, University of Innsbruck, Innsbruck, Austria, 2009]. Our third question follows this tradition in risk perception research and asks respondents to rate their flood risk compared with an average resident, using as answer options "lower than average," "equal to average," and "higher than average." On the basis of our research, most respondents think that they have a lower than average flood risk (48%); 34% expect that they have an average flood risk; but only 18% think that they have a higher than average flood risk. This finding contradicts the fact that almost all respondents have a higher than average flood risk compared with an average person in the Netherlands, because the sample consists of dike ring areas with the lowest protection norm of the country. *Viscusi and Zeckhauser* [2006] who use a similar question to estimate perceptions of several risks based on a representative sample of the USA find a similar result. In their study, most people rate the risk of dying because of a car accident, terrorist attack, or natural disaster as below average or average. An explanation for this finding may be that people realize that the true distributions of these risks are skewed, in the sense that a small fraction of the population is at much higher risk (e.g., because they live in flood prone areas), meaning that most people have, in fact, lower than average risk. This is, however, not a satisfactory explanation for the findings in the present survey, since the sample is drawn from individuals who live in high-risk areas, and therefore it is not a representative sample for the whole country. This implies that individuals who indicate that they have a lower flood risk than the national average are in fact underestimating their own risk or overestimating the national average risk. Many individuals seem to be unaware that they live in an area vulnerable to flooding.

5.4. Perceived Return Period of Flooding and Compliance With the Flood Safety Norm

[24] We further elicited a quantitative estimate of the return period of flooding expected by individuals. This is an indicator of the perceived flood probability, because the inverse of the return period equals the probability of flooding. Asking for a return period rather than a probability may be easier for respondents as judgments under uncertainty are generally improved when risks are expressed in frequencies rather than probabilities [*Gigerenzer and Hoffrage*, 1995]. A logarithmic scale of return periods was used as a visual aid, as by *Schneider and Zweifel* [2004]. It was explicitly stated that respondents could answer any return period, even if it was not on the scale. *Kunreuther et al.* [2001] find that providing an anchor helps respondents to assess low probabilities. A text in the questionnaire explains that the government is responsible for dike maintenance, and that a dike should be high enough to ensure that, on average, it does not flood more than once in 1,250 years, which is the "return period" that represents the legal safety norm of flooding. This is indicated on top of the scale presented to the respondents as an anchor to help respondents give an expected return period of floods (see Appendix A). This makes it possible to assess whether individuals expect a flood return period higher or lower than the legal safety norm. The answers to this question indicate whether individuals expect that dike maintenance is adequate, i.e., it complies with the legal norm. This is of interest since, in the present situation (year 2008), it appears that approximately 20% of the in total 3500 km length of the main dike ring system does not in fact comply with the safety standards as required by the Dutch law. In areas with insufficient dike maintenance, the flood probabilities are higher, as indicated by a recent study [*Dienst Weg-en Waterbouwkunde*, 2005]. This study shows that for some dike rings, flood probabilities may be as high as 1/200 due to the early failure of weirs and sluices in the case of extreme events. Investments in the Dutch dike ring system are ongoing, and it is expected that the system will be updated in the year 2015 [*Aerts et al.*, 2008].

[25] The perceived flood frequencies of respondents are summarized in Figure 1. A large majority of the respondents (70%) expect that the return period of flooding is larger than the legal norm of 1/1,250 years. Almost 40% expect that the return period is 1/100 years or smaller, which indicates that many individuals perceive the flood probability as being considerably higher than the legal norm. These high perceived frequencies are not consistent with actual risk, even when taking into account that the current dike maintenance in some areas is inadequate. A small fraction of respondents (4%) gave a zero return period of flooding, meaning that they expect that a flood will never occur. A similar fraction gave a recurrence interval larger than 10,000 years, which represents a very small perceived flood probability. Overall, pessimistic beliefs about the flood probability outweigh optimistic beliefs, which is in accordance with the findings of other studies [*Camerer and Kunreuther*, 1989; *Schneider and Zweifel*, 2004]. These results are further consistent with findings in the behavioral economics and psychological literature that individuals overestimate low-frequency risks when these are expressed as a probabilistic metric [*Hurley and Shogren*, 2005].

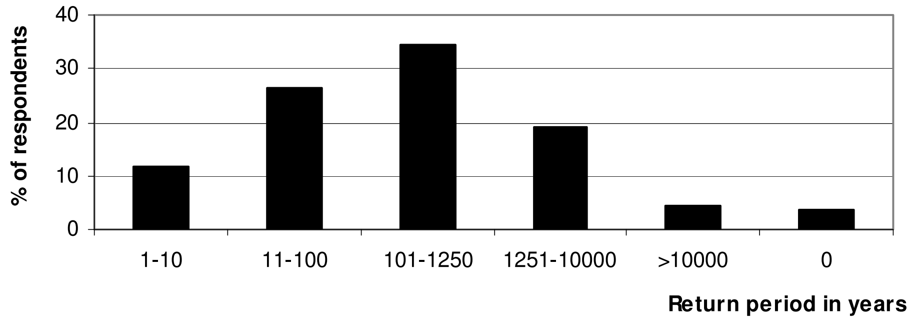

Figure 1. Respondents' perceived return period of flooding (in years). Please note that we used 1250 in defining the categories 101–1250 and 1251–10000 rather than 1000 as would be usual, because the legal norm of flooding is 1 in 1250 and has been provided as an anchor.

5.5. Expected Flood Damage

[26] Flood risk is often defined as flood probability * flood damage. An assessment of perceived risk should examine both probability and damage components. While the first four perception questions address the probability of flooding, the fifth and last question asked the respondents to estimate the amount of flood damage individuals expect to suffer once a flood occurs. This provides insight into the perceived consequences of a flooding event. We did not provide a scale as a visual aid for the question on expected flood damage as we did for the question on the expected return period of flooding. The reason is that the pretests indicated that respondents found it less difficult to assess the expected damage of a flood (on a monetary scale) than the expected return period of a flood, which is an indicator of the flood probability. This is not surprising because, in general, individuals have difficulties with assessing probabilities [*Viscusi*, 1998]. Nevertheless, we note that the open-ended format of this question may result in a large variation of answers to the expected flood damage question.

[27] Figure 2 shows the flood damage expected by individuals. It is remarkable that many individuals expected to suffer very little damage, in particular 12% did not expect to suffer any flood damage and 15% expected to suffer damage between €1 and €100. A large proportion (38%) expected to suffer flood damage between €10,000 and €100,000, which is indeed a realistic range of potential flood damage for most people. The mean expected damage is about €70,000 and the median estimated damage is €15,000, indicating that the distribution is positively skewed. A few large damage estimates of between 1 and 1.5 million euros cause this skewness. This skewness is not unrealistic as, in practice, a small proportion of homeowners whose properties have a high value will suffer very large flood damage, causing a right tail in the loss distribution. It is surprising that the expected mean flood damage is equal to the expected mean damage, as has been estimated by flood models for the sample area of this survey [see *Botzen et al.*, 2008]. This average estimated flood damage to homes and their contents would cost approximately €70,000 in 2008 price levels.

6. Results of Statistical Analyses of Factors Determining Risk Perception

6.1. Statistical Methods

[28] The role of geographical and socioeconomic characteristics in shaping risk perceptions are examined next using statistical models that estimate the independent effect of several explanatory variables on perceived risk. Different regression methods are required, depending on the type of dependent variable. Table 4 shows a description of the dependent variables and their descriptive statistics. The respondents' perceived flood probability and rating of flood risk compared with those of an average resident are ordered categorical variables, and, therefore, the preferred mode of analysis is an ordered probit model. The variable representing perceptions that the flood return period exceeds the safety norm is a binary variable and hence a binary probit model is employed. An OLS regression estimates the model for expected flood damage. Standard errors are corrected for potential heteroskedasticity using the White-Huber estimator [*Huber*, 1967; *White*, 1982].

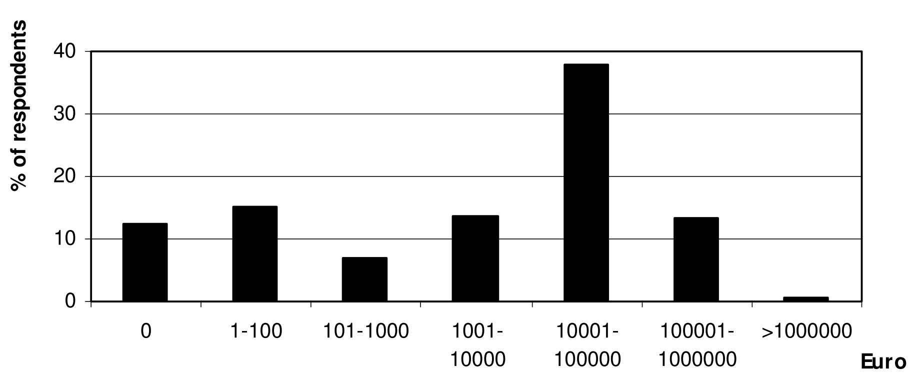

Figure 2. Respondents' perceived flood damage.

Table 4. Mean, Standard Deviation, and Description of the Dependent Variables

Dependent Variables	Mean	Standard Deviation	Description of the Variable
Probability of flooding	2.85	1.13	Categorical (1 is no risk, 2 is very low risk, 3 is low risk, 4 is neutral risk, 5 is high risk, and 6 is very high risk)
Flood risk compared with average resident	1.71	0.76	Categorical (1 is below average, 2 is equal to average, and 3 is above average)
Return period exceeds safety norm	0.34	0.47	Binary (1 is a return period greater than the legal norm and 0 is a return period less than or equal to the legal norm)
Expected flood damage	70,382	185,400	Continuous (damage in €)

[29] The OLS and binary probit regression methods are commonly applied, and no further explanation is needed here. The ordered probit model may be less familiar and is, therefore, briefly explained. An ordered probit model of the dependent variable y that takes on the ordered values {0, 1, ..., J} for some known integer J can be derived from a latent variable y^* that is determined by

$$y^* = x\beta + \varepsilon \quad \text{and} \quad \varepsilon|x \sim N(0,1), \tag{1}$$

where β is a parameter vector of k number of explanatory variables, x excluding a constant; and N represents the normal distribution. Observation of a specific value of y is dependent on whether y^* falls in between certain intervals of unknown threshold parameters $\alpha_1 < \alpha_2 < \ldots < \alpha_J$ according to

$$\begin{gathered} y = 0 \text{ if } y^* \leq \alpha_1 \\ y = 1 \text{ if } \alpha_1 < y^* \leq \alpha_2 \\ \vdots \\ y = J \text{ if } y^* > \alpha_J \end{gathered}$$

The maximum likelihood estimation of the log likelihood function for individual i gives the parameters of interest

$$\begin{aligned} \ell_i(\alpha,\beta) = & 1[y_i = 0]\log[\Phi(\alpha_1 - x_i\beta)] + 1[y_i = 1]\log[\Phi(\alpha_2 - x_i\beta) \\ & - \Phi(\alpha_1 - x_i\beta)] + \ldots + 1[y_i = J]\log[1 - \Phi(\alpha_J - x_i\beta)]. \end{aligned} \tag{2}$$

6.2. Explanatory Variables Used in the Statistical Analysis of the Factors That Shape Risk Perception

[30] The explanatory variables used in the analysis include: respondents' geographical characteristics; their experience with, as well as knowledge about, flooding; and their socioeconomic characteristics. Each variable will now be explained in more detail.

[31] Three variables reflect objective indicators of the flood exposure faced by the respondent based on geographical characteristics. Geographical Information Systems (GIS) maps, such as a digital elevation map, have been linked to the respondents' zip codes to obtain these data. These geographical variables indicate: the difference between the elevation of the zip code area of the respondent and the expected water level of a flood; the distance of the house to a main river; and whether the respondent lives in a flood-prone area that is not protected by dikes. The potential flood damage within an area protected by dikes (dike ring) is largely dependent on the maximum flood depth and the duration of a flood. The r between flood depth and flood damage is usually described with what are called "stage damage functions" [e.g., *Aerts et al.*, 2008]. These functions are based on historical loss data and show the maximum damage according to a particular flood depth. The explanatory variable of the relative elevation of a location compared with the potential water level in a dike ring can be used as a proxy for the potential water level during a flood near an individual's house. This variable was constructed in three steps. First, the mean elevation of the ground level of a zip code area was computed (using the "AHN elevation map"). The zip codes consist of letters and numbers for most respondents and indicate with high precision the location of streets or parts of streets. Therefore, they can be used as a proxy for the location of individual houses. Second, the elevation of the flood protection infrastructure, such as a dike, nearest to the respondent's zip code area is computed (using the "RWS dijkkruinhoogtesbestand"). Third, the elevation of the flood protection infrastructure is subtracted from the elevation of the respondent's zip code area. Note in this context that we assume that the dike system is overtopped with water in case of a 1/1,250 flood (or even lower probability floods), and that water levels in the flooded area are as high as the maximum dike height.

[32] Flood velocity also plays a role in the damage that materializes because of flooding, but only within the vicinity of a dike breach where flow velocities can be high. This has been derived from historical loss data from a large flood that occurred in the southwest of the Netherlands in 1953 [e.g., *Keijzer*, 2008]. The variable distance of the individual's house to a main river is another indicator of potential flood damage in addition to the elevation of the house. It has been created by computing the exact distance of the precise coordinates of the middle of the respondent's zip code area to the closest main riverbed in meters using a Euclidian distance measure. The locations of the main rivers are obtained using the GIS map of main surface waters provided by the Dutch government department Rijkswaterstaat. This variable may also reflect a higher probability of flooding. Houses near a river are more likely to suffer flood damage than houses far away from a river once a dike breaches or is overtopped by high water levels. This is the case because water may not reach areas located far away from dike breaches because of the presence of natural or man-made obstacles, such as elevated railroads or small hills created in historical ice ages that prevent the complete flooding of a dike ring area.

[33] Some houses in floodplains are located outside the protection of the Dutch dike ring system. These houses are very vulnerable to flooding and may already flood with peak river discharges with a recurrence interval of once in

Table 5. Mean, Standard Deviation, and Description of the Explanatory Variables

Explanatory Variables	Mean	Standard Deviation	Description
Distance to main river	9.40	11.77	Continuous variable (distance to main river in km)
Elevation relative to water level	−1.48	6.15	Continuous variable (elevation of area relative to water level in m)
Rural area	0.05	0.22	Dummy variable (1 indicates that the area is a rural area)
No dike protection	0.11	0.32	Dummy variable (1 indicates that the area is not protected by dikes)
Experience of flood and evacuation	0.03	0.16	Dummy variable (1 indicates that the respondent has experienced a flood and evacuation)
No knowledge of the causes of flooding	0.19	0.39	Dummy variable (1 indicates that the respondent cannot state the causes of flooding)
Risk-seeking index	3.24	1.16	Categorical variable (range 1–6, where 1 is very risk averse and 6 is very risk seeking)
Age	45.57	11.98	Continuous variable (age of respondent in years)
Female	0.42	0.49	Dummy variable (1 indicates that the respondent is female)
Education	5.40	1.38	Categorical variable (range 1–7, where 1 indicates an elementary education and 7 indicates an university degree)
Value of property[a]	411.70	169.78	Continuous variable (total value of house and home contents in 1000)
Income[b]	2.86	1.02	Continuous variable (total after-tax household income in 1000)

[a]For housing value the respondent could mark one of the following categories: < €100,000; €100,000–€150,000; €150,000–€200,000; €200,000–€250,000; €250,000–€300,000; €300,000–€350,000; €350,000–€400,000 €400,000–€500,000; €500,000–€600,000; or > €600,000. For home contents values the respondent could mark one of the following categories: < €25,000; €25,000–€50,000; €50,000–€75,000; €75,000–€100,000; €100,000–€125,000; €125,000–€150,000; €150,000–€175,000; €175,000–€200,000; €200,000–€300,000; or > €300,000. Continuous values of housing and home contents variables were constructed by setting the housing and home contents value of each respondent to the midpoint of the interval (€650,000 and €350,000 were used for the highest housing and home contents value categories, respectively).

[b]For income the respondent could mark one of the following categories: < €750; €751–€1000; €1001–€1250; €1251–€1500; €1501–€2000; €2001–€2500; €2501–€3000; €3001–€3500; €3501–€4000; or > €4000. A continuous income variable was constructed by setting the income of each respondent to the midpoint of the interval (€4500 was used for the highest category).

100 or 200 years or even lower. The frequency of flooding in unprotected areas is considerably higher than the frequency in protected areas where dikes are generally designed to prevent overtopping of peak discharges with a recurrence interval of once in 1,250 years. Therefore, the explanatory variable that represents individuals living in unprotected flood-prone areas identifies respondents with a higher flood frequency compared with the remainder of our sample. Finally, a geographical variable has been constructed that represents respondents in rural areas. Inhabitants of rural areas with lower population densities and less concentration of economic activities may be expected to have different attitudes toward flood risk.

[34] The questionnaire included three questions on flood experience. It was asked whether individuals had ever experienced a flood in their residential area. If the individual had experienced a flood, then it was inquired whether any damage was suffered. Finally, it was asked whether the individual had ever been evacuated because of flood threat. The most recent flood events in the Dutch floodplain occurred in the years 1993 and 1995. In 1995, nearly 250,000 inhabitants were evacuated. Most unprotected areas were flooded, and considerable damage occurred, including in the upstream countries of the rivers Meuse and Rhine. However, almost none of the respondents (0.4%) had actually suffered damage because of a flood, so that this variable cannot be used in the statistical analysis. Therefore, we decided to include a variable representing respondents who indicated that they both had experienced a flood in their residential area and were evacuated because of a flood threat. The concrete experience with flooding is likely to affect risk perceptions, as a number of studies indicate (discussed earlier in section 3).

[35] A variable was created to represent individuals who cannot state the causes of flooding events. It is relevant to examine how this lack of knowledge about floods determines risk perceptions. For example, if less knowledgeable individuals have lower perceptions of flood risk, then a campaign providing information about floods may be useful to increase awareness. Individual risk perceptions may be related to the degree of financial risk aversion of the individual. Here, a risk-seeking index is derived from the following question: "Some people avoid financial risks as much as possible. They are also well insured. How similar are these people to you?" The answer options were: "1 extremely similar to me," "2 very similar to me," "3 similar to me," "4 a little bit like me," "5 not similar to me," and "6 not similar to me at all." Thus, a higher category indicates a higher degree of risk seeking attitudes. It may be expected that individuals who are generally risk seeking have a lower perception of risk [*Sitkin and Pablo*, 1992].

[36] Several studies indicate that perceptions of risk vary between different groups of people [*Hakes and Viscusi*, 1997; Leiter, working manuscript, 2009]. The socioeconomic variables included in this study are: the age of the respondent; gender; education level; total value of property; and income. A positive relation between age and risk perception has been found in some studies, while a negative relation has been observed in other research [*Peacock et al.*, 2005]. Gender is often found to be an important determinant of risk perceptions [*Gustafson*, 1998]. Women perceive risk differently than men and are often more likely to view disaster events and natural hazards as risky [*Turner et al.*, 1986; *Fothergill*, 1996]. In addition, individuals with a high income and education level generally have a lower perception of risk [*Slovic*, 1997, 2000]. The education level in this study is a categorical variable which indicates the highest level of education obtained by the respondent. The total value of property is the sum of the current value of the house and the home contents, which we asked respondents in the survey. The expected flood damage is likely to be related to the total value of property because it is an indicator of the financial value exposed to flooding.

Table 6. Parameters of Factors Shaping Risk Perception Estimated by Four Statistical Models With Varying Indicators of Flood Risk Beliefs[a]

	Dependent Variable			
	Model 1 (Probability of Flooding)	Model 2 (Flood Risk Compared With Average)	Model 3 (Return Period Exceeds Safety Norm)	Model 4 (Expected Flood Damage)
Type of model	Ordered probit	Ordered probit	Binary probit	OLS regression
Geographical characteristics				
Distance to main river	−0.0203***[0.0031]	−0.0226*** [0.0042]	0.0141*** [0.0037]	−1117.95*** [382.67]
Elevation relative to water level	−0.0407*** [0.0064]	−0.0434*** [0.0070]	0.0305*** [0.0072]	−1584.10** [653.75]
Rural area	−0.589 [0.1835]	0.4008** [0.1890]	−0.3378* [0.1993]	60,055.67 [42,092.12]
No dike protection	−0.3705*** [0.1187]	−0.3836*** [0.1317]	0.1710 [0.1353]	−16445.44 [12094.05]
Experience and knowledge				
Experience of flood and evacuation	0.9604*** [0.2262]	1.7704*** [0.2816]	−0.3976 [0.2796]	−41,718.79** [19,545.66]
No knowledge of the causes of flooding	−0.1720** [0.0876]	−0.2384*** [0.0974]	0.2136** [0.1112]	−24,056.72* [14,132.16]
Socioeconomic characteristics				
Risk-seeking index	−0.0623* [0.0365]	−0.0152 [0.0397]	−0.0198 [0.0441]	3166.30 [8239.41]
Age	−0.0057* [0.0032]	−0.0019 [0.0036]	−0.0059 [0.0039]	−1055.27* [585.63]
Female	0.0233 [0.0731]	−0.1098 [0.0807]	−0.1298 [0.0901]	−23,194.99** [11,317.38]
Education	−0.0675* [0.0399]	−0.0451 [0.0458]	0.1121** [0.0494]	−21,604.95* [12,298.50]
Value of property	0.0004 [0.0002]	0.0004 [0.0003]	−0.0005* [0.0003]	255.33*** [87.51]
Income	0.01935 [0.0412]	0.0315 [0.0469]	−0.0306 [0.0494]	−4278.70 [12,303.03]
Constant	na	na	0.0799 [0.2325]	47,758.16 [36,031.59]
Other				
Log likelihood	−1408	−937	−603	na
Likelihood Chi-square	131.47***	137.52***	55.72***	na
F statistic	na	na	na	2.75***
Number of individuals	975	981	981	980

[a]Here *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively; na stands for not applicable. Hubert-White heteroskedasticity robust standard errors are given in brackets. Estimations are performed with the statistical software package Stata.

[37] The descriptive statistics of the explanatory variables are shown in Table 5. Different methods of coding categorical variables have been applied, depending on the type of variable. Categorical variables with two outcomes (binary) are coded as dummy variables and can be included as such in the regressions without any further transformation. Continuous variables are created from the categorical variables income and the value of property, which represent monetary classes [e.g., *Blumenschein et al.*, 2008]. Ordinal qualitative variables can be transformed into values on the real axis using an approach proposed by *Terza* [1987], as explained, for example, by *van Praag et al.* [2003] and *Botzen et al.* [2009a]. The variables representing the risk-seeking index and the education level are transformed according to this method. We prefer this method rather than constructing $J - 1$ dummy variables since the transformation of *Terza* [1987] can result in gains in efficiency and bias.

6.3. Estimation Results

[38] Table 6 reports the results of the ordered probit models of the perceived flood probability and perceived flood risk compared with an average resident; the probit model of whether the expected flood return period exceeds the legal safety norm; and the OLS regression of the expected flood damage. Coefficient values are shown for all models and heteroskedasticity-robust standard errors are provided in brackets below the coefficients. It should be noted that coefficients do not equal marginal effects (of x on y) in ordered and binary probit models. The estimates indicate whether the explanatory variables relate positively or negatively to the perceived risk, while the size of the coefficient is not directly informative. Asterisks indicate the significance level, and one, two, and three asterisks represent significance at the 10%, 5%, and 1% level, respectively. The auxiliary parameters (α_J) of the ordered probit models are statistically significant and of reasonable magnitude and sign. Commonly used goodness of fit measures of OLS regressions, such as the R^2 statistic, are not defined for nonlinear (probit) models. Sometimes pseudo-R^2 statistics are reported that are derived from the improvement in the log likelihood by the variables added to the model. However, the interpretation of such statistics is not immediately clear [e.g., *Train*, 2003], which makes some authors sceptical about reporting them [see *Hoetker*, 2007]. The reason is that the underlying latent variable y^* is not observed so that it is impossible to calculate the percentage of its variance that a model explains. The R^2 of model 4 is 0.07 and the pseudo-R^2 statistics of our models are in between 0.05 and 0.1, which may be approximated by R^2 statistics between 0.1 and 0.2, according to *Hensher et al.* [2005]. Often R^2 statistics of models of risk perceptions are low [e.g., *Peacock et al.* 2005], which indicates that it is difficult to model differences in perceived risk across individuals. The likelihood Chi square statistic of the probit models and the F statistic of the OLS regression indicate overall model significance at the 1% level. The results of the four models will be discussed in detail below.

6.3.1. Model 1 of the Perceived Flood Probability

[39] The results of the ordered probit model of the perceived flood probability indicate the importance of the proxies of actual flood exposure in shaping perceptions. The distance the individual lives from a main river is negatively related to the expected flood probability, i.e., the further the individual is situated from a river, the lower is the perceived flood probability. This indicates that perceived risk

is correlated to the flood exposure of the respondent, which is consistent with the findings of other studies that individuals have a larger perception of the risk of a hazard, the closer they live to the hazard. In addition, the perceived risk relates to the elevation of the area relative to the potential water level of a flood in the expected manner. Specifically, the higher the elevation of the area relative to the potential water level, the lower are individual risk perceptions. There is no statistical difference in the perceived risk of individuals who live in rural areas compared with individuals who live in urban areas. Individuals living in floodplains that are not protected by dikes have a lower perceived probability of flooding than individuals who live in protected areas, which is contrary to actual flood exposure. This finding suggests that inhabitants of unprotected floodplains are insufficiently informed about the risk they face. *Baan and Klijn* [2004] argue that people living in unprotected floodplains in the Netherlands may be less frightened of flooding than people in areas protected by dikes, since people in floodplains are more used to the dynamic of the river. Previous experience with flooding and evacuation is related to a higher perceived flood probability. This is consistent with studies which find that personal experience with a hazard increases its perceived probability. The significance of the experience variable supports views prevalent in the psychological literature that the affect heuristic plays a role in individual risk assessment in addition to analytical reasoning. A lack of knowledge about the causes of flooding results in a lower perceived flood probability.

[40] The risk-seeking index relates negatively to the perceived flood probability, meaning that risk-seeking individuals expect a lower probability of flooding. Older individuals and individuals with a higher education level have a lower perceived flood probability, which confirms the general stance in risk perception research. Gender, the value of property, and household income are not statistically significant.

6.3.2. Model 2 of the Respondents' Perceived Flood Risk Compared With an Average Resident

[41] The geographical characteristics are the main determinant in shaping the respondents' perceived flood risk compared with an average resident. All four geographical indicators are statistically significant, while the socioeconomic characteristics are insignificant. Individuals living far away from a main river are less likely to rate their flood risk as higher than average. Furthermore, the higher the elevation of the respondents' dwelling relative to potential water level, the lower they perceive their flood risk compared with the national average. Contrary to actual flood exposure, individuals who live in floodplains that are not protected by dike infrastructure are more likely to underestimate their risk, and hence indicate that their flood risk is lower than average. The relations between these geographical variables and perceived flood risk compared with an average resident are similar to their relations with the perceived flood probability (Model 1). A difference with the previous model is that the variable representing the inhabitants of rural areas is statistically significant. Inhabitants of rural areas are more likely to indicate that their flood risk is higher than an average resident, perhaps because they think that rural areas with fewer inhabitants and a lower concentration of economic activities are less well protected than urban areas. Experience with flooding and evacuation increases the likelihood that an individual expects to be at a higher than average risk, while a lack of knowledge about the causes of floods decreases the perceived riskiness. The effects of these latter two variables in Model 2 are consistent with their effects in Model 1.

6.3.3. Model 3 of Respondents' Perceptions That the Flood Return Period Exceeds the Legal Safety Norm of Dike Design

[42] Estimates show that individuals who live far away from a main river are more likely to expect a flood return period larger than the legal norm. Such individuals have a lower probability of suffering flood damage and are, therefore, more likely to state a flood return period that is higher than the legal norm of dike designs. The positive and significant coefficient of the elevation variable indicates that individuals who live in a high area relative to the potential water level are more likely to expect that maintenance of dikes is adequate so that dike designs comply with the safety norm. These results are consistent with those of the first two models which show that individuals living far from a main river and in relatively high areas generally have a lower perception of flood risk. It makes sense that these individuals who, in practice, will have a lower exposure to flooding are more likely to predict a return period of flooding higher than the legal safety norm. On the other hand, inhabitants of rural areas are less likely to expect that the flood return period exceeds the norm, which is consistent with the findings of Model 2 that such individuals are more likely to view their risk as higher than average. The variable representing individuals in floodplains not protected by dikes is not statistically significant. In practice, the safety norm of a 1/1,250 years flood event is not met in those areas, but the results indicate that inhabitants do not realize this.

[43] Experience with flooding and evacuation does not affect expectations of whether the return period exceeds the legal norm. An explanation of this may be that the near flood events in 1993 and 1995 did not actually result in breaches or overtopping of the primary dikes. The evacuations in anticipation of the flood threat were unwarranted from an after the fact perspective since major flooding did not take place, and almost none of the respondents suffered flood damage. Therefore, these flood experiences may have little effect on expectations of whether dike maintenance is sufficient to meet the dike safety norm, even though, they generally increased risk perceptions as Models 1 and 2 indicate.

[44] Individuals who do not know the causes of flooding are more likely to expect that the authorities are complying with the safety norm. In general, less knowledgeable individuals have a lower perception of flood risk, as the results of Models 1 and 2 show. Respondents with a high education level are more likely to expect that the flood return period exceeds the safety norm. The estimate of the coefficient of total value of property is significant and negative in this model, which indicates that individuals with a higher value of their house and contents are less likely to indicate a return period larger than the legal norm. Perhaps this is the case because such individuals are more financially vulnerable in terms of potential damage due to flooding.

6.3.4. Model 4 of the Amount of Flood Damage That Is Expected by Individuals

[45] In accordance with the previous three models, the variables representing distance to a main river and elevation of the area are statistically significant. Individuals who live far from a main river or in areas that are relatively high expect to suffer lower flood damage than individuals who live close to a river or in relatively low areas. These judgements are likely to hold in practice, since flood damage is generally larger for houses close to rivers because of high flow velocities of water. Also, low-lying areas suffer more damage during floods than high areas because of elevated water levels and a higher probability of a building collapse. The expected flood damage is unrelated to living in a rural area. In practice, it is also unlikely that flood damage per house is significantly higher in rural areas than urban areas. The damage per square km in urban areas is obviously higher than in rural areas with a higher density of houses, but that does not imply that the damage per house differs. Neither is expected flood damage significantly different between inhabitants of areas that are protected and those who live in floodplains that are not protected by dikes. This is consistent with reality since it is unlikely that a flood event would inflict more damage in unprotected areas than in areas protected by dikes. It may be the case that damage to houses in an unprotected area is larger if the area lies closer to the river. However, the effect of proximity to the river on expected damage is included as a separate variable in Model 4. Its coefficient already captures the higher risk perception of individuals who live close to the river. Obviously, the frequency of flooding will be higher in unprotected floodplains, but this does not necessarily imply that the damage per house for a specific flood event will be higher as well.

[46] Individuals who have experienced a flood and evacuation expect to suffer lower flood damage than individuals who did not have such an experience. The results of the first two models indicate that individuals who have experienced a flood and evacuation have a larger perceived flood probability. These findings appear contradictory, but may be explained by the observation that practically none of the respondents who have experienced a flood or have been evacuated have actually suffered any damage. Although these individuals have a larger perception of the probability of flooding, their experience of not having suffered damage during the 1993–1995 flood threat seems to have lowered their expected amount of flood damage. Expected flood damage is lower for individuals who do not know the causes of flooding. Older individuals and individuals with a higher education level also expect to suffer less flood damage. Surprisingly, females expect to suffer about €23,000 less damage than males. Households with higher property values expect to suffer more flood damage: expected flood damage is about €250 higher per €1000 value of their home and its contents.

7. Conclusions and Policy Implications

[47] This study has examined individual perceptions of flood risks in floodplains of the Netherlands, where flooding can have catastrophic consequences. A survey was conducted among approximately 1000 homeowners to elicit their expectations on diffe spects of the risk posed by flooding. A range of statistical models estimated the factors shaping flood risk perceptions, such as: relations with indicators of actual risk exposure using geographical characteristics; experience with, and knowledge about, the risk; and socioeconomic characteristics. The study provides insights into individual perceptions of flood risk that are potentially useful to policy makers and water managers. Risk perceptions are an important factor which causes individuals to take precautionary measures and give support to policies that aim to limit flood risk. In addition, information about risk perceptions is useful for insurance companies, since individual beliefs concerning flood risk affect household demand for flood insurance. Moreover, the results are relevant for low probability, high impact risk assessments in general.

[48] An examination of the various indicators of perceived risk shows that individuals generally expect that the probability of flooding is low. The flood probability is underestimated relative to other risks and most people rate the flood probability as very low or low when it is elicited independently of other hazards. Moreover, many individuals underestimate their flood risk when it is compared with the national average. Most individuals expect a lower flood return period than the safety norm, which suggests that they expect that dike maintenance is inadequate to comply with the safety norm of dike design. Nevertheless, on average, individuals do provide realistic estimates of the damage they expect to suffer because of a flood, since the average damage expected by respondents is similar to estimates of expert models.

[49] These findings have important implications for policy makers. Currently, considerable investments have been made and are planned in the future to limit the projected rise in flood risk due to climate change. The low perception of flood risk may undermine the public's perceived legitimacy of these flood risk reduction policies. Recent research advocates that Dutch households should be stimulated to invest in measures that limit flood damage, such as the "flood proofing" of buildings. An enhanced awareness of flood risk may be needed to promote the implementation of such damage mitigation investments. In light of the evidence presented here, the government could consider undertaking a communication campaign to increase awareness of flood risks.

[50] Even though perceptions of flood risk are low in general, it is important to note that variation exists among individuals' risk beliefs. Evidently, insights into what type of individuals have high or low risk perceptions is very relevant for the adequate targeting of information campaigns and insurance products that provide coverage against flood damage. The statistical models concerning the shaping of risk perceptions provide five main insights. First, differences in expected risk are consistently related to actual flood risk exposure since individuals in the vicinity of a main river in low-lying areas generally have higher risk perceptions. There is some evidence that the inhabitants of rural areas are more aware of their risk of flooding than inhabitants of cities. Second, individuals in flood-prone areas that are unprotected by dikes tend to underestimate their risk of flooding. Third, we find evidence in support of psychological studies that indicate the importance of the affect heuristic which depends on previous experiences with

Table A1. Scale of Question 1 From Appendix A

	No Probability		Neutral		Very High Probability
Event	0	1 2 3 4	5	6 7 8 9	10
a. Terrorist attack	o	o o o o	o	o o o o	o
b. Burglary	o	o o o o	o	o o o o	o
c. House fire	o	o o o o	o	o o o o	o
d. Car theft	o	o o o o	o	o o o o	o
e. Car fire	o	o o o o	o	o o o o	o
f. Flood/water inside house	o	o o o o	o	o o o o	o
g. Traffic accident	o	o o o o	o	o o o o	o
h. Storm	o	o o o o	o	o o o o	o

hazards in the formation of perceived risk. It should be noted, however, that flood experience has different effects on distinct aspects of risk beliefs. Individuals who have experienced flooding and evacuation, but hardly suffered any flood damage, have an elevated perception of the flood probability but expect lower flood damage. Fourth, individuals with little knowledge of the causes of flooding have lower perceptions of flood risk. This suggests that providing information to households about flooding may increase flood risk perceptions. Fifth, some support is found for the role of socioeconomic variables in shaping perceived risk that has also been observed in other studies. The education level relates negatively to perceived risk in three out of our four models, and age relates negatively to perceived risk in two of these models, which are the expected effects according to other studies. The risk-seeking index is only significant in the model of the flood probability, and more risk-seeking individuals have a lower risk perception. Other studies usually find that women have a larger perceived probability of hazards, which is not observed in our results. The results of Model 4 even indicate that women expect to suffer less flood damage than men. The value of property relates negatively to perceptions about the return period exceeding the legal norm, while it affects the perceived flood damage positively, which is intuitively clear. For policy makers these results imply that it is especially important to improve knowledge of the flood risk of individuals who live in flood-prone areas unprotected by dike infrastructure since these individuals tend to be unaware or ignore the high risk they face.

[51] We note that, although the focus of this study is on the Netherlands, the survey method used and some of the results obtained could also be applicable to other countries. Moreover, the range of statistical models employed can provide examples of how different type of risk perception variables should be treated if their determinants are to be analyzed. The statistical methods presented provide an alternative to the simple correlation analyses often used in risk perception research and result in more accurate estimates of the independent effects of explanatory variables on perception. The survey elicited various indicators of perceived risk, which could also be useful to examine vulnerability to flooding in other regions. In particular, our study shows that perceptions and determinants of the two distinct components of flood risk (damage and probability) differ, while this is neglected by several studies that only examine perceptions of probabilities. Our results show the importance of indicators of ob ective risk exposure based on geographical characteristics in determining risk perceptions. It would be useful to analyze whether similar relations are also obtained in the entire river basins. Evidently, knowledge about levels of risk perceptions and relations with objective risk may also provide practical information to improve flood risk communication policies in other regions. The results of our survey may be applicable to risk perceptions of households living near the Meuse and Rhine rivers in upstream countries, such as Germany and France, but future research is needed to confirm this.

[52] Further research is needed to explore the relationship between perceived flood risk and actual risk by comparing large samples of individuals living in areas with varying degrees of protection in the Netherlands. Hedonic price modeling that assesses the relationship between housing values and the spatial characteristics of flood risks could complement this research. Moreover, it would be interesting to analyze the influence on risk perceptions of the different responsibilities concerning compensation for flood damage between private insurance and the public sector. This may be assessed by implementing comparable studies across a range of countries with distinct compensation schemes. The effectiveness of information campaigns on increasing the awareness of flood risks is another important topic for future research.

Appendix A: Questions Used to Elicit Risk Perception

[53] This appendix presents the questions that were used to elicit risk perception in the survey. Table A1 shows the scale of question 1 and Figure A1 shows the scale of question 3.

[54] 1. How high do you estimate the probability that your household will suffer financial damage to property due to the events mentioned below? Rate each possible event on a scale from 0 to 10, where 0 is no probability and 10 is an extremely high probability.

[55] 2. How high or low do you estimate the probability that you will experience a flood in your home?
I do not have any flood risks.
Very low.
Low.
Not low/not high.
High.
Very high.
Do not know.

[56] 3. How would you rate your flood risk compared with an average person in the Netherlands?
I have an average flood risk.
I have a higher than average flood risk.
I have a lower than average flood risk.

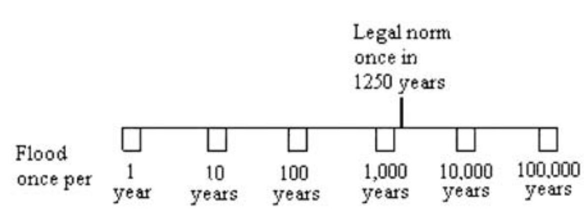

Figure A1. Scale of question 3 from Appendix A.

[57] The government is responsible for the maintenance of dikes. A dike in your region should be high enough so that a flood does not occur on average more often than once every 1250 years. The scale below depicts different flood probabilities decreasing from once per year to once in 100,000 years. The legal norm is shown on the top of the scale.

[58] 4. Can you indicate how often you would expect a flood to occur at your home? You can fill in one of the probabilities shown on the scale above or fill in another probability below.
I expect that a flood can occur once in __ years.

[59] 5. How much damage do you expect that a flood would cause to your house and home contents?
__ euro.

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References

Aerts, J. C. J. H., T. A. Sprong, and B. Bannink (Eds.) (2008), Aandacht voor veiligheid, *Rapp. Besluit Subsidies Investeringen Kennisinfrastruct. Programma Klim. Ruimte 009/2008*, Vrije Univ., Amsterdam.

Baan, P. J. A. (2004), Overstromingsrisico's langs rivieren meer dan kans X gevolg: Beleving en implicaties voor veiligheidsstrategie, *Res. Rep. Q3673.20*, Delft Hydraulics, Delft, Netherlands.

Baan, P. J. A., and F. Klijn (2004), Flood risk perception and implications for flood risk management in the Netherlands, *Int. J. River Basin Manage.*, *2*(2), 113–122.

Blumenschein, K., G. C. Blomquist, M. Johannesson, N. Horn, and P. Freeman (2008), Eliciting willingness to pay without bias: Evidence from a field experiment, *Econ. J.*, *118*(525), 114–137.

Botzen, W. J. W., and J. C. J. M. van den Bergh (2008), Insurance against climate change and flooding in the Netherlands: Present, future and comparison with other countries, *Risk Anal.*, *28*(2), 413–426, doi:10.1111/j.1539-6924.2008.01035.x.

Botzen, W. J. W., and J. C. J. M. van den Bergh (2009), Bounded rationality, climate risks and insurance: Is there a market for natural disasters?, *Land Econ.*, *85*(2), 266–279.

Botzen, W. J. W., C. J. M. J.van den Bergh, and J. C. J. H. Aerts (2008), Report on a survey about perceptions of flood risk, willingness to pay for flood insurance, and willingness to undertake mitigation measures: Explanation of the survey instrument, report, Inst. for Environ. Stud., Vrije Univ., Amsterdam. (Available at www.adaptation.nl.)

Botzen, W. J. W., J. C. J. H. Aerts, and J. C. J. M. van den Bergh (2009a), Willingness of homeowners to mitigate climate risk through insurance, *Ecol. Econ.*, *68*(8–9), 2265–2277, doi:10.1016/j.ecolecon.2009.02.019.

Botzen, W. J. W., J. C. J. M. van den Bergh, and L. M. Bouwer (2009b), Climate change and increased risk for the insurance sector: A global perspective and an assessment for the Netherlands, *Nat. Hazards*, in press.

Brilly, M., and M. Polic (2005), Public perceptions of flood risk, flood forecasting and mitigation, *Nat. Hazards Earth Syst. Sci.*, *5*, 345–355.

Burn, D. H. (1999), Perceptions of flood risk: A case study of the Red River flood of 1997, *Water Resour. Res.*, *35*(11), 3451–3458, doi:10.1029/1999WR900215.

Camerer, C. F., and H. C. Kunreuther (1989), Decision processes for low probability events: Policy implications, *J. Policy Anal. Manage.*, *8*(4), 565–592, doi:10.2307/3325045.

Central Bureau voor de Statistiek (2007), *Assurantiejaarboek 2007*, Kluwer, Amsterdam.

Dienst Weg-en Waterbouwkunde (2005), Veiligheid Nederland in kaart: Hoofdrapport onderzoek overstromingsrisico's, *Rep. DWW-2008–081*, Rijkswaterstaat, Den Haag, Netherlands.

Epstein, S. (1994), Integration of the cognitive and the psychodynamic unconscious, *Am. Psychol.*, *49*(8), 709–724, doi:10.1037/0003-066X.49.8.709.

Finucane, M. L., A. Alhakami, P. Slovic, and S. M. Lohnson (2000), The affect heuristic in judgements of risks and benefits, *J. Behavioral Decis. Making*, *13*, 1–17, doi:10.1002/(SICI)1099-0771(200001/03)13:1<1::AID-BDM333>3.0.CO;2-S.

Flynn, J., P. Slovic, C. K. Mertz, and C. Carlisle (1999), Public support for earthquake risk mitigation in Portland, Oregon, *Risk Anal.*, *19*(2), 205–216.

Fothergill, A. (1996), Gender, risk, and disaster, *Int. J. Mass Emerg. Disasters*, *14*(1), 33–56.

Gaillard, J.-C., R. D'Ercole, and F. Leone (2001), Cartography of population vulnerability to volcanic hazards and lahars of mount pinatubo (Philippines): A case study in Pasig-Potrero river basin (province of Pampanga), *Geomorphol. Relief Processes Environ.*, *7*(3), 209–222.

Gigerenzer, G., and U. Hoffrage (1995), How to improve Bayesian reasoning without instruction: Frequency formats, *Psychol. Rev.*, *102*(4), 684–704, doi:10.1037/0033-295X.102.4.684.

Gustafson, P. E. (1998), Gender differences in risk perception: Theoretical and methodological perspectives, *Risk Anal.*, *18*(6), 805–811, doi:10.1023/B:RIAN.0000005926.03250.c0.

Hakes, J. K., and W. K. Viscusi (1997), Mortality risk perceptions: A Bayesian reassessment, *J. Risk Uncertainty*, *15*(2), 135–150, doi:10.1023/A:1007782217912.

Hensher, D. A., J. M. Rose, and W. H. Greene (2005), *Applied Choice Analysis: A Primer*, Cambridge Univ. Press, Cambridge, U. K.

Hoetker, G. (2007), The use of logit and probit models in strategic management research: Critical issues, *Strategic Manage. J.*, *28*(4), 331–343, doi:10.1002/smj.582.

Huber, P. J. (1967), The behavior of maximum likelihood estimates under non-standard conditions, in *Proceedings of the Fifth Berkeley Symposium on Mathematical and Statistics and Probability*, edited by L. M. Le Cam and J. Neyman, pp. 221–233, Univ. of California Press, Berkeley, Calif.

Hurd, M. D., and K. McGarry (1995), Evaluation of the subjective probabilities of survival in the health and retirement study, *J. Hum. Resour.*, *30*, S268–S292, doi:10.2307/146285.

Hurley, T. M., and J. F. Shogren (2005), An experimental comparison of induced and elicited beliefs, *J. Risk Uncertainty*, *30*(2), 169–188, doi:10.1007/s11166-005-6565-5.

Intergovernmental Panel on Climate Change (2007), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by S. Solomon et al., Cambridge Univ. Press, Cambridge, U. K.

Kabat, P., W. van Vierssen, J. Veraart, P. Vellinga, and J. Aerts (2005), Climate proofing the Netherlands, *Nature*, *438*(7066), 283–284, doi:10.1038/438283a.

Kahneman, D. (2003), Maps of bounded rationality: Psychology for behavioral economics, *Am. Econ. Rev.*, *93*(5), 1449–1475, doi:10.1257/000282803322655392.

Kahneman, D., and S. Frederick (2002), Representativeness revisited: Attribute substitution in intuitive judgment, in *Heuristics and Biases: The Psychology of Intuitive Judgment*, edited by T. Gilovich, D. Griffin, and D. Kahneman, pp. 49–81, Cambridge Univ. Press, New York.

Kahneman, D., P. Slovic, and A. Tversky (1982), *Judgment Under Uncertainty: Heuristics and Biases*, Cambridge Univ. Press, New York.

Kaplan, S. (1973), Cognitive maps in perception and thought, in *Image and Environment*, edited by R. M. Downs, D. Stea, and K. E. Boulding, pp. 63–78, Aldine, Chicago, Ill.

Keijzer, X. (2008), The effectiveness of flood mitigation measures, M.Sc. thesis, Vrije Univ., Amsterdam.

Keller, C., M. Siegrist, and H. Gutscher (2006), The role of the affect and availability heuristics in risk communication, *Risk Anal.*, *26*(3), 631–639, doi:10.1111/j.1539-6924.2006.00773.x.

Kunreuther, H. C., W. H. Desvousges, and P. Slovic (1988), Nevada's predicament: Public perceptions of risk from the proposed nuclear waste repository, *Environment*, *30*(8), 17–33.

Kunreuther, H. C., N. Novemsky, and D. Kahneman (2001), Making low probabilities useful, *J. Risk Uncertainty*, *23*(2), 103–120, doi:10.1023/A:1011111601406.

Lindell, M. K. (1994), Perceived characteristics of environmental hazards, *Int. J. Mass Emergencies Disasters*, *12*(3), 303–326.

Loewenstein, G., and J. Mather (1990), Dynamic processes in risk perception, *J. Risk Uncertainty*, *3*(2), 155–175, doi:10.1007/BF00056370.

Loewenstein, G. F., C. K. Hsee, E. U. Weber, and N. Welch (2001), Risk as feelings, *Psychol. Bull.*, *127*(2), 267–286, doi:10.1037/0033-2909.127.2.267.

Middelkoop, H., K. Daamen, D. Gellens, W. Grabs, J. C. J. Kwadijk, H. Lang, B. W. A. H. Parmet, B. Schädler, J. Schulla, and K. Wilke (2001), Impact of climate change on hydrological regimes and water resources management in the Rhine basin, *Clim. Change*, *49*(1–2), 105–128, doi:10.1023/A:1010784727448.

Mileti, D. S., and J. D. Darlington (1997), The role of searching in shaping reactions to earthquake risk information, *Soc. Probl.*, *44*(1), 89–103, doi:10.1525/sp.1997.44.1.03x0214f.

Norris, F. H., T. Smith, and K. Kaniasty (1999), Revisiting the experience-behavior hypothesis: The effects of Hurricane Hugo on hazard preparedness and other self-protective acts, *Basic Appl. Soc. Psychol.*, *21*(1), 37–47.

Palm, R. I., M. E. Hodgson, R. D. Blanchard, and D. I. Lyons (1990), *Earthquake Insurance in California*, Westview Press, Boulder, Colo.

Peacock, W. G., S. D. Brody, and W. Highfield (2005), Hurricane risk perceptions among Florida's single family homeowners, *Landscape Urban Plann.*, *73*(2–3), 120–135, doi:10.1016/j.landurbplan.2004.11.004.

Perry, R. W., and M. K. Lindell (1990), Predicting long term adjustment to volcano hazard, *Int. J. Mass Emergencies Disasters*, *8*(2), 117–136.

Riad, J. K., F. H. Norris, and R. B. Ruback (1999), Predicting evacuation in two major disasters: Risk perception, social influence and access to resources, *J. Appl. Soc. Psychol.*, *29*(5), 918–934, doi:10.1111/j.1559-1816.1999.tb00132.x.

Ruin, I., J.-C. Gaillard, and C. Lutoff (2007), How to get there? Assessing motorists' flash flood risk perception on daily itineraries, *Environ. Hazards*, *7*(3), 235–244, doi:10.1016/j.envhaz.2007.07.005.

Schneider, Y., and P. Zweifel (2004), How much internalization of nuclear risk through liability insurance?, *J. Risk Uncertainty*, *29*(3), 219–240, doi:10.1023/B:RISK.0000046144.89048.9e.

Siegrist, M., and H. Gutscher (2006), Flooding risks: A comparison of lay people's perceptions and expert's assessments in Switzerland, *Risk Anal.*, *26*(4), 971–979, doi:10.1111/j.1539-6924.2006.00792.x.

Sitkin, S. B., and A. L. Pablo (1992), Reconceptualizing the determinants of risk behavior, *Acad. Manage. Rev.*, *17*(1), 9–38, doi:10.2307/258646.

Sjöberg, L. (2000), Factors in risk perception, *Risk Anal.*, *20*(1), 1–11, doi:10.1111/0272-4332.00001.

Sloman, S. A. (1996), The empirical case for two systems of reasoning, *Psychol. Bull.*, *119*(1), 3–22, doi:10.1037/0033-2909.119.1.3.

Slovic, P. (1987), Perception of risk, *Science*, *236*(4799), 280–285, doi:10.1126/science.3563507.

Slovic, P. (1997), The public perception of risk, *J. Environ. Health*, *59*(9), 22–29.

Slovic, P. (2000), *Perceptions of Risk*, Earthscan, London.

Slovic, P., M. L. Finucane, E. Peters, and D. G. MacGregor (2004), Risk as analysis and risk as feelings: Some thoughts about affect, reason, risk, and rationality, *Risk Anal.*, *24*(2), 311–322, doi:10.1111/j.0272-4332.2004.00433.x.

Terpstra, T., and J. M. Gutteling (2008), Households' perceived responsibilities in flood risk management in the Netherlands, *Water Resour. Dev.*, *24*(4), 555–565, doi:10.1080/07900620801923385.

Terpstra, T., J. M. Gutteling, G. D. Geldof, and L. J. Kappe (2006), The perception of flood risk and water nuisance, *Water Sci. Technol.*, *54*(6–7), 431–439, doi:10.2166/wst.2006.573.

Terza, J. V. (1987), Estimating linear models with ordinal qualitative regressors, *J. Econometrics*, *34*(3), 275–291, doi:10.1016/0304-4076(87)90013-3.

Train, K. E. (2003), *Discrete Choice Models with Simulation*, Cambridge Univ. Press, Cambridge, U. K.

Turner, R. H., J. M. Nigg, and D. H. Paz (1986), *Waiting for Disaster: Earthquake Watch in California*, Univ. of Calif. Press, Berkeley, Calif.

Tversky, A., and D. Kahneman (1973), Availability: A heuristic for judging frequency and probability, *Cognitive Psychol.*, *5*(2), 207–232, doi:10.1016/0010-0285(73)90033-9.

Tversky, A., and D. Kahneman (1974), Judgment under uncertainty: Heuristics and biases, *Science*, *185*(4157), 1124–1131, doi:10.1126/science.185.4157.1124.

Tversky, A., and D. Kahneman (1983), Extensional versus intuitive reasoning: The conjunction fallacy in probability judgment, *Psychol. Rev.*, *90*(4), 293–315, doi:10.1037/0033-295X.90.4.293.

Tversky, A., and D. Kahneman (1986), Rational choice and the framing of decisions, *J. Bus.*, *59*(S4), 251–278, doi:10.1086/296365.

van Praag, B. M. S., P. Frijters, and A. Ferrer-i-Carbonell (2003), The anatomy of subjective well-being, *J. Econ. Behavior Organ.*, *51*(1), 29–49, doi:10.1016/S0167-2681(02)00140-3.

Verbond van Verzekeraars (2007), *Verzekerd van Cijfers 2007*, Lelystad, Netherlands.

Viscusi, W. K. (1998), *Rational Risk Policy*, Oxford Univ. Press, Oxford, U. K.

Viscusi, W. K., and J. T. Hamilton (1999), Are risk regulators rational? Evidence from hazardous waste cleanup decisions, *Am. Econ. Rev.*, *89*(4), 1010–1027.

Viscusi, W. K., and R. J. Zeckhauser (2006), National survey evidence on disasters and relief: Risk beliefs, self-interest, and compassion, *J. Risk Uncertainty*, *33*(1–2), 13–36, doi:10.1007/s11166-006-0169-6.

White, H. (1982), Maximum likelihood estimation of misspecified models, *Econometrica*, *50*(1), 1–25, doi:10.2307/1912526.

Windham, G. O., E. I. Possey, P. Ross, and B. Spencer (1977), *Reactions to Storm Threat During Hurricane Eloise*, Miss. State Univ., Mississippi State, Miss.

Wooldridge, J. M. (2002), *Econometric Analysis of Cross Section and Panel Data*, MIT Press, Cambridge, Mass.

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