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ORIGINAL PAPER

Implementing a trans-boundary flood risk management plan: a method for determining willingness to cooperate and case study for the Scheldt estuary

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Abstract In this paper, I applied statistical, econometric, and mathematical methodologies to evaluate the conditions required for implementing a publicly supported trans-boundary flood risk management plan in accordance with the EU Floods Directive (2007/60/EU). Although this paper adopts a focus on the methodology rather than on solving a specific problem, the Scheldt estuary is used to provide an illustrative case study of this approach. I showed that, apart from some expected minor differences, the Belgians and the Dutch can be considered a relatively homogeneous population. Moreover, I estimated the main determinants of both perceived flood risk (PFR) and willingness to pay (WTP) for a compensation fund by using a linear model and an ordered probit model (based on a double-bounded dichotomous-choice approach), respectively. Some policies appear to be potentially effective: a campaign to inform the general public about evacuation and trauma management could increase WTP by 19 and 21 %, respectively; an information campaign focused on young women could reduce PFR; and a campaign to inform the general public about flood strategies and the need to disregard flood events in the press could reduce PFR by 56 and 54 %, respectively. Finally, I showed that, apart from some expected differences between the values at risk in Belgium and the Netherlands, both individual rationality and overall feasibility conditions are met. Thus, if information campaigns and other measures are designed to account for differences between the Belgians and the Dutch, a publicly supported trans-boundary flood risk management plan can be successfully implemented.

Keywords Contingent valuation · Risk perception · EU Floods Directive · Scheldt estuary

1 Introduction

The purpose of the EU Floods Directive (http://floods.jrc.ec.europa.eu/eu-floods-directive) is "to establish a framework for the assessment and management of flood risks, aiming at a

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reduction of the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods" (2007/60/EC, Chapter 1, Article 1), by accounting for future changes in the risk of flooding as a result of climate change. In the Directive, *flood* means "the temporary covering by water of land not normally covered by water," and *flood risk* means "the combination of the probability of a flood event and of the potential adverse consequences" (Chapter 1, Article 2). The focus in the present paper is on flood risk management. Moreover, Chapter 4, Article 7 states that "Member States shall establish flood risk management plans coordinated at the level of the river basin district." In addition, Article 8 states that, "where an international river basin district falls entirely within the Community, Member States shall ensure coordination with the aim of producing one *single* international flood risk management plan" or, where this is not possible, "Member States shall produce flood risk management plans covering at least the parts of the international river basin district falling within their territory." As far as possible, these multiple plans should be "coordinated at the level of the international river basin district." The focus in the present paper is on trans-boundary flood risk management plans. Finally, the EU Floods Directive encourages "the active involvement of interested parties in the production, review, and updating of the flood risk management plans" and recommends making these plans "available to the public" (Chapter 5, Article 10). The focus in the present paper is on gaining public support for a single international flood risk management plan for the Western Scheldt estuary, which lies between Belgium and the Netherlands.

The Western Scheldt estuary, which originates in Belgium and ends in the Netherlands, is an international river basin with many intertidal areas in the Netherlands that have unique flora and fauna. These areas form a crucial overwintering site for large populations of migratory birds (i.e., the environment is important), but the estuary also provides the only access channel for the Belgian port of Antwerp in Flanders (i.e., economic activities are also important). Researchers believe that *climate change* will greatly increase the risk of flooding in the Netherlands, where even today, floods originate from tides and storms. In the Netherlands, the situation is exacerbated by dredging of the channel demanded by Belgium and by the smaller secondary water channels required by Dutch farmers. In Belgium, floods originate from tides and runoff, mainly due to housing development, and can also be caused by dyke breaches. Although great efforts have been made to prevent such disasters, fatalities cannot be excluded in either country (De Bruijn et al. 2008; Warner and van Buuren 2009; van Buuren et al. 2010). In other words, the Western Scheldt estuary has all the features mentioned in the EU Floods Directive.

For this reason, a single unified flood risk management plan would be beneficial to all the interested parties in both countries. In particular, total management costs could be reduced for a given reduction in flood probability or flood risk (i.e., the flood probability multiplied by the flood damage), or a larger reduction in flood probability could be achieved at a given total cost if Belgian strategies (i.e., increasing dyke height, establishing water-retention areas) were coordinated with Dutch strategies (i.e., dredging, sand maintenance). The overall environmental value could be increased by balancing the need for salt marshland in the Netherlands (i.e., returning fertile soil to the sea) with the need for water-retention areas in Belgium (i.e., covering fertile soil with fresh water).

An ambitious plan (the *Long-Term Vision for the Scheldt Estuary in 2030*) was developed by governments, stakeholders, and local authorities and was approved in 2001, with the goals of (for example), improving access to the Antwerp channel, restoring the ecological qualities of the estuary, increasing protection against floods, conserving the physical characteristics of the estuary, and achieving mutual cooperation in decision

making. In addition, the *Development Plan for 2010* was drafted and a *Consultation Group* was established. Despite these efforts, various attempts by the main stakeholders to negotiate between policy bodies (e.g., national departments, the Consultation Group, and responsible ministers) to maximize their benefits are still ongoing. These stakeholders include the pro-development Antwerp coalition, the international environmentalist coalition, and the Dutch farmers' coalition. Because of their competing interests, mutual trust has yet to be developed, as illustrated by the so-called zip principle, according to which deepening of the channels must go hand in hand with measures to develop and protect the natural environment (Meijerink 2008). In other words, the magnitude of the cooperative attitude among stakeholders must be increased.

In this context, the purpose of the present study was twofold: first, to suggest a methodology for evaluating the conditions required for implementing a publicly supported trans-boundary flood risk management plan (i.e., individual rationality and overall feasibility); second, to apply this methodology to the Scheldt estuary.

In particular, I applied econometric methodologies, based on field survey data, to estimate the main determinants of both perceived flood risk (PFR) and willingness to pay (WTP) for a compensation fund that would be used to implement a single flood risk management plan for both countries. I grouped the independent variables for the estimation of PFR into personal variables (i.e., age, sex, occupation, education, country, the perceived relative risk (i.e., the belief that the participant bears a greater risk than others), main flood cause, and main risk mitigation strategy), variables to cope with biases (i.e., the interviewer's name), and policy variables (i.e., sources of knowledge about flood phenomena and risk mitigation strategies). Similarly, I grouped the independent variables for the estimation of WTP into personal variables (i.e., age, sex, income, country, experiences with evacuation or trauma management, experiences with direct or indirect and tangible or intangible flood damage, PFR, feelings about the personal ability to control the flood risk, whether flooding could be prevented by government or other management measures, feelings about the personal ability to control the flood damage, the main flood damage), variables to cope with biases (i.e., first bid, risk reduction, attitudes, and values), and policy variables (i.e., knowledge about evacuation and trauma management and public or private insurance schemes).

I chose the concept of a compensation fund as a reference for both practical and analytical reasons. For practical reasons (i.e., the ability of interviewed people to more easily understand the contextual issues), a compensation fund could be used to cope with inconsistent timings of some costs and benefits. In addition, the fund avoids the necessity to define explicit solutions that would resolve controversial evaluations of some environmental or health benefits. For example, not all experts agree that the new strategies and techniques for dredging and dumping sediments will have no long-run negative impacts on the Scheldt ecosystem; similarly, some experts still argue that increasing the water storage capacity of the estuary is necessary for long-term flood control.

For analytical reasons (i.e., the achievement of a consistent estimation of the willingness to cooperate (WTC) in an international flood risk management plan by people in both countries), international cooperation is a public good, that is, WTC is a non-exclusive good, because people who do not cooperate cannot be excluded from the benefits arising from cooperation. WTC is also a non-rival good, because the benefits received by cooperating people are not detrimental to non-cooperating people. Thus, international cooperation is affected by the "free rider" problem, in which people can agree on cooperation in principle, but in practice, they could expect other people (but not themselves) to cooperate. In this context, there is no overuse problem (i.e., too much cooperation) nor are

there moral hazard issues (i.e., risky behaviors that jeopardize cooperation). For these analytical reasons, it was necessary to estimate the magnitude of active consent rather than passive consent.

Next, international cooperation is a process, not a benefit from non-market goods or services. Although I informed the interview participants that cooperation could reduce flood risk by 10 or 15 %, the same results could be achieved in alternative ways. In other contexts, together with WTP, it is possible to ask for cooperative behaviors. For example, in the context of "green" hotels, some consumers are willing to pay extra for the use of renewable energy, are willing to accept the use of key switches (which turn on electrical power only when a guest is in the room), or are willing to accept the lack of individual soaps, and it is possible to ask them to voluntarily turn off air conditioning or lights (Dalton et al. 2008). In other words, it was not possible in the present context to ask for cooperative behaviors, and the magnitude of active consent had to be represented by a parameter such as WTP.

Moreover, I applied the *stated* PFR and WTP declared by the interview participants in response to open questions in my analyses. The goal was to assess possible differences between the Belgians and the Dutch in *individual rationality* (i.e., for each individual, the condition that the expected benefits must cover the contributions) by stressing the potential ability of policies identified by the econometric analysis to reduce these differences. Certainly, a majority supporting a single flood risk management plan would provide political direction to governments and local authorities, typically characterized by a relatively short time horizon.

Finally, I applied the *estimated* PFR and WTP that was assessed by properly applying econometric methodologies based on answers to closed questions to evaluate the *overall feasibility*. I defined this as a condition in which the total contributions must cover the total costs of the flood risk management plan.

There is no literature on quantitative WTC for flood management at an international level. However, Slinger et al. (2010) qualitatively focused on the use, availability, and adequacy of information for future decision making related to the trans-boundary Incomati River, which is shared by Mozambique, South Africa, and Swaziland. Bakker (2009) identified international river basins with adequate institutional capacity for the management of trans-boundary floods in terms of biophysical and socioeconomic variables. Becker et al. (2007) qualitatively suggested a network for discussion to promote social learning for the Rhine basin, which is shared by the Netherlands and Germany, in order to generate a common problem perception and problem analysis as well as to develop a common vision of future flood strategies.

Note that in this study, people in Belgium and the Netherlands were not asked to express an opinion about negotiations between the three main advocacy coalitions (the pro-development Antwerp coalition, the environmentalist coalition, and the Dutch farmers' coalition): the focus was instead on the willingness to adopt a cooperative attitude to achieve the goals of the EU Floods Directive. Moreover, people in both countries were asked to state their WTP for a fund required to support a trans-boundary flood risk management plan capable of reducing the overall flood risk in both countries, to the greatest extent possible at the smallest cost, and to reduce the overall flood damage to the environment, to economic activities, and to human health. Finally, people in both countries were not be asked to express an opinion about linkages among the water quality and quantity in the Scheldt estuary, maintenance and improvement of navigation channels in the western Scheldt estuary, or the construction of new waterways aimed at improving

maritime access to the port of Antwerp. Instead, the focus was on flood risk management strategies.

2 Methodology

Two main methodologies can be applied to estimate WTC for flood management at an international level: a choice experiment and contingent valuation methods. For recent applications of these methods to risk perception and risk assessment, see Winter and Fried (2000), Chilton et al. (2002), Hammar and Johansson-Stenman (2004), Rekola and Pouta (2005), Tsuge et al. (2005), Vassanadumrongdee and Matsuoka (2005), and Mozumder et al. (2009). Both approaches are stated-preference methods, which are the only methods by which the total economic value can be measured because they can incorporate both *non-use values* and *option values*, thus making it possible to value hypothetical (pure public or quasi-public) goods and interventions. The primary alternative to these approaches is the revealed-preference method, which can only capture *use values* (Carson and Louviere 2012). In general, contingent valuation directly measures the value of a good holistically (i.e., by valuing the good in its entirety), whereas a choice experiment asks the respondents to decide which of two or more mutually exclusive multi-attribute alternatives they prefer. As a result, it indirectly estimates the value of a good by introducing a price variable. The other two main choice techniques (i.e., contingent ranking and contingent rating) are more cognitively demanding, as they require respondents to rank all the alternatives, thereby providing a complete preference order, or to place a value on each alternative, thereby characterizing the strength or degree of preference.

Both choice experiments and contingent valuation can estimate the value of a flood risk management plan as a whole, based on individual characteristics and on the perceptions of complementary policies, although choice experiments also provide information that could support a cost-benefit analysis or the design of multi-dimensional flood risk management plans, that is, they could reveal alternative policies that affect alternative risks or damage (e.g., for houses, the environment, economic activities, and lives) to various extents by measuring the marginal contribution that each single characteristic of a flood risk management plan adds to an individual's utility. For example, consider a flood risk management plan that reduces the risk for houses to a greater extent than the risk for the environment and that is quite expensive, whereas another plan reduces the risk for the environment to a greater extent than the risk for economic activities and that is quite inexpensive. In other words, contingent valuation is best suited to valuing the overall policy package, whereas choice experiments are better suited to valuing the individual characteristics that constitute actual or hypothetical flood risk management plans. In addition, contingent valuation studies are easier, cheaper, and faster, whereas choice experiments are more difficult and artificial.

The purpose of the present study was to assess the WTP for a common flood risk management plan in two different places, rather than to compare alternative flood risk management plans that cope with different risks or different forms of damage in the same place. Moreover, flood risk management plans in the Netherlands are expected to defend the land below sea level as a whole, so it is less meaningful to refer to policies targeted to specific Dutch issues. Finally, there is no uncertainty in the commodity definition or quantity, and there is no potential sequencing effect (in which the WTP value for a particular good differs depending on the order of the good in a sequence), since the purpose of this study is to assess the public support for a common flood risk management plan.

For these reasons, the contingent valuation method was a better choice and was the method that I used for this study. In particular, I chose a double-bounded dichotomous-choice approach, that is, after a first question, in which respondents stated whether they were or were not willing to pay a certain amount (the bid value) for the plan, I asked them in a follow-up question whether they were willing to pay a higher bid value, if the first answer was "yes," or a lower bid value, if the previous answer was "no." The goals of this approach were to deal with the strategic bias (unlike in an open-ended format), to achieve incentive compatibility (unlike in the payment card response format), to cope with the rounding effect (unlike in the open-ended format), and to reduce non-responses (unlike in the open-ended format). Two consecutive open questions were used in the questionnaire to test for the possibility of strategic behaviors (e.g., free riding) and to understand the main reasons for not being willing to pay (e.g., the belief that the government should pay). I introduced some independent variables in the econometric model to cope with problems such as starting-point bias and the embedding effect.

Note that the hypothetical bias or reliability issues (i.e., divergences between real and hypothetical payments) should be irrelevant due to the realistic context presented to interviewees. Moreover, I expected the Belgian WTP to be greater than the Dutch WTP, since the defense of national coasts is more integrated in Dutch culture (i.e., the Dutch might be proud of existing national flood defense policies, whereas Belgians might perceive a larger national benefit from trans-boundary flood risk management). To test this hypothesis, I performed an overall estimation using a dummy variable for "lives in Belgium," Finally, the WTP could depend on complementary flood policies such as the available information, public and private insurance, evacuation plans, and management of psychological trauma. I also introduced dummy variables in the econometric model to account for these factors. This approach could also account for the information effect, in which differences in WTP arise due to asymmetric background information among the interviewees.

I made the following simplifying assumptions in this analysis: the period of risk reduction was 10 years; flood risk reductions were 10 or 15 %; and the starting point for the percentages of renounced income were 1 or 1.5 %. I did not attempt to tackle the following problems: post hoc rationalization, cognitive dissonance, individual heterogeneity in processing information, over-optimism, and time-inconsistent discounting of future benefits.

There is no literature on quantitative WTC at international level for flood management, although there are many quantitative papers on WTP for non-market goods or services within the environmental valuation literature. There are also many qualitative but few quantitative papers on individual and social risk perception within the psychological and sociological literature.

As examples of recent papers on WTP for reducing flood risks, Zhai et al. (2006) estimated the WTP for risk reduction within a multi-risk context by showing that WTP may increase with increasing per capita income, individual preparedness, individual experience with flooding, and perception of flood risk, but may decrease with increasing distance from a body of water, acceptability of flood risk, provision of information on the potential environmental impacts caused by flood control constructions, and perception of other risks. Botzen et al. (2012) showed that most homeowners were willing to make a substantial investment to elevate a new house to a level above the expected flood depth by emphasizing that WTP was correlated with the expected negative effects of climate change, perceptions of flood risk, individual attitudes toward risk, and living close to a main body of water.

However, the present study does not belong to the literature on quantitative flood risk commodification or flood insurance (e.g., Botzen and van den Bergh 2012; Brouwer and Schaafsma 2012), although my interview participants expressed monetary agreement on trans-boundary flood management, which they expected to reduce their flood risk.

As an example of a recent paper on quantitative individual flood risk perception, Ge et al. (2011) distributed questionnaires to the members of the community and to representatives of the local authorities in the Yangtze River Delta and used their responses to identify sources of differences in perception and to suggest management measures.

I asked about PFR using open-ended questions, but this parameter was not the focus of my study, although I relied on the analytical and experiential systems by Slovic et al. (2004) in my questionnaire; for instance, I introduced questions about risk probability assessments and experiences of evacuation or trauma. Instead, I used PFR as an independent variable to estimate WTC for flood management at an international level, in order to assess the degree of independence of WTC from PFR, together with other individual variables.

As an example of a recent paper on quantitative social perception of flood risk, Kellens et al. (2012) reviewed 57 empirical peer-reviewed articles on flood risk perception and communication, and concluded that there is little methodological standardization in measuring and analyzing flood risk perception and adaptive behavior. The present study does not belong to the literature on qualitative risk governance (e.g., Renn et al. 2011; Renn and Schweizer 2009), although I relied on the main concepts of complexity, ambiguity, and uncertainty from this literature in my questionnaire. For complexity, I stressed that the flood risk analyzed in my study was not confined to national borders (i.e., both countries are involved), did not refer to a single sector (i.e., many sectors were potentially damaged), and could not be linked to a single cause (i.e., many past and future causes were possible, and interacted, with synergisms and antagonisms, positive and negative feedback loops, and long delay periods between causes and effects). For uncertainty, I allowed respondents to express difficulty in assessing the probability and possible outcomes of undesired effects by referring to evacuation and trauma experiences, awareness of evacuation and trauma policies, alternative flood causes and damage, different sources of knowledge about causes and strategies, and knowledge about past and future flood strategies. For ambiguity (based on values to a greater extent than on perspectives), I used variables such as attitudes, the personal ability to control the flood risk (i.e., voluntary), whether flooding could be prevented by government or other management measures (i.e., responsibility), the personal ability to control the flood damage (i.e., controllability), and the positive or negligible values of some effects. I estimated PFR as dependent on socially observable variables such as age, sex, and different sources of knowledge about causes and strategies.

In summary, my context was closer to the qualitative and quantitative tax compliance literature (e.g., Hofmann et al. 2008; Hashimzade et al. 2012; Konrad and Qari 2012), in which WTC and willingness to spontaneously comply with the law turn out to depend not only on external variables (e.g., tax rates, income, probability of audits, and severity of fines), but also on internal variables (e.g., knowledge of taxation, personal and social norms, and distributive, procedural, and retributive justice). In the context of the present study, there is no knowledge of taxation (i.e., the fund does not yet exist), distributive justice is negligible (i.e., I asked people how much to contribute), procedural justice is irrelevant (i.e., all people are treated neutrally), retributive justice is neglected (i.e., audits and punishment are absent), and subjective personal and social norms are disregarded. However, I applied both subjective variables, such as attitudes, voluntary, controllability,

responsibility, and the positive or negligible values of some effects, and objective variables, such as sources of knowledge, age, sex, and income.

In my methodology, the probability density function for risk expectations was not evaluated (Rekola and Pouta 2005), although I estimated the means for both countries and used them as dependent variables in estimating WTC. In addition, the risk perception relative to alternative policies was irrelevant (Chilton et al. 2002), since a single plan was under scrutiny. The provision of a risk map was not a reasonable policy (Mozumder et al. 2009), because residents are not expected to efficiently sort mitigation efforts spatially. Thus, the main relevant studies in the literature were Winter and Fried (2000) and Vassanadumrongdee and Matsuoka (2005), although I also obtained insights from Hammar and Johansson-Stenman (2004) and Tsuge et al. (2005). Moreover, there was no valuation of the objective exposure to risk (which I considered to be identical for all respondents), so there was no underestimation of risk, although there might have been over-optimism or inconsistent time-based discounting of future benefits. Finally, I assumed that a private good such as safety or cost savings would be valued domestically, so that trans-boundary effects such as contentment or moral satisfaction would be relevant only for the environment and for lives saved.

Since WTP must be applied to estimate WTC, and since contingent valuation was more suitable than a choice experiment in this context, I applied a method perspective rather than a problem perspective. In other words, I tested the extent to which contingent valuation fit my context by highlighting which issues were not tackled or which simplifications were made rather than by viewing the problem in terms of its peculiarities and justifying the choice of contingent valuation.

2.1 The field survey

The questionnaire (see the "Appendix") consisted of four sections. The first section provided an overview of the main purposes, issues, and scopes of the interview: the goal of the survey, causes of flood risk, reasons for a common flood risk management plan, current problems in implementing a common flood risk management plan, and the scope of the survey. The second section aimed to identify the personal characteristics and attitudes of participants. In particular, I asked participants to express their agreement (from strongly agree to strongly disagree) about four statements on the rights of inhabitants near the Scheldt estuary and the rights of nature in general, as well as on possible economic evaluations of safeguarding human life and environmental conservation. The third section aimed to assess risk perception as a function of personal knowledge (evacuation and trauma management strategies, public and private insurance schemes or compensation for damage, main causes, and potential flood damage), personal feelings (acceptance of flood damage, controllability of flood risk, responsibility for flood protection, and the perceived relative flood risk), and personal experience (evacuation and trauma management strategies, direct and indirect tangible or intangible damage due to flooding). The fourth section aimed to assess the WTC for a common flood risk management plan. In particular, I asked participants to explain why they were or were not willing to pay. Moreover, I asked them whether they attached a positive value to general issues such as maintenance of biodiversity and recreational activities in the estuary as well as to the reduction of risk and trauma exposure of affected communities. Finally, I asked participants to identify the most important general issues and strategies in the past and the future.

In my questionnaire, mortality risk was implicitly considered in questions about previous experiences (Vassanadumrongdee and Matsuoka 2005). I also evaluated the

Table 1 Characteristics of the theoretical sample groups in Belgium and the Netherlands

	Risk reduction			
	Age ≤ 40		Age > 40	
	10 %	15 %	10 %	15 %
First bid				
1.0 %	44	44	22	22
1.5 %	44	–	22	–
Total	88	44	44	22

sensitivity to the magnitude of the risk reduction (Tsuge et al. 2005), although specific risk standards are specified in the Netherlands. I asked participants to state whether their exposure to risk was voluntary or involuntary (Hammar and Johansson-Stenman 2004) and to identify the main responsibilities for risk reduction (Winter and Fried 2000).

Note that the purpose was not to describe to the reader or to interview participants details of the real-world situation or to explain how to improve the participant's knowledge or reduce their misperceptions about flood risk and flood causes, but rather to estimate how these perceptions affected WTC and whether WTC was rational and feasible, despite any possible misperceptions. Consequently, some causes were kept general (e.g., climate change), some were left to the participants to imagine ("others"), and some were left unspecified (e.g., dredging or channel deepening) to avoid creating so many details that the questions puzzled the participants, most of whom were not experts in this subject.

The theoretical sample consisted of 198 people in Belgium and 198 in the Netherlands, with the following key focal cities: Antwerp in Belgium and Middleburg or Vlissingen in the Netherlands. The questionnaire was administered to 66 people in the two countries with the expressed goal of a 10 % overall flood risk reduction due to the common flood risk management plan and with 1 % of annual income relinquished to implement the common flood risk management plan. The questionnaire was administered to 66 people in both countries with the flood risk reduction expressed as 15 % to estimate the sensitivity to the amount of risk reduction, and to 66 people in both countries with the income relinquished set to 1.5 % to estimate the impact of the starting point for the bids. The possibility of differences in the future perspective related to climate change prompted me to split the sample asymmetrically, with 2/3 of the interviews conducted with young people (≤40) and 1/3 of the interviews conducted with older people (>40).

Table 1 presents the details of the theoretical sample group, which had a similar proportion of men and women in each subsample. I used alternative first bids to measure the extent to which WTP depends on the first bid and used the alternative risk reductions to test the extent to which WTP was sensitive to the magnitude of the risk reduction.

2.2 The econometric models

As the dependent variables, I used the stated PFR and the four possible pairs of responses (yes–yes, yes–no, no-yes, and no–no) to the double-bounded dichotomous choices about WTP for a compensation fund to implement a single trans-boundary flood risk management plan. I used the stated PFR as the independent variable in the estimation of WTP to test for the independence of the two econometric models.

I grouped the independent variables used for the estimation of PFR into personal variables, variables used to cope with potential biases, and policy variables. For the personal variables, I introduced the participant's age, sex, occupation, education, country, and feelings (perceived relative risk, main flood causes, and strategies). To cope with biases, I used a dummy variable to identify the interviewer who performed each interview. For policy variables, I introduced references to knowledge sources about flood phenomena and strategies. I also grouped the independent variables for the estimation of WTP into personal variables, variables to cope with biases, and policy variables. For personal variables, I used the participant's age, sex, income, country, and experience (evacuation or trauma management, direct or indirect, and tangible or intangible damage), as well as their feelings (the personal ability to control the risk, acceptance, controllability of the risk, PFR, the main flood damage). To cope with biases, I used the following main variables. The *attitude effect* variable took values from −4 to +4 to represent the range from strong disagreement (–4) to strong agreement (+4) with two statements about the rights of inhabitants near the Scheldt estuary as well as possible economic evaluations for safeguarding human life; I used the same scale for two further statements about the rights of nature in general and about economic evaluations of environmental conservation. The *embedding effect* variable took values between 0 and 2, with no values attached to general issues (0), positive values attached to some general issues (1), and positive values attached to all general issues (2) such as maintenance of biodiversity and recreational activities in the estuary; I used the same parameter values for no values and for positive values attached to the reduction of risk and trauma exposure of affected communities. The *starting point* variable took a value of 0 if the first bid was 1 % and a value of 1 if it was 1.5 %. The *risk sensitivity* variable took a value of 0 if the expected risk reduction was 10 % and a value of 1 if it was 15 %. To account for policy variables, I introduced variables for knowledge about evacuation and trauma management and for public and private insurance schemes: a value of 0 if they did not know about these policies and a value of 1 if they did know.

I defined the econometric models as a linear model for PFR, and as an ordered probit model for WTP for a compensation fund to implement a single trans-boundary flood risk management plan. I used a linear model for PFR because this dependent variable was based on answers to open-ended questions. I applied an ordered probit model to estimate WTP because this dependent variable was based on answers to dichotomous questions. In particular, I assumed that answers to the initial and follow-up questions were driven by a single latent WTP amount, where the bid offered in response to the second question depended on the information gained from the response to the initial payment question (e.g., Hanemann et al. 1991). I pooled the responses to the first and second questions by considering that the second set of responses was an additional observation generated by the same latent WTP (e.g., Shyamsundar and Kramer 1996).

Note that I did *not* use a single-bounded dichotomous-choice approach (e.g., Cameron 1991) because this approach is less efficient than the double-bounded dichotomous-choice approach (Carson and Groves 2007). Indeed, the responses reveal an interval for WTP, which can be large or even unbounded. Moreover, I did *not* use the random-effect probit model (e.g., Alberini et al. 2003). Since the respondents are not allowed to express uncertainty (i.e., only yes or no responses are allowed for the first and second bids) and since a change in the quantity or quality of the offered plan is meaningless, the individual's WTP responses are driven by a single WTP distribution or by two highly correlated underlying WTP distributions (Vossler and Pole 2005). Finally, I did *not* apply the bivariate probit model (e.g., Cameron and Quiggin 1994) because the double-bounded estimates of the mean WTP (Wang and Whittington 2005) measure the distributions of

individual valuations rather than a single point value, and these valuations are always more efficient than those obtained by fitting a bivariate probit model, whenever the individual's WTP responses are driven by a single WTP distribution or by two highly correlated underlying WTP distributions (Alberini 1995).

3 Results

In this section, I apply the methodology developed in Sect. 2 to highlight any differences between Belgian and Dutch respondents, and to estimate the main determinants of PFR and WTP that could potentially be used to reduce these differences.

In particular, the econometric estimates included all potentially relevant variables *at the beginning* of the analysis. They excluded the least significant variables *at each step* (i.e., those that have $P > 0.10$) to identify the most effective policies. They disregarded the country dummy variable *at the end of the analysis* to assess the advisability of implementing specific policies for the two countries. Moreover, variables that turned out to be nonsignificant when determining WTP or PFR were still described statistically: these included why a response to WTP was yes or no, the main expected type of flood damage, voluntary, controllability, and responsibility for WTP, and included activities, education, main flood causes, main current strategies, and main future strategies for PFR. Finally, in estimating WTP, it proved difficult to estimate *ex-ante* the adequacy of evacuation policies (39 non-responses missed) and trauma policies (49 non-responses), with 38 experienced and inadequate evacuations and 45 experienced and inadequate trauma interventions. Thus, I used the experiences with evacuation and trauma policies instead. Similarly, the adequacy of public insurance (39 non-responses) and private insurance (47 non-responses) turned out to be difficult to estimate *ex-ante*, so I used the experiences of direct and indirect tangible and intangible damage instead. To estimate PFR, questions about the main current and future flood strategies were considered to be preliminary to questions about knowledge sources concerning flood strategies.

3.1 The descriptive statistics

The face-to face survey was conducted in the native language of the participants in September 2010 by a total of seven interviewers, with consistency achieved by using the same standard questionnaire for all interviewers. The questionnaire was validated before using it to collect data by interviewing 20 Belgians and 20 Dutch, so that any misunderstandings could be resolved and so that questions that did not provide answers suitable for use in the analysis could be revised to provide more suitable data. To simplify the process, I deleted questions about payment methods, since only two alternatives (taxes and current accounts) were chosen in the pilot interviews. Moreover, for the sake of symmetry, I retained the question about the possibility of private insurance for floods, even though this approach would not be feasible in the Netherlands. Finally, after validation testing of the original questions, I deleted questions about how to reduce overall expenditure, since I observed embarrassment and confusion among the interview participants.

Tables 2 and 3 summarize the empirical samples for both countries, excluding responses with no flood or damage risk estimates or with no income range and activity responses. The empirical sample in both countries was balanced with respect to the sex of the respondents. The reference subsample (i.e., age ≤ 40, first bid at 1 %, and risk reduction at 10 %) was slightly oversized in both countries.

Table 2 Characteristics of the empirical sample in Belgium

	Risk reduction			
	Age ≤ 40		Age > 40	
	10 %	15 %	10 %	15 %
First bid				
1.0 %	58	45	15	24
1.5 %	34	–	20	–
Total	92	45	35	24

The sample represented the populations of both countries relatively well in terms of per capita incomes, education levels, and economic activities after accounting for the over-representation of young people (2/3 of the participants were 40 or younger) due to the climate change issues under consideration.

Table 4 provides summary statistics for the quantitative variables. The average monthly income was consistent with national statistics: 1790 and 1720 € in the Netherlands and Belgium, respectively. The average age was also consistent: 35 and 34 in the Netherlands and Belgium, respectively. Risk perception was lower in the Netherlands (i.e., 11 % < 13 %), but it was closer to damage perception (i.e., 11–9 % < 13–7 %). The maximum *stated* WTP was smaller in the Netherlands: the Dutch value was close to 1.0, whereas the Belgian value was closer to 1.5.

Tables 5, 6, 7, 8, and 9 present summary statistics for the qualitative variables that were not significant in estimating WTP. Note that the rankings of the main types of flood damage were the same in both countries (lives, followed by economic/housing and the environment). Moreover, the perceived voluntary of flood risk and the perceived controllability of flood damage were relatively high (14 and 22 % in Belgium; 13 and 18 % in the Netherlands) and were similar in the two countries. Finally, both trauma and evacuation experiences were greater in the Netherlands, as expected.

Tables 10, 11, 12, 13, and 14 present statistics for the qualitative variables that were not significant for estimating PFR. Note that the same rankings of education levels were observed in the two countries (secondary degree, then bachelor's degree, then higher than bachelor's degree), and the recorded frequencies of economic activities were similar; people with a relatively predictable income per month (i.e., private and public employees, unemployed, and retired) represented 27 % of the total in Belgium and 26 % in the Netherlands, whereas people with low incomes (i.e., students) represented 42 % of the total in Belgium and 38 % in the Netherlands and people with a relatively unpredictable monthly income (i.e., farmers, merchants and businessmen, professional or service workers) represented 26 % of the total in Belgium and 29 % in the Netherlands. The "other" category of activity accounted for a reasonable 5 % of the total in both countries. The most common "other activity" was "housewife." The questionnaire included an illustration aimed at helping people to estimate small risks. The vast majority specified a percentage well above the reference range (i.e., <1 % flood risk in the next 10 years), which includes the actual flood probability estimated by experts; this suggests that participants overestimated this percentage. Based on the means and standard deviations for each interviewer (Table 13), responses did not differ significantly among the interviewers (ANOVA, $P = 0.93$). In terms of perceptions about whether they faced a greater risk than other people, 19 and 42 % made this claim in Belgium and the Netherlands, respectively,

Table 3 Characteristics of the empirical sample in the Netherlands

	Risk reduction			
	Age ≤ 40		Age > 40	
	10 %	15 %	10 %	15 %
First bid				
1.0 %	48	43	24	21
1.5 %	45	–	19	–
Total	93	43	43	21

Table 4 Mean values of the quantitative variables

	Age (years)	Per capita income (€ per month)	Risk perception (%)	Damage perception (%)	Maximum stated WTP (% of annual income)
Belgium	34	1720	13	7	1.32
The Netherlands	35	1790	11	9	0.98

Risk perception = the perceived probability of a flood in the next 10 years. Damage perception = the perceived probability, the participant would be affected by a flood in the next 10 years. Maximum stated WTP = the maximum income contributed to implement the EU Directive

Table 5 Statistics for the main types of flood damage (not significant for estimating WTP)

	Belgium		The Netherlands		Grand total	
Nuclear power station	3	2 %	6	3 %	9	2 %
Navigation	11	6 %	19	10 %	30	8 %
Environment	27	14 %	35	18 %	62	16 %
Housing	34	17 %	38	19 %	72	18 %
Agriculture	25	13 %	19	10 %	44	11 %
Tourism	4	2 %	3	2 %	7	2 %
Industry	10	5 %	2	1 %	12	3 %
Lives	71	36 %	57	29 %	128	32 %
Other (specify)	11	6 %	21	11 %	32	8 %
Grand total	196	100 %	200	100 %	396	100 %

Table 6 Statistics for the perceived voluntary component of flood risk (i.e., personal ability to control flood risk) (not significant for estimating WTP)

	Belgium		The Netherlands		Grand total	
No	160	82 %	169	85 %	329	83 %
Unknown	8	4 %	5	3 %	13	3 %
Yes	28	14 %	26	13 %	54	14 %
Grand total	196	100 %	200	100 %	396	100 %

which emphasizes the much greater perceived relative flood risk in the Netherlands, as expected. Climate change was the most important perceived cause of flooding in both countries, but accounted for a greater percentage of the responses in Belgium. This

Table 7 Statistics for the perceived controllability component of flood damage (i.e., personal ability to control flood damage) (not significant for estimating WTP)

	Belgium		The Netherlands		Grand total	
No	140	71 %	160	80 %	300	76 %
Unknown	13	7 %	4	2 %	17	4 %
Yes	43	22 %	36	18 %	79	20 %
Grand total	196	100 %	200	100 %	396	100 %

Table 8 Statistics for the evacuation experiences (not significant for estimating WTP)

	Belgium		The Netherlands		Grand total	
No	181	92 %	179	90 %	360	91 %
Unknown	1	1 %	0	0 %	1	0 %
Yes	14	7 %	21	11 %	35	9 %
Grand total	196	100 %	200	100 %	396	100 %

Table 9 Statistics for the trauma experiences (not significant for estimating WTP)

	Belgium		The Netherlands		Grand total	
No	189	96 %	185	93 %	374	94 %
Unknown	1	1 %	4	2 %	5	1 %
Yes	6	3 %	11	6 %	17	4 %
Grand total	196	100 %	200	100 %	396	100 %

supports the driving force highlighted by the EU Floods Directive. However, this may have resulted at least in part from bias created by how the interview questions were expressed. Dyke breaches were the second-most-important perceived cause of flooding, but the percentage was higher in the Netherlands, followed by housing development in Belgium and dredging in the Netherlands. These results demonstrate that the participants have a clear picture of the relevant flood causes in their country.

Tables 15, 16, and 17 present statistics for other qualitative variables related to WTP. Note that the reasons for being willing to pay received the same ranking in both countries (avoiding future damage, followed by avoiding current damage and ethical responsibility). A belief that the government should pay was the most important reason for not being willing to pay in both countries, with an expected greater emphasis in the Netherlands. Income constraints were the second-most-important reason in the Netherlands, followed by a belief that flood risk was relatively low for the participant, with the reverse order for these reasons in Belgium. These results are consistent with the current flood policies in the two countries, since the Dutch pay more taxes than the Belgians. The most commonly specified "other reason" for not being willing to pay was a lack of trust in the government. The frequencies of perceived responsibilities were similar in Belgium and the Netherlands, where 13 and 11 % of the people, respectively, emphasized that the community of residents should work together with the government. This suggests a new perspective that could be adopted in future flood policies.

Tables 18 and 19 present statistics for the other qualitative variables related to PFR. Note that there was a greater unawareness of current strategies in Belgium (45 %) than in the Netherlands (27 %), which agrees with the expected larger concern for flood risk in the Netherlands. The greater importance accorded in Belgium to the Dutch Delta Project (i.e.,

Table 10 Statistics for the education levels (not significant for estimating PFR)

	Belgium		The Netherlands		Grand total	
Primary	11	6 %	4	2 %	15	4 %
Secondary	95	48 %	106	53 %	201	51 %
Bachelor's degree	47	24 %	55	28 %	102	26 %
Higher than bachelor's degree	34	17 %	23	12 %	57	14 %
Other (please specify)	9	5 %	12	6 %	21	5 %
Grand total	196	100 %	200	100 %	396	100 %

Table 11 Statistics for the economic activities (not significant for estimating PFR)

	Belgium		The Netherlands		Grand total	
Farmer	1	1 %	4	2 %	5	1 %
Public or private employee	29	15 %	24	12 %	53	13 %
Merchant or businessman	36	18 %	38	19 %	74	19 %
Professional or service industry	14	7 %	17	9 %	31	8 %
Unemployed or retired	24	12 %	29	15 %	53	13 %
Student	83	42 %	77	39 %	160	40 %
Other (please specify)	9	5 %	11	6 %	20	5 %
Grand total	196	100 %	200	100 %	396	100 %

Table 12 Statistics for the perceived relative risk (i.e., the belief that the participant bears a greater risk than others) (not significant for estimating PFR)

	Belgium		The Netherlands		Grand total	
No	154	79 %	90	45 %	244	62 %
Unknown	4	2 %	26	13 %	30	8 %
Yes	38	19 %	84	42 %	122	31 %
Grand total	196	100 %	200	100 %	396	100 %

Table 13 Statistics for the PFR with respect to the interviewer (not significant for estimating PFR)

	Mean	SD
Benjamin	12	19
Daan	10	19
Elianne	13	17
Hanne	12	22
Nick	11	21
Philip	10	20
Robin	13	23
Total	11	20

Table 14 Statistics for the main flood causes (not significant for estimating PFR)

	Belgium		The Netherlands		Grand total	
Dredging	3	2 %	15	8 %	18	5 %
Climate change	107	55 %	83	42 %	190	48 %
Housing development	15	8 %	12	6 %	27	7 %
Dike breaches	60	31 %	83	42 %	143	36 %
Shallower water in secondary channels	1	1 %	3	2 %	4	1 %
Other (specify)	10	5 %	4	2 %	14	4 %
Grand total	196	100 %	200	100 %	396	100 %

Table 15 Statistics for the reasons for being willing to pay (significant for explaining WTP)

	Belgium		The Netherlands		Grand total	
To avoid losses to me and my family	38	30 %	35	33 %	73	32 %
To avoid losses to other people in the future or in the other country	41	33 %	38	36 %	79	34 %
It is my duty	26	21 %	23	22 %	49	21 %
To get satisfaction from having paid to avoid losses	12	10 %	3	3 %	15	7 %
Other (specify)	8	6 %	6	6 %	14	6 %
Grand total	125	100 %	105	100 %	230	100 %

Table 16 Statistics for the reasons for not being willing to pay (significant for explaining WTP)

	Belgium		The Netherlands		Grand total	
The government should pay	32	45 %	49	52 %	81	49 %
The other country should pay	1	1 %	2	2 %	3	2 %
The users (e.g., shipping) should pay	2	3 %	3	3 %	5	3 %
I refuse to think of flood safety in monetary terms	5	7 %	3	3 %	8	5 %
I do not believe that flooding is a risk for me	19	27 %	11	12 %	30	18 %
My income limits my ability to pay	10	14 %	24	25 %	34	20 %
Other reasons (specify)	2	3 %	3	3 %	5	3 %
Grand total	71	100 %	95	100 %	166	100 %

Table 17 Statistics for the responsibility for flood protection (significant for explaining WTP)

	Belgium		The Netherlands		Grand total	
Government	154	79 %	159	80 %	313	79 %
Private	8	4 %	11	6 %	19	5 %
Community of residents	25	13 %	22	11 %	47	12 %
Other (specify)	9	5 %	8	4 %	17	4 %
Grand total	196	100 %	200	100 %	396	100 %

Table 18 Statistics for the main current strategy (significantly related to PFR)

	Belgium		The Netherlands		Grand total	
Sigma Project in Belgium	23	12 %	2	1 %	25	6 %
Delta Project in the Netherlands	81	41 %	141	71 %	222	56 %
Other (specify)	4	2 %	3	2 %	7	2 %
I do not know	88	45 %	54	27 %	142	36 %
Grand total	196	100 %	200	100 %	396	100 %

Table 19 Statistics for the main future strategy (significantly related to PFR)

	Belgium		The Netherlands		Grand total	
Sigma Project in Belgium	14	7 %	2	1 %	16	4 %
Delta Project in the Netherlands	24	12 %	65	33 %	89	22 %
Long-term vision	63	32 %	70	35 %	133	34 %
Other (specify)	7	4 %	6	3 %	13	3 %
I do not know	88	45 %	57	29 %	145	37 %
Grand total	196	100 %	200	100 %	396	100 %

a strategy developed after a disastrous flood in 1953 that was aimed at ensuring safety from floods for the inhabitants of the Delta Region by strengthening and raising dykes, by closing some tidal inlets, and by constructing the storm surge barriers at the opening of the Eastern Scheldt estuary and in the Nieuwe Waterweg) than to the Belgian Sigma Project (i.e., a plan initiated after a flood in 1976 and that was based on the same design level as the Dutch Delta Project, and which included the strengthening and raising of 512 km of dykes along the Zeeschelde and its tidal branches, the creation of 13 controlled flooding areas, and the construction of a storm surge barrier near Oosterweel to protect the city of Antwerp) highlights the perceived linkages between the two national flood policies. The greater unawareness of future strategies in Belgium than in the Netherlands (45 vs. 28 % replied "I do not know") agrees with the expected greater Dutch concern for flood risks, whereas the small frequencies of the *Long-Term Vision* plan in both countries (32 % in Belgium and 35 % in the Netherlands) suggest that a similar inadequacy of current information holds in both countries.

To summarize, apart from some expected differences (e.g., the trauma and evacuation experiences are both greater in the Netherlands, the Dutch perceive that they face a greater relative risk because of their experience) and some minor differences (i.e., the third perceived flood cause was housing development in Belgium, versus dredging in the Netherlands; the second reason for not being willing to pay in Belgium was a lack of concern about flooding, versus a "limited income" in the Netherlands), people in both countries appear to represent a relatively homogeneous population in terms of the characteristics that would affect their support for a publicly supported common flood risk management plan.

3.2 The econometric estimates

Table 20 summarizes the main analytical results for the WTP estimates. WTP was positive in both countries (an average of 2.7 % of annual income), with a greater (but not significantly greater) value in Belgium.

Table 20 Ordered probit estimates for WTP (the dependent variable represents possible pairs of answers to the double-bounded dichotomous choices: 3 = yes–yes, 2 = yes–no, 1 = no–yes, 0 = no–no) ($N = 396$)

	Coefficient	Standard error	z	$P > \|z\|$	[95 % confidence interval]	
First bid	−0.676965	0.2106117	−3.21	0.001	−1.089756	−0.2641736
Risk reduction	−0.3962749	0.1869611	−2.12	0.034	−0.762712	−0.0298379
Age	−0.0023413	0.004799	−0.49	0.626	−0.0117472	0.0070645
Woman	−0.1939462	0.1662118	−1.17	0.243	−0.5197153	0.1318229
Income	0.1546156	0.0817882	1.89	0.059	−0.0056863	0.3149174
Attitude toward environmental conservation	0.0246749	0.0546174	0.45	0.651	−0.0823731	0.1317230
Attitude toward human life	−0.0471826	0.0545672	−0.86	0.387	−0.1541323	0.0597671
Value attached to environmental issues	0.2667893	0.115008	2.32	0.020	0.0413777	0.492201
Value attached to human issues	0.3263449	0.1126855	2.90	0.004	0.1054853	0.5472045
Knowledge of evacuation management	0.5139912	0.2575589	2.00	0.046	0.0091851	1.018797
Knowledge of trauma management	0.5759628	0.3288593	1.75	0.080	−0.0685897	1.220515
Perceived flood risk	0.002994	0.003969	0.75	0.451	−0.004785	0.010773
Experience of direct tangible damage	−0.638796	0.3116667	−2.05	0.040	−1.249651	−0.0279406
Experience of direct intangible damage	0.1363756	0.2950281	0.46	0.644	−0.4418689	0.7146201
Experience of indirect tangible damage	0.6523582	0.2975017	2.19	0.028	0.0692657	1.235451
Experience of indirect intangible damage	−0.374156	0.2559629	−1.46	0.144	−0.8758341	0.1275221
Knowledge of public insurance	0.0579436	0.1953495	0.30	0.767	−0.3249343	0.4408216
Knowledge of private insurance	−0.3094989	0.2141134	−1.45	0.148	−0.7291535	0.1101557
Cut1	−1.067986	0.3397744	–	8.08	–	–
Cut2	−0.208027	0.3274501	–	24.24	–	–
Cut3	1.134367	0.3330636	–	21.21	–	–

Values for cut1, cut2, and cut3 represent the probabilities that results will be between cut1 and cut2, between cut2 and cut3, and greater than or equal to greater than cut3, respectively

My analysis revealed three main biases in the WTP estimates. An increase in the first bid significantly decreased the WTP, which is consistent with previous results in the literature. Second, an increase in risk reduction significantly decreased the WTP, which is also consistent with previous results in the literature. Third, WTP did not depend significantly on PFR, although the positive sign for its coefficient was reasonable. This result means that independent estimates can be performed for WTP and PFR.

The WTP estimates depended on three main personal characteristics: WTP did not depend on the sex or age of the participant, although the negative signs for both age and being a woman are plausible. WTP increased with increasing income, which is also consistent with previous results in the literature. WTP did not depend significantly on attitudes (e.g., rights of inhabitants near the Scheldt estuary and rights of nature in general), but did depend on values attached to human beings to a greater extent than to the environment (e.g., purchase of moral satisfaction or an embedding effect).

Because the goal of my study was to evaluate WTC, I did not rigorously examine potential policies that would increase this parameter. However, to demonstrate that the study results have practical implications because they revealed the aspects of the citizens of both countries that could be targeted by future policy development, I have proposed some strategies (based on statistically significant factors) that could be examined by future researchers. In other words, by providing recommendations only in general terms, my specific goal was to indicate that the study results have policy implications, not to prescribe the actual approaches. These suggestions should clearly be followed up by other researchers to confirm their validity. Three main policy insights were revealed by the WTP estimates. WTP was larger for participants with evacuation or trauma knowledge. This suggests that it would be useful to implement an information campaign to inform the public about evacuation and trauma management. Direct experience of tangible damage reduced WTP, possibly because participants felt that they had received inadequate compensation, that they had already suffered enough, or that they had other problems to deal with. The magnitude of this response was similar to that for indirect experience of tangible damage, which increased WTP, possibly because participants felt that relatives or friends had been only partially compensated for their losses, fear that it could happen to them, or sympathy for relatives or friends. WTP did not depend significantly on the knowledge of public and private insurance opportunities, although the positive and negative signs (respectively) for these factors are plausible.

Table 21 summarizes the main analytical results from the PFR estimates. PFR was biased upward (13.6 %) and to a greater extent (but not significantly greater) in Belgium. In terms of personal characteristics, PFR estimates were negatively correlated with the participant's age, but were larger for women. This suggests that an information campaign for young girls would be important. In terms of policy insights, the PFR estimates indicate that PFR depended positively on information about floods, particularly information in the press (i.e., newspapers and magazines), but depended negatively on information about strategies, particularly those reported in the press. This suggests the need for a greater emphasis on flood management strategies than on the main causes of flooding.

In summary, the *estimated* WTP (2.7 %) and PFR (14.0 %) were both greater than the *stated* WTP (1.1 %) and PFR (12.0 %). Moreover, personal psychological variables turned out to be nonsignificant (e.g., attitudes, experiences of direct and indirect intangible damage). Finally, the most significant policy variables appear to be potentially effective: an information campaign for the general population about evacuation and trauma management strategies could increase WTP by 0.5 and 0.6 %, respectively (which should be added to the total of 2.7). An information campaign focused on women in particular and young

Table 21 Ordinary-least-squares estimation (linear regression) for PFR (the dependent variable is the stated perceived flood risk) ($N = 396$)

	Coefficient	Standard error	z	$P > \|z\|$	[95 % confidence interval]	
Age	−0.1445704	0.0453281	−3.19	0.002	−0.2336919	−0.0554489
Woman	6.484013	2.166781	2.99	0.003	2.223807	10.74422
Knowledge source on flood: press	7.302277	4.745842	1.54	0.125	−2.028735	16.63329
Knowledge source on flood: scientific study	13.56763	10.92936	1.24	0.215	−7.921061	35.05633
Knowledge source on flood: friends	−0.6661413	5.426542	−0.12	0.902	−11.33551	10.00323
Knowledge source on flood: television	5.009479	4.725952	1.06	0.290	−4.282427	14.30138
Knowledge source on strategies: press	−7.693317	4.269164	−1.80	0.072	−16.08711	0.7004783
Knowledge source on strategies: scientific study	−13.41192	9.047385	−1.48	0.139	−31.20039	4.376544
Knowledge source on strategies: friends	−4.033913	8.690992	−0.46	0.643	−21.12166	13.05384
Knowledge source on strategies: television	−5.638171	4.561732	−1.24	0.217	−14.6072	3.330855
Constant	13.61819	3.998404	3.41	0.001	5.756745	21.47963

The most common specified "other information source" about flood causes and flood strategies were "study" and "experience," both of which increased in frequency in the age group older than 40 years

people in general, among other potential measures, could decrease PFR by 6.5 % for women in particular and by 0.1 % per year of age in general (which should be subtracted from the total of 14.0 %). An information campaign for the general population that emphasizes flood strategies and de-emphasizes flood events in the press could decrease PFR by 7.7 and 7.3 %, respectively (which should be subtracted from the total of 14.0 %).

Note that these suggestions about PFR were based on a linear model. However, the qualitative information about sources of knowledge (to obtain policy insights into the most effective media for reducing risk perception) and the yes/no answers about the perceived relative risk (to obtain reliable data) would not have enabled the identification or the measurement of possible thresholds for feelings and knowledge by applying a nonlinear model (e.g., a logistic model), where a certain minimum level of these variables must be achieved to observe an impact on PFR.

4 Discussion

In this section, I apply the statistical and econometric results obtained in Sect. 3 to assess both individual rationality (i.e., for each individual, whether the expected benefits cover contributions) and overall feasibility (i.e., total contributions must cover the total costs of the flood risk management plan) of a publicly supported trans-boundary flood risk management plan.

In terms of *individual rationality*, Raaijmakers et al. (2008) highlighted the following flood risk characteristics: voluntary versus involuntary, chronic versus catastrophic flooding, certainly not fatal versus certainly fatal, known to be exposed versus not known to be exposed, immediate versus delayed, known to science versus unknown to science, controllable versus not controllable, and old versus new (i.e., how recently flooding occurred). The relevant features in the present study were the voluntary versus involuntary component and the controllable versus not controllable component. However, the correlations between risk acceptance and the *stated* WTP (Pearson's coefficient at 0.05) and the *stated* PFR (Pearson's coefficient at 0.02), and the correlations between controllable risk and the *stated* WTP (Pearson's coefficient at 0.02) and the *stated* PFR (Pearson's coefficient at 0.08) were low and not statistically significant. This led me to disregard the impacts of these flood risk characteristics on individual rationality and, for each individual, to solve the following formula with respect to the value at risk:

$$\text{value at risk} \times \text{PFR} \times \text{risk reduction} \geq \text{WTP} \times \text{monthly income}$$

where value at risk × PFR represents the expected loss, whereas value at risk × PFR × risk reduction depicts the expected benefit from paying to mitigate the risk.

The perceived values at risk (expressed as a multiple of the participant's monthly income) differed between the Belgians (17 with a standard deviation of 4.63) and the Dutch (34 with a standard deviation of 10.45), mainly due to the larger PFR in Belgium and the smaller WTP in the Netherlands. However, an information campaign about evacuation and trauma management strategies in the Netherlands to increase WTP for the general public and an information campaign about flood strategies in Belgium (preferably in the press) to reduce PFR (particularly for women and young people) could reduce these differences.

Note that a common flood risk management plan between the two countries could become individually *irrational* in the case of a correct PFR (e.g., 0.025 % per year based on experts' estimations), since the value at risk would then average more than 113 times the mean monthly income.

In terms of *overall feasibility*, Broekx et al. (2010) showed that the net present value (discounted at 4 %) of investment and maintenance costs for flood protection measures in the Scheldt estuary between 2000 and 2100 would amount to at most 1597 million €. This is much lower than the WTP values suggest. Calculations based on the *estimated* average WTP (2.7 % of monthly income for the next 10 years) and *stated* average incomes in Belgium and the Netherlands (1720 and 1790 € per month, respectively), and official statistics on the overall populations of the two countries (6 and 16 million, respectively) and the proportion of the adult population (around 70 %) in Belgium and the Netherlands lead to an estimated 75,364 million € as the total amount of money people would be willing to contribute in the next 10 years (discounted at 4 %). Note that this figure evaluates not only the perceived direct and indirect *tangible* flood damage, estimated by Jonkman et al. (2008) for central Holland at 2.5–5.0 % of 2000 GDP, but also the perceived direct and indirect *intangible* flood damage.

In summary, apart from some expected differences between the values at risk in the two countries (the Dutch value is almost double the Belgian value and has nearly twice the SD), the conditions for both individual rationality and overall feasibility of a publicly supported trans-boundary flood risk management plan are met.

Note that these insights refer to the overall economic feasibility and individual economic acceptability, but do not account for the social feasibility and acceptability. Future research should expand on the present analysis to include a consideration of these factors.

5 Conclusions

The purpose of this study was to develop a *general methodology* that could be used to evaluate the extent to which the conditions required to implement a publicly supported trans-boundary flood risk management plan could be met. To make the general methodology more concrete, a *specific application* using the Scheldt estuary is provided as a case study of the method.

The *statistical descriptions* showed that, apart from some expected differences and some minor differences, people in Belgium and the Netherlands can be considered a relatively homogeneous population in terms of the measures required to generate a willingness to cooperate in the implementation of a common flood risk management plan, as suggested by the EU Floods Directive. The *econometric analysis* highlighted that the *estimated* WTP and PFR were both greater than the *stated* WTP and PFR. The personal psychological variables turned out to be not significant, whereas the significant policy variables appear to be potentially effective target factors for efforts aimed at increasing WTP and reducing PFR. Simple calculations showed that the conditions for both individual rationality and overall feasibility were met.

Therefore, the required conditions exist for implementing a publicly supported trans-boundary flood risk management plan for the Scheldt estuary. The costs can be shared equally between people of the two countries, perhaps progressively (e.g., taxes could be increased by 0.2 % for each 1,000 € of monthly income), provided that information campaigns are organized to reduce some of the differences between people in the two countries with respect to perceived values at risk, WTP, and PFR. Note that this methodology could be applied in any case study of a possible risk management plan *where trans-border issues are relevant* and where the flood risk is *common* between the parties on both sides of the border.

I implicitly assumed a command-and-control approach, which could be implemented through trans-boundary spatial planning, binding agreements or regulations, and joint

enforcement. However, one could also consider a market- or incentive-based approach, such as the development of a "tradable flood reduction permit" at a river basin level. For example, Chang and Leentvaar (2008) discuss this approach in their case study of the Dutch and German Rhine River. Once the difference between the maximum level of flood risk that people of an area are willing to accept and the current level is estimated and translated into the number of permits that can be distributed to mitigation suppliers (with the permits either auctioned or grandfathered), transactions may occur between measures taken at different locations (e.g., the upstream area provides flood retention and may face an increase in flood risk, whereas the downstream area pays for the corresponding reduction in flood risk). However, in the Scheldt estuary, bidirectional transactions might arise due to the non-univocal distribution of flood risks, and transaction costs might be high due to the multiple zones involved in the flood reduction market (Samuels et al. 2006). The present results confirm this insight, since 19 and 42 % of the participants in Belgium and the Netherlands, respectively, perceived themselves as bearing a greater risk than others.

Moreover, I did not ask interviewees to express their opinions on preferred policy strategies to reduce flood risks, on preferred measures to provide relief to flood victims, or on preferred designs for a private, public, or combined insurance program. Vari et al. (2003) carried out a public survey in the upper Tisza River basin and found that few stakeholders were willing to propose that downstream Hungary should help finance reforestation in the upstream Ukraine. Another possibility would be to develop a decision-support system in which the public's views are incorporated into a trans-boundary flood risk management model that embodies all aspects of the natural and socioeconomic systems. In reality, there is already a sound technical and scientific collaboration between the two countries to support the development of trans-boundary flood management policies, and both countries include public and stakeholder participation in policy development to reduce public opposition to the policies and reduce delays in the implementation of the policies (Van Alphen and Lodder 2006).

Finally, I implicitly referred to financing instruments in which governments self-insure by setting aside funds to finance some of the recovery costs following a disaster. One could also consider hedging instruments, in which governments obtain financial protection after a disaster by either paying a premium for insurance or by paying interest on a capital market-based security (Kunreuther et al. 2003). Other possible forms of hedging include "catastrophe bonds," in which the obligation to make interest and principle payments (at least partially) ends once a specific catastrophe occurs or when insurer-specific losses are suffered (Kron 2009), or multi-layered insurance programs, in which a public–private partnership provides incentives to limit flood losses while at the same time overcoming capital shortages in insuring large catastrophe losses by relying on a risk premium that varies across risk classes, deductibles, co- and re-insurance, and upper limits on coverage (Botzen and van den Bergh 2008). However, it might be difficult to make mandatory flood insurance acceptable, since society as a whole is perceived by people in both countries to be collectively responsible for flood protection that is financed via the tax system, irrespective of the risk levels resulting from the locations of taxpayers and their actual tax payments. In addition, the impacts on land prices of a compulsory flood insurance program used as a flood risk communication device might not be fair, since poorer people may tend to be located in riskier areas (Filatova et al. 2011). The present results confirm this finding, since 78 and 79 % of the participants in Belgium and the Netherlands, respectively, stated that governments are responsible for preventing flood damage.

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Appendix. The questionnaire

The text presented in this appendix represents an English translation of the interview questions, which were presented in Flemish or Dutch, depending on the native language of the participant.

Overview

Hello. My name is (*name of interviewer*). I am conducting a survey for the EU to get insights for implementing the EU Floods Directive that prescribes both stakeholder involvement and public participation. This particular survey is being conducted to find out how much inhabitants of the Scheldt estuary region are willing to cooperate in the development of a *common* flood risk management plan for both Belgium and the Netherlands.

The Western Scheldt estuary, originating in Belgium and ending in the Netherlands, is an international river basin that contains many intertidal areas with unique flora and fauna in the Netherlands and forms a crucial overwintering site for a large population of migratory birds (i.e., the environment is important). In addition, it is the only access channel for the Belgian port of Antwerp in Flanders and therefore has important economic value. Climate change will have a strong impact on the risk of flooding in the Netherlands, where floods originate from tides and storms and are exacerbated by dredging demanded by Belgium and by the smaller secondary water channels required by Dutch farmers, as well as in Belgium, where floods originate from tides and runoff, and result mainly from housing development and dyke breaches. Fatalities caused by flooding cannot be excluded in either country. In other words, the Western Scheldt estuary shows all the features mentioned in the EU Floods Directive.

The development of a single unified flood risk management plan could be beneficial to all the interested parties in both countries. In particular, total management costs could be reduced for a given reduction in flood probability or flood risk (i.e., the flood probability multiplied by the flood damage), or a larger reduction in flood probability could be achieved at a given total cost if Belgian strategies (e.g., increasing the height of dykes and the size of retention areas) were coordinated with Dutch strategies (e.g., combining dredging with sand maintenance). The overall environmental value could be increased by balancing the need for salt marshland in the Netherlands (i.e., returning fertile soil to the sea) with the need for water-retention areas in Belgium (i.e., covering fertile soil with freshwater).

Personal profile

Characteristics

1. Respondent's given name and sex
2. What is your age? … (years)
3. What is your occupation?

a. Farmer
b. Public or private employee
c. Merchant or businessman
d. Professional or service worker
e. Unemployed and looking for job
f. Retired
g. Student
h. Other (please specify)
4. What is your educational qualification?
a. Primary
b. Secondary
c. Bachelor's degree
d. Higher than a bachelor's degree
e. Other (please specify) …
5. What is your net income (€) per month?
a. 0–1000
b. 1000–2000
c. 2000–3000
d. 3000–4000
e. More than 4000 (specify if within 4000–5000, 5000–6000, …)

Attitudes

I am going to read out a few statements. Please indicate your opinion on a scale of "strongly agree" to "strongly disagree". There is no right or wrong answer; I only need your frank opinion. *(Legend: SA = strongly agree; A = agree; NU = neutral; DA = disagree; SDA = strongly disagree)*

1. Animals and plants have a right to exist even though they may be of no use to mankind.

   SA/A/NU/DA/SDA.

2. I should not have to sacrifice my income and standard of living so that the next generation may benefit from the plants and animals on Earth.

   SA/A/NU/DA/SDA.

3. People living nearby the Scheldt estuary have a right to be *better* defended against flooding in their original villages.

   SA/A/NU/DA/SDA

4. Belgian and Dutch populations should not renounce development programs in order to *further* reduce flood risks in either country.

   SA/A/NU/DA/SDA.

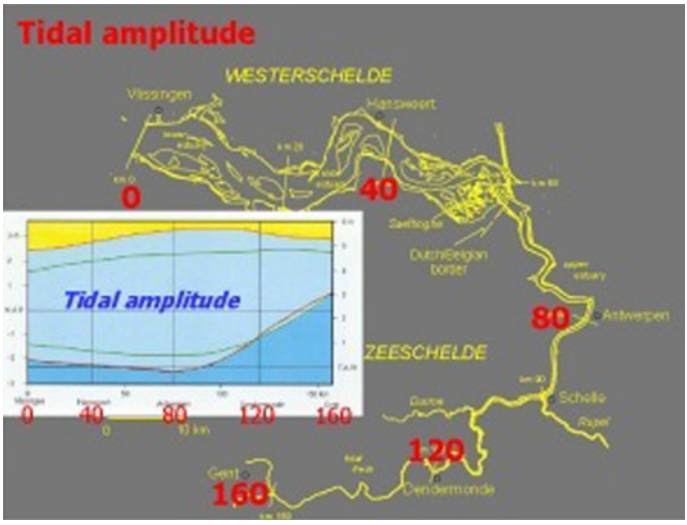

Fig. 1 The tidal amplitude in the Scheldt estuary

Flood events

Description

The areas near the Scheldt river have been subject to intensive use in the past when more homes, businesses, and industrial premises and farms were developed. This has increased both runoff (and consequently *flood probability* in Belgium) and *flood risk* (i.e., the consequences of flooding are likely to be greater). Similarly, the main channel of the Scheldt river has been deepened for navigation purposes: cargo traffic has increased from 60 million tonnes in 1975 to 130 million tonnes in 2000, with ship sizes increasing from 1.5 TEU (i.e., Twenty-foot Equivalent Units) in 1975 to more than 8.0 TEU in 2000 and the ship draft dragging increasing from 9 to 14.5 m. This has decreased lateral flows (and consequently ecological values) and has increased tidal currents and their penetration upstream, and consequently, has increased the *flood probability* in the two countries (Figs. 1, 2).

The areas near the Scheldt river will become more vulnerable to flooding in the future due to global climate change. Temperatures in Europe are expected to rise by 6 °C during the next century, with a hotter climate, more frequent droughts, more precipitation, more and stronger winds, and a rise in sea levels. The higher temperature will result in an increase in meltwater and tides, with increased precipitation in the winter leading to higher peak discharges. Stronger winds will lead to higher waves, with more intense but short storms in the summer causing more frequent floods.

Risk perception

Please respond to the following statements about the perceived flood risk:
Voluntary: Whether a flood will cause damage to me is up to me Y/N
Controllability: I can avoid being affected by a flood through my own efforts Y/N
Responsibility: The main party that is responsible for flood protection is:

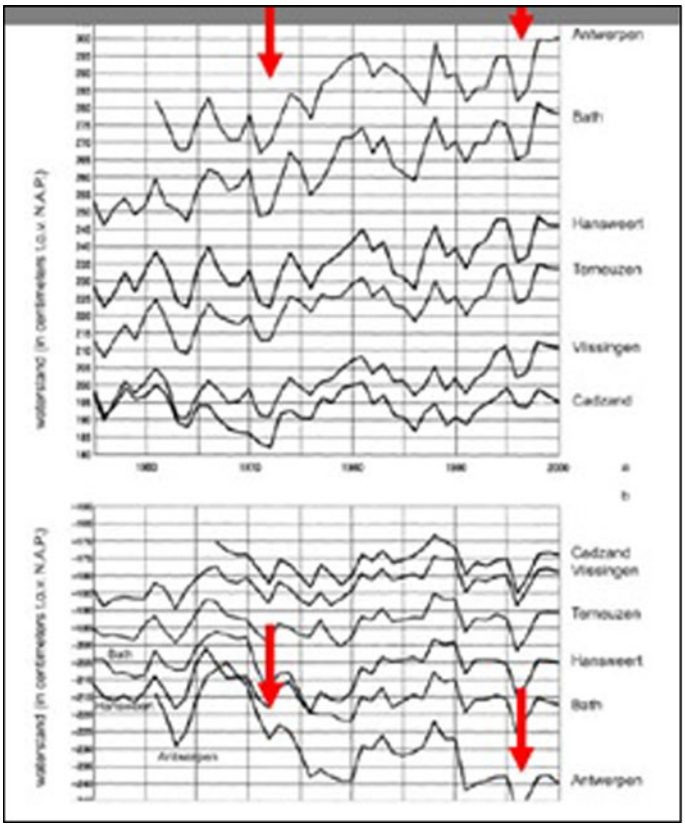

Fig. 2 The changes in the tidal amplitude in different parts of the estuary since 1960

a. Government
b. Private
c. Community
d. Other (specify)

Evacuation management:
I am aware of evacuation management strategies Y/N

- I think they are adequate Y/N

I have experienced the evacuation management strategies Y/N

- I think they were adequate Y/N

Trauma management:
I am aware of post-flood trauma management strategies Y/N

- I think they are adequate Y/N

I have experienced the post-flood trauma management strategies Y/N

- I think they were adequate Y/N

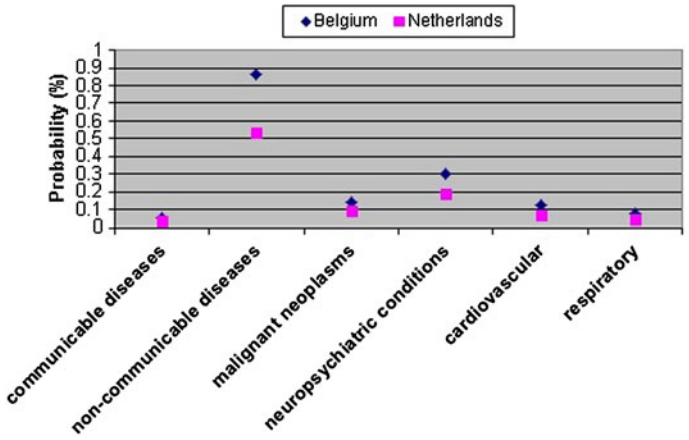

Fig. 3 Probability that you will be affected in the next 10 years (%). Values were provided by the World Health Organization for the year 2008

Personal exposure:
Risk perception: % chance that a flood will occur in the next 10 years (Fig. 3)

SPECIFY A PERCENTAGE BETWEEN 0 AND 1

Initial risk: % chance that a flood will cause significant damage to me or my family in the next 10 years

SPECIFY A PERCENTAGE BETWEEN 0 AND 1

Flooding is more likely to affect me or my family than other people Y/N
Previous experience:

- I had direct tangible damage due to flooding Y/N
- I had direct intangible damage due to flooding Y/N
- I had indirect tangible damage due to flooding Y/N
- I had indirect intangible damage due to flooding Y/N

Public insurance: I am aware of insurance schemes or damage compensation Y/N

- I think it is adequate Y/N

Private insurance: I signed an insurance or compensation damage contract Y/N

- I think it is adequate Y/N

Personal knowledge:
The main cause of flooding is:

a. Dredging
b. Climate change
c. Housing development
d. Dyke breaches
e. Shallower water in secondary channels
f. Other (specify)

The main potential damage caused by flooding is for:

a. Nuclear power stations
b. Navigation
c. Environment
d. Housing
e. Agriculture
f. Tourism
g. Industry
h. Human lives
i. Other (specify)

My most important source of knowledge about flooding is:

a. Press
b. Scientific research
c. Friends
d. Television
e. Other (specify)

Flood damage

Description

I am now going to give you some information about flood risks and introduce you to some of the crucial issues that policymakers will face in the future.
The most important strategy in the past:

a. Sigma in Belgium
b. Delta in the Netherlands
c. Other (specify)
d. I do not know

The most important strategy for the future:

a. Sigma in Belgium
b. Delta in the Netherlands
c. Long-term vision
d. Other (specify)
e. I do not know

My most important source of knowledge about strategies is

a. Press
b. Scientific research
c. Friends
d. Television
e. Other (specify)

Risk assessment

There are four main effects I would like to focus on:

1. Human safety (evacuation and exposure of river communities to flooding)
2. Human welfare (psychological trauma and awareness of river communities)
3. Environmental short-run safety (recovery of endangered species, recreational activities)
4. Environmental long-run damage (biodiversity, ecosystem)
5. Other (specify)

I am now going to ask you the last set of questions. […]
Please bear the following points in mind when you answer:

1. The issues discussed here are only a few among many other environmental and human problems.
2. The Scheldt estuary is only one of the important issues between Belgium and the Netherlands.

Among the considered effects, which effects do you believe have a positive value:

Maintenance of biodiversity in the estuary	Yes/Negligible
Maintenance of recreational activities within the estuary	Yes/Negligible
Reduction of the exposure of river communities	Yes/Negligible
Reduction of the psychological trauma of residents in river communities	Yes/Negligible

1. Are you willing to relinquish up to 1 % of your monthly income for the next 10 years to pay for implementing a common flood risk management plan to reduce the overall risk of flooding by 10 % in Belgium and the Netherlands?

Please, before you reply, note that the amount you state is not what governments will charge you in the form of taxes, and does not represent government expenditures to develop new flood risk management plans, but this is essential information for me to understand your attitude toward international cooperation for the Scheldt estuary and how much, on average, residents are willing to pay in order to implement this cooperation.

If you answered yes to question 1:

1y. Are you willing to relinquish up to 2 % of your monthly income for the next 10 years to implement a common flood risk management plan to reduce the overall risk of flooding by 10 % in Belgium and the Netherlands?

If you answered yes to question 1y,

1yy. What is the maximum amount you would be willing to relinquish for the same purpose?

If you answered no to question 1y,

1yn. What is the maximum amount you would be willing to relinquish for the same purpose?

If you answered no to question 1,

1n. Are you willing to relinquish up to 0.5 % of your monthly income for the next 10 years to implement a common flood risk management plan to reduce the overall risk of flooding by 10 % in Belgium and the Netherlands?

If you answered yes to question 1n,

1ny. What is the maximum amount you would be willing to relinquish for the same purpose?

If you answered no to question 1n,

Why are you not willing to pay?

a. The government should pay
b. The other country should pay
c. The users (e.g., shipping) should pay
d. I refuse to think about flood safety in monetary terms
e. I do not believe that flooding is a risk for me
f. My income limits my ability to pay
g. Other reasons (specify)

If you answered '**YES**' to at least one bid:
Why are you willing to pay for flood strategies?

a. To avoid losses to me and my family
b. To avoid losses to other people in the future or in the other country
c. It is my duty
d. To get satisfaction from having paid to avoid losses
e. Other (specify)

If you answered '**YES**' to at least one bid:

What is your preferred method of payment?

Again, I remind you that your income has several important and competing uses, and that this is not a once and for all payment.

If you answered '**YES**' to at least one bid:

Which expenditure from your monthly budget would you be willing to reduce in order to make this payment?

Thank you for your time and effort. Your responses will help decision-makers protect citizens of Belgium and the Netherlands against flooding.

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