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Valuing Flood Risk Reductions

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Abstract A choice experiment is used to estimate how Vietnamese households value a flood risk reduction. The empirical analysis is conducted on a sample of households located in the Nghe An Province, one of the provinces which is the most affected by floods in Vietnam. The results reveal that there is a high level of heterogeneity in preferences across households. We compute the willingness to pay (WTP) for a flood risk reduction, and we identify how it relates to different attributes of flood management policies (reduction of economic losses, reduction of human losses, political level in charge of implementing the flood management policy). In particular, the marginal WTP for reducing the flood fatality rate, which can be interpreted as the value of statistical life (VSL), varies from 2 517 million VND (approximately 120,818 USD) to 3 590 million VND (approximately 172,323 USD) depending on the model considered. The VSL represents between 77 and 111 times the annual household average income in our sample, a result in line with previous estimates in similar countries.

Keywords Choice experiment · Environmental valuation · Flood risk · Value of statistical life · Vietnam

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1 Introduction

According to [34], flooding is the most frequent natural hazard and the third most damaging (after storms and earthquakes) worldwide. In 2010 alone, 178 million people have been affected by floods with total losses exceeding $40 billion [15]. In some regions such as Europe and South Asia, flooding is already the most costly natural hazard [18].

Several structural policies (dams, dikes, reservoirs, etc.) and non-structural policies (flood warning systems, land control, flood insurance, public information and education, etc.) can be implemented in order to reduce flood risk exposure, and the portfolio of effective measures typically depends upon local conditions. If the cost of policies aiming at reducing flood risks is usually well known,[1] the way these policies are valued by populations is much more uncertain. This lack of knowledge is problematic since a reliable information regarding the willingness to pay (WTP) for a reduced exposure to the risk of flooding is needed for an efficient implementation of any flood management policy.

We propose in this paper a generic approach for estimating how people value an hypothetical flood risk reduction which affects their properties or their health. In existing studies on flood risk reduction valuation, when a generic flood management program has been used, only an aggregate willingness to pay (WTP) is derived [20, 36].[2] On

[1]For a country at high flood risk such as the Netherlands, flood defense expenses were in 2005 approximately equal to 1.3 billion euro, representing around 0.25 % of the country-level GDP [27].

[2]This is also the case for studies assessing the WTP for a catastrophic flood risk insurance such as the recent work conducted in Vietnam by [7].

contrary, when a specific flood management program is under study (for instance an early warning system as in [36] or a house floor elevation policy as in [2]), the resulting WTP for a flood risk reduction then only reflects a valuation of properties protected by the program considered (value for limiting risk of injuries in the first example and value associated with protecting housing and house content in the second example). We propose to use a choice experiment (CE), one of the most popular stated preference approaches. In our setting, the different dimensions which can be impacted by a flood (health, house, professional activity) are jointly valued by a respondent. This is made possible by asking households to make some trade-offs between these different dimensions, and by deriving an implicit price for each of them. As a result, our generic approach allows to provide some specific estimates of the WTP for flood management policies targeted toward protecting human lives or toward protecting people's properties (agricultural production or housing).

Our framework is applied to flood risk reduction in Vietnam, one of the most disaster-prone country in the world. Despite the high impact of floods on Vietnamese population, our knowledge of Vietnamese household's WTP for flood risk reduction remains limited. Our empirical application aims at filling this gap.

The remainder of the paper is organized as follows. Section 2 describes flood policies in Vietnam, and the related literature having addressed how people value a flood risk reduction. Section 3 presents the CE design and its administration. The results of the econometric models are reported in Section 4 where we also analyze household's willingness to pay for flood management policies. Lastly, Section 5 concludes the paper.

2 Context and Relevant Literature

2.1 Flood Management Policies and Flood Risks in Vietnam

With 89.4 % of its GDP generated in areas at risk, Vietnam is the world seventh most exposed country to natural disasters [33]. Within natural disasters, flood is the single most important cause of loss, accounting for 49 % of total economic losses [35]. Disaster management has then a long institutional tradition within the country. Both structural (dikes, seadikes, channelization) and non-structural strategies (warning systems, education and preparedness programs) have been implemented by Vietnamese authorities for long [24]. Even if there has been recently a noticeable change in the flood control and management practices from large-scale structural measures toward non-structural ones, population preparedness to floods remains still limited, especially in mountainous areas of Vietnam [24].

One difficulty when considering flood management policies is that they are by nature multi-sectoral. Some policies can be dedicated to protecting human lives (i.e., early warning system or population preparedness), whereas other may focus on a particular sector of the economy such as agriculture and aquaculture, tourism, industry, etc.[3] The valuation of a specific flood management policy by a household may then depend upon his involvement in a particular economic sector. To address this issue in the CE, we will consider that a flood management policy may have differentiated sectoral impacts. Some policies may solely reduce the risk of population injury, whereas others may also diminish the risk of housing damage and/or the risk of agricultural losses.

One specific characteristic of flood management in Vietnam is its multilayered structure, where each level of government (state, province, district, village) has its own responsibilities. At the national level, flood management is defined and implemented by the Central Committee for Flood and Storm Control (CCFSC) which is responsible for gathering data, monitoring flood and storm events, issuing official warnings, and coordinating disaster response and mitigation measures. Other levels of governments are involved through the sub-national structures of CCFSC for provinces, districts, and communes. In what follows, we propose to examine if Vietnamese households have some specific preferences for a particular level of implementation of flood policies. Indeed, based on their past experience, household's confidence in the different levels of government (state, province, district, village) for managing flood risk may differ. Another explanation is related to the fact that the different levels of governments are not responsible for the same flood management policies.[4] To test if the

[3] The multi-sectoral objectives of the flood policy in Vietnam are summarized in the national strategy for natural disaster prevention, response and mitigation to 2020 which states that the main goals of flood management policy are to "*mobilize resources to effectively implement disaster prevention, response and mitigation from now up to 2020 in order to minimize the losses of human life and properties, the damage of natural resources and cultural heritages, and the degradation of environment, contributing significantly to ensure the country sustainable development, national defense and security*."

[4] Largest dikes (category 1) are managed at the state level by the CCFSC, whereas smaller dikes (categories 2 and 3) are operated at provincial, district, or village level. Province CFSCs are, according to the Law, required to store necessary materials for dyke protection such as bags of sand, rock stones, or bamboo trunks. Broadcasting of flood-related information (warnings, evacuation, etc.) is processed by commune CFSCs which usually manage the system of loudspeakers.

Table 1 Stated preference studies having assessed household valuation for flood risk reduction

Study	Country	Method[a]	Flood risk policy evaluated
Public flood policies			
Zhai et al. [37]	Japan	CV	Structural, Non-structural
Zhai et al. [36]	Japan	CE	Generic
Zhai et al. [38]	Japan	CV	Structural
Fuks and Chatterjee [12]	Brazil	CV	Structural
Brouwer et al. [6]	Bangladesh	CV	Structural
Navrud et al. [20]	Vietnam	CV	Generic
Private flood policies			
Brouwer and Atker [5]	Bangladesh	CE	Insurance
Botzen et al. [4]	Netherlands	CE	Insurance
Botzen et al. [2]	Netherlands	CV	Non-structural
Reynaud and Nguyen [26]	Vietnam	CE	Insurance
Brouwer et al. [7]	Vietnam	CE	Insurance

[a]CV and CE for contingent valuation and discrete choice experiment

multilayered structure matters, we propose in what follows to introduce the level of implementation as an attribute of a flood management policy in the CE.

2.2 Literature on Valuation of Flood Risk Reduction

Our work is related to the existing initiatives which have been carried out to assess household's valuation for flood risk reduction using stated preference approaches, see Table 1.[5]

Most of studies having elicited flood risk reduction valuation by using a public flood policy rely on a contingent valuation (CV) approach. The CV approach belongs to survey-based economic techniques used by economists for the valuation of non-market resources. Within this category, [37] is the only work having used a non-structural flood policy (early warning system). Two studies, [36] and [20], use a generic flood management policy, whereas all others have considered some structural policies such as building dams, levees, or embankments. A positive WTP for reducing flood risks is usually found, although a high level of heterogeneity in individual preferences is documented. Past flood experience and flood risk exposure are often found to have a significant and positive impact on the WTP [6, 20]. Socioeconomic characteristics of households matter much less, at the exception of income and education levels which are found to be almost always significant.

Private flood mitigation policies have also been considered to assess individual's WTP for reducing flood risks. Most studies rely on flood insurances, at the exception of [2] who consider house floor elevation. Three out of five studies use a CV approach. Working on two developing countries, [5] and [26] report that credibility of insurance providers and affordability of risk premiums remain key issues. Recently, [7] have shown that there exists a substantial demand for flood insurance in Vietnam. The results provided by [4] indicate that there are opportunities for the development of a flood insurance market in the Netherlands.

A first general conclusion to be drawn from the existing literature is that there is a positive WTP for flood risk reduction, although a high heterogeneity among the population is usually documented. Second, implementing stated preference methods for valuing flood risk reductions in developing countries raises some important methodological and empirical issues [6]. These issues include in particular difficulties in manipulating low probability events or the fact that some households are unable to contribute to the proposed programs in monetary terms, but are willing to contribute in kind [6, 20]. Third, all the previous studies provide an aggregate WTP for flood risk reduction at the household level. We argue that a disaggregate measure of flood risk reduction might be relevant for two reasons. First, households may value in very different ways a flood risk reduction which impacts on their house, their agricultural production of their fatality rate. Second, flood management policies are typically domain-specific. For instance, implementing an early warning system reduces fatalities due to floods but it has only a limited impact on protecting agricultural production. Some structural flood management policies such as dams, levees, and dikes typically protect people and properties from floods but they may increase flood risk for

[5]Revealed preference methods have also been used by scholars, but mainly in the context of developed countries [1, 10, 16, 19, 23].

households located downstream. As a result, these policies may be valued differently across households.

3 Design of the Choice Experiment

This section describes our CE used for assessing how Vietnamese households value an hypothetical flood risk reduction which may affect their properties or their health.

3.1 Attributes of Flood Risk Reduction Programs

Defining the Good "Flood Risk Reduction" The good to be valued is a flood risk reduction policy to be implemented by public authorities. Based on discussions we have had with representatives of the Ministry of Agriculture and Rural Development (MARD), reducing the losses of human life is the primary objective of flood management policies in Vietnam. For Vietnamese authorities, a second objective is to reduce the economic losses due to flood occurrence. In what follows, we will consider two types of economic losses for households: damage to house and house content due to flood and damage to agricultural production.[6]

CE Attributes The exploratory research resulted in the selection of five attributes to describe flood risk reduction programs: (1) chance per year that the respondent house is flooded and substantially damaged by a flood occurrence,[7] (2) chance per year that paddy and agricultural land may be flooded and substantially damaged by a flood occurrence, (3) chance per year that one member of the household may die in case of a flood (fatality rate due to floods), (4) administrative level at which the flood protection program is implemented, and (5) payment of the household for the program. In Table 2, we report the list of attributes with the associated levels chosen for the CE.

Attribute (1) describes the benefit of the flood protection programs in terms of reducing the annual risk of a substantial damage to home content and house of the respondent.[8] According to figures provided by the MARD, the current risk is estimated to be 2 % per year. Levels of the risk reduction were thus selected at 1.5, 1, and 0.5 %.

Attribute (2) describes the benefit of flood protection programs in terms of reducing the annual risk of a substantial damage to the agricultural production (crop, cattle, fishes, etc.) of the respondent. According to figures provided by the MARD, the current risk is estimated to be 20 % per year. Levels of the risk reduction were thus selected at 15, 10, and 5 %.

Attribute (3) describes the benefit of the flood protection programs in terms of reducing the annual fatality rate due to flood.[9] Since a flood management policy aiming at reducing the mortality rate will typically benefit to all household members, this attribute was presented in the CE in the following way: "*Chance per year that you or one member of your household may die in case of a flood (fatality rate due to floods)*." In explanations provided to respondents, it was made explicit that this attribute had to be interpreted as the chance per year for the next 10 years that one member of the household may die due to a flood. According to data provided by the MARD covering the last 10 years, 30 persons have died each year on average in the Nghe An Province due to floods. This translates to a status quo flood mortality rate estimated to be 12 per million per year. In the CE, two additional levels have been considered: 9 per million, and 3 per million.

Attribute (4) describes which administrative level is responsible for implementing the flood protection program. For the reasons previously discussed, we hypothesize that the WTP for a particular flood risk reduction policy can be impacted by the political institution (state, province, district, village) in charge of it implementation, in particular because each institutional level has in charge some specific flood management policies.[10]

Attribute (5) corresponds to the payment for the flood risk reduction program. The choice of an appropriate payment vehicle has often proved difficult in applications of CE in developing countries because governments often have in place only a limited number of tax instruments and because compliance is low [32]. In Vietnam, households are familiar with paying for flood protection. Indeed, all Vietnamese households face a taxation system specifically dedicated to fund flood protection. All households must pay the monetary equivalent of 2 kg of paddy rice (5500 VND) for each

[6]While agriculture's share of GDP has fallen significantly over the years and now accounts for about 20 %, the primary sector still employs more than half of the labor force.

[7]Intentionally, we did not use the term probability which may have been difficult to understand for some of the households we have interviewed. See the Supplementary Material available online.

[8]Damage to home has been also used by [4] in the context of flood insurance valuation in Netherlands.

[9]The fatality rate due to floods has also been used by [36] in the Japanese context.

[10]Largest dikes (category 1) are managed at the state level by the CCFSC whereas smaller dikes (categories 2 and 3) are operated at provincial, district or village level. Province CFSCs are, according to the Law, required to store necessary materials for dyke protection such as bags of sand, rock stones, or bamboo trunks. Broadcasting of flood-related information (warnings, evacuation, etc.) is processed by commune CFSCs which usually manage the system of loudspeakers.

Table 2 Attributes and levels used in the CE

Attribute description	Attribute levels
Annual risk of damage on home content and house	*2*, 1.5, 1, 0.5 (in %)
Annual risk of damage on agricultural production	*20*, 15, 10, 5 (in %)
Annual fatality rate	*12*, 9 , 3 (per million)
Administrative level in charge program	*State*, Province, District, City/Village
Flood program fee (per capita)	Farmers: *5.5*, 16.5, 33, 49.5, 66 (in 10^3 VND)
	Other: *11*, 33, 66, 99, 132 (in 10^3 VND)

Italicized attribute levels corresponds to the status quo situation
1 USD for 20 822 VND

household member between 18 and 60 years old.[11] Farmers get a discount and are required to pay the monetary equivalent of 1 kg of paddy rice per capita. This flood management fee will be used as our vehicle payment. We have considered five different levels: 5.5, 16.5, 33, 49.5, and 66 thousand VND corresponding respectively to 1, 3, 6, 9, and 12 kg of rice per capita for farmers and 11, 33, 66, 99, and 132 thousand VND corresponding, respectively, to 2, 6, 12, 18, and 24 kg of rice per capita for non-farmer households.

3.2 Questionnaire Development and Design of the CE

Following a pilot conducted in 2011 on 30 randomly-selected households, the final survey took place from April 4 to June 10 2012, a period during which no flood and no natural disaster was recorded in the Nghe An Province. To minimize cultural biases, all (face-to-face) interviews have been conducted in Vietnamese by faculty members and/or students from the Vanxuan University of Technology at Cua Lo (Nghe An Province). At the beginning of each household interview, it what mentioned that our survey had been officially approved by the head of the village People's Committee. As a result, less than 10 % of households contacted refused to participate to the survey. We interviewed 448 households observed in 28 villages/communes from 14 districts in the Nghe An province.

In the questionnaire, we start by collecting data to characterize each household. Then, respondents are trained with manipulating risks of floods. Conveying risk reduction to survey respondents has been a challenging task in CE surveys, especially in developing countries. We rely on two types of visual aids: a risk ladder which presents the probabilities of dying in Vietnam from various causes on a visual scale (including flood) and 10,000 square grids in which deaths are represented using red squares. Next, we present the CE for flood risk reduction. It starts with a brief description of flood risks and flood policies in the Nghe An Province. Then, all attributes of the flood risk reduction program are exposed and an example of choice set is presented. The following section is the CE, which ends with some debriefing questions designed to identify protest answers of respondents.[12] A description of the main sections of the questionnaire is available as Supplementary Material.

To construct the choice sets of the CE, we have used a fractional factorial designs using the Ngene software, one of the popular software allowing to generate experimental designs for stated choice experiments. We then have selected a particular subset of complete factorials, so that particular effects of interest can be estimated as efficiently as possible according to the D-optimal criterion. We constructed 32 choice sets, each consisting of three alternative flood risk reduction programs (two flood risk reduction programs and the status quo scenario). Because of respondent's cognitive capacity, the 32 choice sets have been blocked into 4 versions of the CE, each containing 8 choice sets (see Fig. 1 for an example of choice set).

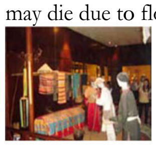
3.3 Household Characteristics

In our sample, the household head is on average 49.8 years old. The average household size is a little bit higher than four persons. Furthermore, 16.7 % of households have at least one child below 3 years old and 30.6 % of household's head have attended at least high school. The average household income in 2011 is 32.5 million VND per year (1560 USD), a figure lower than the average for the Nghe An province in 2010 (48 millions VND). In 79.2 % of cases, the main occupation of the household head is farming (or fishing). Employees represent 5.6 % of our sample. Retired household is the second occupation the most represented with 26.7 %.

[11] The official conversion rate is 1 USD for 20 833 VND on May 14th 2013.

[12] The last section, not discussed here, is a CE for assessing the WTP for a flood insurance, see [26].

Fig. 1 Choice set example

CHOICE SET 4	PROGRAM A	PROGRAM B	STATUS QUO
Chance per year that your house will be flooded and substantially damaged 	2%	2%	2%
Chance per year that paddy and agricultural land will be flooded and substantially damaged 	10%	20%	20%
Chance per year that one member of your household may die due to flood 	12 per million	12 per million	12 per million
Level at which flood policies are set and enforced 	State	Village/city	State
Flood management fee 	3kg of paddy if farmer (16,500 VND) 6kg of paddy otherwise (33,000 VND)	3kg of paddy if farmer (16,500 VND) 6kg of paddy otherwise (33,000 VND)	1kg of paddy if farmer (5,500 VND) 2kg of paddy otherwise (11,000 VND)
I would choose (select one only)	☐	☐	☐

Concerning flood experience, 40.4 % of households report that their house has been flooded at least once in the last 5 years. Moreover, 20.3 % of households have been evacuated at least one time over the last 5 years because of a flood event. Only 4.9 % of the respondents report that one member of the household has been injured in the last 5 years, due to flooding. To have an idea of the cost of flooding for respondents, they were asked to provide an estimate of the average annual cost of flood for their household in the last 5 years distinguishing damage to house and house content, damage to agricultural production and damage to health (all medical expenses due to flood for any member of the household).[13] The average annual cost of flood damage caused to agricultural (and fishery) production is 3.5 million VND representing 14.8 % of household income on average. The average annual cost of flood damage caused to house and house content is slightly lower. It represents on average 2.6 million VND per year or 9.3 % of the annual household income. Damage to health ranks third in terms of cost (0.310 million VND on average). Those expenses represent 1.9 % of the household annual income on average. We then get

[13] Due to missing answers, flood costs have been computed on a sub-sample of 407 households.

an average annual cost equal to 6.4 million VND per year which represents 25.26 % of the average annual household income.

4 Empirical Results

4.1 Individual Choices and Status Quo Responses in the CE

In each choice set, a respondent selects his/her preferred program among three possible (A, B, and Status quo). Programs A and B have been chosen respectively in 36.66 and 28.15 % of the cases, see Table 3. The status quo option ranks second with 35.18 %. This high percentage may be explained by a *status quo bias* [29].

In our case, 33 households (7.37 % of our sample) have chosen the status quo in the 8 proposed choice sets. To identify protest answers, respondents have been asked if they agree or disagree with the two following sentences: "I oppose any additional taxation for government programs" and "I distrust the government, the province, and the commune to manage my money properly." Among the 33 respondents who have chosen the status quo alternative in all choice sets, 18 who agree with at least one of the previous sentence can be qualified as "false zeros" (which correspond to respondents having reported a zero WTP even though their true value for the good is positive). For them, it is likely that their status quo choices reflect more a protest behavior than a true zero valuation.

Households may have chosen the status quo simply because they were uncertain about the amount they were willing-to-pay or because of difficulties for understanding the experiment. The 33 households having chosen the status quo in the 8 proposed choice sets have then been asked if they agree or disagree with the three following sentences: "I needed more information than the one provided," "The survey was not clear," "The alternative flood management programs were unrealistic." Thirty two of them have answered yes at least to one of the previous sentences. Combining protest and uncertain answers, we get 32 households who may be qualified as "false zero bids." In the econometric analysis, we will conduct some robustness analyzes with respect to the "false zero bids" households.

Table 3 Frequency of individual choices in the CE

Choice	Frequency (%)
Program A	36.66
Program B	28.15
Status Quo	35.18
Progam A for all choice sets	2.01
Progam B for all choice sets	1.79
Status Quo for all choice sets	7.37

4.2 Modeling of Individual Choices

The utility derived from a flood risk reduction program j is obtained by adding to the indirect utility function V (representing individual tastes for flood risk reduction) an error term. The random utility for individual i from choosing program j in choice task k writes:

$$U_{ijk} = V(X_{ijk}|\beta) + \epsilon_{ijk} = V_{ijk} + \epsilon_{ijk} \quad (1)$$

where X_{ijk} denotes a vector of explanatory variables describing program j and respondent i, and β denotes the corresponding vector of coefficients. Respondents are assumed to choose the program providing the highest level of utility.

4.3 Conditional Logit Models

Assuming a type I extreme value distribution for $\epsilon's$ in Eq. 1 leads to the Conditional Logit (CL) model, a generalization of the multinomial logit model [30]. We start with a basic specification in which the indirect utility derived from a flood management program is simply a linear function of all attributes of that program and of an alternative specific constant (ASC), which is equal to 1 when the status quo program is selected. Omitting the choice set index for simplicity, the specification of the indirect utility function for household i choosing program j becomes:

$$\begin{aligned} V_{ij} = {} & ASC_j \cdot (\alpha) + RiskAgri_j \cdot (\beta) + RiskHouse_j \cdot (\zeta) \\ & + RiskDeath_j \cdot (\gamma) + LevelState_j \cdot (\eta) \\ & + LevelDistrict_j \cdot (\mu) + LevelVillage_j \cdot (\lambda) \\ & + C_{ij} \cdot (\kappa) \end{aligned} \quad (2)$$

where $RiskAgri$, $RiskHouse$, and $RiskDeath$ are the three attributes corresponding, respectively, to the risk of damage to agricultural production, the risk of damage to home and home content, and the risk of death due to flooding. $LevelState$, $LevelDistrict$, and $LevelVillage$ are three dummy variables corresponding to the fact that the flood management policy is implemented at the State, province, or village level (the reference category is province level). These three dummies aim at capturing the presence of a non-linear impact of the level of implementation on the indirect utility. Lastly, C is the cost of the program paid by each household (in million VND). As discussed previously, this cost depends on the value of the per capita flood fee, on the fact that the head of the household is a farmer or not and on the number of household members whose age is between 18 and 60 years.

Table 4 gives the estimate of the CL model with a basic specification of the utility function. The overall fit of the model measured by the MacFadden's ρ^2 is low, and the model predicts only 59.23 % of choices correctly. We reject at 1 % the null hypothesis of all coefficients equal to zero. Using a Hausman test, we find that the independence of irrelevant alternatives (IIA) property cannot be rejected at the 99 % level.

The positive and significant sign of the ASC coefficient indicates some strong preferences for the status quo alternative. Preferences for the status quo could be due to doubts over the ability of Vietnamese authorities to effectively implement the flood risk reduction programs described in the choice sets. Alternately, it could be that individuals

Table 4 CL models

	Basic model		Interaction model	
Variable	Coefficient	(Std. Err.)	Coefficient	(Std. Err.)
ASC	0.195**	(0.089)	0.164*	(0.090)
RiskAgri	−0.026***	(0.005)	−0.055***	(0.009)
RiskDeath	−276.363***	(69.963)	−523.687***	(138.778)
RiskHouse	−0.037	(0.051)	−0.133	(0.090)
LevelState	0.191***	(0.070)	0.291***	(0.085)
LevelDistrict	0.183**	(0.072)	0.218***	(0.083)
LevelVillage	0.153*	(0.079)	0.071	(0.094)
C	−2.110***	(0.333)	−2.335***	(0.337)
RiskAgri × MoreFlood	–	–	−0.014	(0.011)
RiskDeath × MoreFlood	–	–	−484.666***	(173.316)
RiskHouse × MoreFlood	–	–	−0.093	(0.106)
RiskAgri × Injured	–	–	0.059***	(0.020)
RiskDeath × Injured	–	–	697.066**	(330.464)
RiskHouse × Injured	–	–	0.266	(0.189)
RiskHouse × Evacuated	–	–	−0.264***	(0.095)
LevelState × StateConfidenceHigh	–	–	−0.175**	(0.085)
LevelDistrict × DistConfidenceHigh	–	–	0.241*	(0.133)
LevelVillage × CityConfidenceHigh	–	–	−0.076	(0.114)
RiskAgri × ProtectDike	–	–	0.028***	(0.008)
RiskDeath × ProtectDike	–	–	280.306**	(133.168)
RiskHouse × ProtectDike	–	–	0.171**	(0.080)
RiskAgri × HealthInsurance	–	–	0.001**	(0.000)
RiskDeath × HealthInsurance	–	–	2.256	(7.522)
RiskHouse × HealthInsurance	–	–	0.000	(0.004)
RiskAgri × IncomeCap	–	–	−0.005	(0.009)
RiskDeath × IncomeCap	–	–	−215.207	(144.315)
RiskHouse × IncomeCap	–	–	−0.063	(0.086)
RiskAgri × EducHigh	–	–	0.014*	(0.008)
RiskDeath × EducHigh	–	–	483.317***	(133.735)
RiskHouse × EducHigh	–	–	0.212***	(0.080)
N	10,752		10,752	
Log-likelihood	−6008.993		−5932.23	
χ^2	$\chi^2_{(8)}$: 85.421		$\chi^2_{(30)}$: 238.59	
MacFadden's ρ^2	0.015		0.0197	

Significance levels: * 10 %, ** 5 %, *** 1 %

chose the status quo because they view the flood management program choice as too complex. As a robustness check, we have re-estimated the model first by excluding the 33 respondents having always selected the status quo option and, second, by removing the 32 households identified previously as "false zeros." The only notable change is that the coefficient of the ASC becomes negative, but not significant. Hence, the strong preference for the status quo alternative seems to be highly driven by "false zeros."

Two risk attributes of a flood management program (risk of agricultural loss, risk of death) are significant for explaining the choice of a flood management program, and ceteris paribus, a lower level of the risk of agricultural loss or the risk of death increases the probability for a flood program to be selected. In other words, respondents prefer a flood management program, which results in lower levels of agricultural production loss and in a lower risk of death. The risk of damage on home and home content does not appear to be significant. Since a little bit more than 40 % of households report that their house has been flooded at least once in the last 5 years, they may consider the risk of house flooding as a risk they are able to deal with. This corresponds to the "inoculation hypothesis" in psychology, which states that individuals who have experienced a similar type of natural disaster in the past will be less likely to suffer long-term negative effects after subsequent disasters because disaster exposure brings more experience [21]. Our interpretation is also supported by the fact that only 13.1 % of households have reported that reducing the number of houses flooded and damaged should be the primary objective of any flood management policy.

The sign of the payment coefficient indicates that the effect on utility of choosing a choice set with a higher payment level is negative, which is an expected and intuitive result. Finally, evidence concerning preferences for provision of the flood risk reduction policy at a central level (State or province) or at decentralized level (district or village/commune) are mixed. Compared to the reference category (province level), implementing a flood management program at the State, district, or village levels increases its probability to be selected.

To account for heterogeneity in the sample, we have also estimated the CL model by including various respondent-specific characteristics.[14] After an extensive testing of the various possible interactions, we ended up with the CL model presented in columns 4–5 in Table 4.[15] Compared to the basic specification, the goodness of fit of the CL with interactions is slightly higher (the MacFadden's ρ^2 is 0.0197) but it remains very low. Using a Hausman specification test, we reject the null hypothesis that the estimated parameters in the basic CL model and in the CL model with interactions are the same ($p<0.001$).

Individual valuation of flood management programs may be driven by flood probability perception [8]. To measure flood risk perception, we have asked each respondent if, compared to the last 10 years, he/she expects for the next 10 years more or less floods.[16] Furthermore, 18.08 % of respondents expect more floods in the next 10 years. We have then created a dummy variable ($MoreFlood$) equal to 1 in that case. Respondents who expect in the future more floods have a significant higher valuation to reduce flood mortality risk. No significant impact of flood risk perception is found for the two other risk attributes.

It has been recently suggested that experiencing a natural disaster may affect risk behaviors or risk preferences [11]. To explore the potential link between flood exposure and WTP to reduce flood risks, we have crossed some measures of individual's flood experience with the three risk attributes. Household flood experience is measured through two dummy variables: $Evacuated$ is equal to one if the respondent has been evacuated due to a flood at least once over the last 5 years and $Injured$ is equal to one if one household's member has been injured at least once over the last 5 years. Having been evacuated results in a higher valuation for reducing the housing risk (the coefficient of RiskHouse×Evacuated is negative and significant at 1 %). Surprisingly, the coefficient signs of RiskAgri×$Injured$ and RiskDeath×$Injured$ are positive and significant, which would indicate a lower valuation for reducing agricultural loss and death risks for households having experienced flood injuries.

Flood management program's valuation could also depend upon the institution in charge of implementing it. In the questionnaire, we have asked each respondent if he believes that the State, the province, the district, or the village can manage in an efficient way flood risk, using a scale from 1 (not at all confident) to 10 (very confident). We have then created some dummy variables for high level of confidence (confidence levels greater than 8) in the different institutions. We find that a household having a high level of confidence for the State has a lower valuation for a flood management program implemented at this level. A possible explanation could be that households consider that flood management is a prerogative of the State and that it should be provided without any additional payments. On contrary,

[14] Since respondent characteristics do not vary over the repeated choices of a respondent, they have to be interacted with the ASC or at least with one of the five attributes of flood risk reduction programs.

[15] See Appendix for the definition of each variable.

[16] We have in fact four modalities for this variable namely "more floods," "less floods," "the same number of floods," and "I don't know if there will be more or less floods."

a household having a high level of confidence in the district has also a higher valuation for a program implemented at this level. This may indicate the possibility to implement some flood management program at a decentralized level.

Flood management program valuation may be affected by public flood management policies under effect in a given area, and by private flood mitigation strategies taken by households [14]. We have used two variables to capture these two dimensions. $ProtectDike$ and $HealthInsurance$ are two dummy variables equal to 1, respectively, if a household is protected by a dike and if he possesses a health insurance. The cross effects between dike protection and risk attributes are all positive and significant: being protected by a dike reduces the valuation for any flood risk reduction program. These households may consider that there are already well-protected against floods. Households possessing an health insurance (43.9 % in our sample) have also a lower valuation for any flood risk reduction program, but the effect is statistically significant only in case of agricultural risk.

Finally, we find that socio-economic characteristics of households have only a small impact on flood risk reduction valuation.[17] Income per capita (variable $IncomeCap$) is never significant, whereas households with a high level of education have a lower valuation for reducing flood risks.

One implicit assumption with the linear specification of the indirect utility function in Eq. 2 is that there is a constant marginal utility of risk attributes: the marginal value of reducing a risk attribute by 1 % does not depend upon the level of this risk attribute. To relax this assumption, the model has been re-estimated by considering a piece-wise linear indirect utility function including a specific coefficient for each level of each risk attribute. We have obtained some mixed evidence regarding the linearity assumption. We cannot reject the linearity of the indirect utility with respect to the probabilities for agricultural damage (1 % level) and with respect to the probabilities for health damage (1 % level). On contrary, for housing damage, we reject the null hypothesis of the linearity of the indirect utility with respect to the probabilities. Moreover, using the piece-wise linear indirect utility function does not result in any significant improvement of the model goodness of fit.

4.4 Random Parameter Logit Model

Building on the existing literature, we use a Random Parameter Logit (RPL) model which accounts for unobserved, unconditional heterogeneity [25]. In the RPL model, the random utility gained by individual i from choosing program j in a particular choice task k writes:

$$U_{ijk} = V(X_{ijk}|\beta_i) + \epsilon_{ijk} \tag{3}$$

where β_i is a vector of utility coefficients (for observed variables X_{ijk}) representing individual's tastes. The coefficient vector varies over respondents with a specified density function $f(\beta)$ and is assumed to be independent of the density of $\epsilon's$. Similarly to the CL models, we consider a basic RPL model and a RPL model with interaction variables. Estimates of the RPL models by maximum simulated likelihood are reported in Table 5.

In the basic specification, all parameters at the exception of the flood management program payment have been assumed to be normally distributed and correlated.[18] The flood management program payment is included here as a fixed effect parameter. Thus, preferences for the the flood management program payment are assumed to be homogeneous, that is, the marginal utility of money is assumed to be constant over the sample. Such a specification allows for the estimation of WTP for different flood management schemes. Following [30], the distribution simulations have been based on 1000 Halton sequence draws. Introducing random preference variations improves the model significantly ($\chi^2_{(28)}$ = 1221.17, p<0.0001). Some coefficients of the standard deviation parameters are highly significant, which suggests a high level of heterogeneity in our data. The log-likelihood ratio test rejects at 1 % the null hypothesis that all the standard deviations are equal to zero.

All signs of flood management program attributes remain the same in the CL and RPL basic specifications. For the mortality risk attribute, the magnitude of the standard deviation coefficient is greater than the mean coefficient. This indicates a large heterogeneity across the respondents for flood management programs aiming at reducing mortality risks. In fact, the estimated coefficients for $RiskDeath$ imply a positive valuation for reducing the mortality risk only for 63.9 % of the households. Similarly to the CL model, we find that respondents value significantly a flood risk reduction on agricultural production (positive valuation for 65.1 % of the sample) and on housing (positive value for 89.7 % of the sample). A high level of heterogeneity is found for implementing a flood risk reduction program at the State level. A positive valuation for State-level implementation is found only for 53.12 % of the sample.

Next, we have included in the RPL model some respondent-specific characteristics interacted with the ASC or with the attributes of the flood risk reduction programs, see columns 4 and 5 in Table 5. As mentioned in [25],

[17] In addition to the socio-economic variables presented in Table 4, we have considered some other potential determinants including household' age, number of children, professional occupation, housing characteristics, risk, and time preferences. These variables were never significant.

[18] Estimates of the main parameters of interest considering log-normal distributions are quite similar.

Table 5 RPL models

	Basic model		Interaction model	
Variable	Coefficient	(Std. Err.)	Coefficient	(Std. Err.)
Coefficients				
C	−3.752***	(0.442)	−3.443***	(0.418)
ASC	−0.252	(0.197)	−0.420**	(0.167)
RiskAgri	−0.041***	(0.009)	−0.049***	(0.012)
RiskDeath	−305.708***	(102.381)	−565.880***	(144.028)
RiskHouse	−0.128*	(0.069)	−0.256***	(0.096)
LevelState	0.048	(0.120)	0.304***	(0.098)
LevelDistrict	0.146	(0.096)	0.202**	(0.087)
LevelVillage	0.143	(0.104)	0.146	(0.092)
RiskAgri × MoreFlood	–	–	−0.004	(0.018)
RiskDeath × MoreFlood	–	–	−527.610**	(244.875)
RiskHouse × MoreFlood	–	–	−0.015	(0.144)
RiskAgri × Injured	–	–	0.067*	(0.035)
RiskDeath × Injured	–	–	572.183	(425.970)
RiskHouse × Injured	–	–	0.216	(0.266)
RiskHouse × Evacuated	–	–	−0.290**	(0.140)
RiskAgri × ProtectDike	–	–	0.021	(0.014)
RiskDeath × ProtectDike	–	–	219.932	(172.786)
RiskHouse × ProtectDike	–	–	0.145	(0.109)
RiskAgri × HealthInsurance	–	–	0.003	(0.014)
RiskDeath × HealthInsurance	–	–	509.757***	(174.216)
RiskHouse × HealthInsurance	–	–	0.133	(0.108)
Coefficient standard deviations				
ASC	3.069***	(0.229)	2.543***	(0.169)
RiskAgri	0.106***	(0.011)	0.057***	(0.017)
RiskDeath	855.453***	(176.865)	577.948**	(278.376)
RiskHouse	0.101	(0.124)	0.003	(0.165)
LevelState	0.613**	(0.274)	0.936***	(0.114)
LevelDistrict	0.049	(0.317)	−0.096	(0.372)
LevelVillage	0.011	(0.303)	−0.173	(0.485)
RiskAgri × MoreFlood	–	–	0.002	(0.035)
RiskDeath × MoreFlood	–	–	885.974**	(424.976)
RiskHouse × MoreFlood	–	–	−0.186	(0.410)
RiskAgri × Injured	–	–	−0.018	(0.063)
RiskDeath × Injured	–	–	46.410	(743.419)
RiskHouse × Injured	–	–	0.008	(0.419)
RiskHouse × Evacuated	–	–	0.287	(0.361)
RiskAgri × ProtectDike	–	–	0.051*	(0.030)
RiskDeath × ProtectDike	–	–	377.547	(529.811)
RiskHouse × ProtectDike	–	–	−0.201	(0.247)
RiskAgri × HealthInsurance	–	–	0.066***	(0.023)
RiskDeath × HealthInsurance	–	–	−19.809	(531.215)
RiskHouse × HealthInsurance	–	–	−0.009	(0.195)
N	10752		10752	
Log-likelihood	−3343.39		−3323.5097	
χ^2	$\chi^2_{(7)}$: 1111.85		$\chi^2_{(20)}$: 1044.33	

Significance levels: * 10 %, ** 5 %, *** 1 %

this specification with interactions captures preference variation in terms of unconditional taste heterogeneity (random heterogeneity) and individual characteristics (conditional heterogeneity). Similarly to the CL model with interactions, respondents who expect in the future more floods have a significant higher valuation to reduce flood mortality risk. No significant impact of flood risk perception is found for the two other risk attributes. As expected, a higher valuation for reducing flood risk affecting housings is found for households who have been evacuated from their home due to a flood. This result is consistent with the existing literature having shown that past flood experience tends to shape behaviors [8]. Holding a health insurance reduces the valuation of a flood policy reducing mortality risk. This results could be interpreted as a form of substitution between a private flood mitigation strategy (holding a health insurance) and the proposed public flood risk reduction programs. A similar substitution effect has also been found by [3] in the Netherlands.

4.5 Willingness to Pay and Value of a Statistical Life

The interpretation of coefficient estimates in the indirect utility functions is not straightforward except for the significance. One more convenient way is to present the results in terms of marginal willingness to pay (WTP) for a change in a given attribute (Att):

$$WTP_{Att} = -\frac{\partial V/\partial Att}{\partial V/\partial C} \tag{4}$$

which corresponds to minus the marginal rate of substitution between the attribute considered and the cost of the program. For the three risk attributes, the WTP is equal to the marginal rate of substitution between the attribute considered and the cost of the program multiplied by 100 since risk attributes have been expressed in the CE as percentages. Moreover, for the mortality risk, the marginal rate of substitution is divided by the number of household members since the risk reduction in the CE benefits to *all* household's members.

In Table 6, we report the marginal WTP obtained for the attributes of our CE. The level of implementation of the flood management program appears to have a significant impact on household's WTP. With the RPL-basic model, the marginal WTP for implementing flood risk reduction policies at State, district, and village/commune levels are respectively equal to 0.089, 0.058, and 0.041 million VND (4.27, 2.78, and 1.97 USD). As a result, our estimates do not provide any evidence of a monotonic relationship between the level of implementation of a flood risk reduction program and its valuation.

Depending upon the model, the marginal WTP to reduce the risk of damage to agricultural production varies from 1.01 million VND (48 USD) to 1.25 million VND (60 USD), representing between 3.1 and 3.8 % of household annual average income. Since respondents report an average cost for flood damage to agricultural production equal to 3.5 million VND, a significant gap exists between their WTP and the value of damage they report. One explanation could be that farmers consider that they are able by themselves to deal with floods impacting upon their agricultural production. Another explanation could be that they do not want to contribute in monetary terms to a flood risk reduction program, as suggested by [20].

The WTP to reduce the risk of damage to housing varies significantly with the model used. Using the RPL-basic model, the WTP to reduce the risk of damage to housing is equal to 1.761 million VND (77 USD) which represents 5.0 % of the annual average household income. If we consider the RPL model with interactions, the WTP increases to 5.523 million VND (265 USD euros) which represents

Table 6 Marginal WTP (in million VND) for flood risk reduction program attributes

	CL basic		RPL basic		RPL interactions	
Attribute	Est.	CI (95 %)	Est.	CI (95 %)	Est.	CI (95 %)
RiskAgri	1.246	(0.721; 2.023)	1.042	(1.017; 1.067)	1.011	(0.985; 1.038)
RiskHouse	1.761	(−0.031; 6.345)	5.523	(5.522; 5.524)	5.118	(5.026; 5.209)
RiskDeath	3590	(2021; 4120)	2517	(2454; 2580)	2319	(2237; 2401)
LevelState	0.090	(0.027; 0.171)	0.089	(0.086; 0.092)	0.088	(0.085; 0.091)
LevelDistrict	0.086	(0.015; 0.165)	0.058	(0.058; 0.058)	0.059	(0.058; 0.059)
LevelVillage	0.072	(−0.002; 0.156)	0.041	(0.041; 0.041)	0.042	(0.042; 0.042)

For the CL model, the associated confidence intervals are obtained using the parametric bootstrapping technique proposed by [17] with 1000 replications (similar intervals have been obtained with the delta and Fieller methods). For the RPL models, they are based on the unconditional parameter estimates through simulation

17.0 % of the annual average household income. This points out the need to account for observed and unobserved heterogeneity in estimating CE.

The marginal WTP for reducing fatality rate, which can be interpreted as the value of statistical life (VSL), varies from 2 517 million VND (approximately 120,818 USD) using the RPL with interactions model to 3 590 million VND (approximately 172,323 USD) when using the CL-basic model. The WTP represents between 77 and 111 times the annual household average income in our sample.

It is difficult to compare our VSL in Vietnam with existing VSL in similar countries since they have typically been estimated in different contexts (health risk, environmental risk, professional risk) using different methods, CE or contingent valuation (CV) approach. Our VSL is, however, in line with previous estimates. Recently, [22] have provided a measure of the VSL in Vietnam by considering diarrhea mortality risk and using a CV approach. They report a VSL for Vietnam varying from 65,726 to 209,660 USD. In Thailand, [31] have used two CV surveys to measure the WTP to reduce mortality risks in the context of air pollution and traffic accidents. They find a VSL between 0.74 and 1.48 million USD. Using a CV approach in rural Cambodia, [9] report a mean VSL equal to 446,196 USD based on a reduction of death risk due to landmine accidents.

5 Policy Implications and Conclusion

A choice experiment has then been employed to estimate how Vietnamese households value different generic flood management policies. We have found very different WTP depending upon the type of flood risk reduction program. As it could have been expected, the WTP is the highest for reducing the flood mortality risk. It varies from 2 517 million VND (approximately 120,818 USD) to 3 590 million VND (approximately 172,323 USD) depending upon the model considered and it represents between 77 and 111 times the annual household average income. The WTP to reduce the risk of damage to housing and house content ranks second, but it varies a lot from 1.761 million VND (77 USD) to 5.523 million VND (265 USD euros) representing between 5.0 and 17 % of the annual average household income. Lastly, the marginal WTP to reduce the risk of damage to agricultural production varies from 1.01 million VND (48 USD) to 1.25 million VND (60 USD), representing between 3.1 and 3.8 % of the household annual average income. These significant differences in WTP suggest the need for a careful design of flood risk reduction policies. A policy aiming at reducing the flood mortality rate (early flood warning system for instance) will then be valued differently compared to a flood policy aiming at reducing the risk on housings (flood risk zoning for instance). Our result suggests that a valid valuation assessment of a flood risk reduction program should simultaneously take into account mortality risk, risk on housings, and risk on agricultural production (or more generally speaking on professional activities). Results obtained with the RPL models reveal a high level of heterogeneity in household's preferences for flood risk reduction programs, especially for programs affecting the mortality risk and the agricultural production risk. This heterogeneity is partially driven by past flood experience, perception of flood risks, and by some socioeconomic characteristics of households.

Our WTP estimates are useful for designing and evaluating flood management policies, even in a highly centralized country such as Vietnam. Relying on elicited WTP to define flood management policies in Vietnam raises, however, a few important issues that should be addressed by public authorities. First, as mentioned by [13], environmental goods in developing countries are intrinsically characterized by multiple market failures. In that case, since individual WTP may not reflect the social value of the environmental good under study, they should be considered by public authorities with caution. Second, citizens may have biased preferences. This raises the issue for public authorities to decide how to act when people may have a distorted vision from the reality. In our specific context, households having being recently flooded may overweight the risk of flooding. Whether or not public authorities should respond to citizen (possibly biased) beliefs raises a puzzling normative question with two different views. The tenants of the paternalistic view consider that differences in perceptions reflect differences not in values but in the understanding of facts and that a public policy should be based on these facts rather than on people's misperceptions. On contrary, for the tenants of the populist, the view is that public authority's choices should be based on consumer's preferences, even biased. The appropriate view highly depends upon the context [28]. In both cases, designing efficient water policies will require at some point to try to conciliate the view of experts and citizens.

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Appendix: Definition of Variables

Table 7 Name and definition of variables used in the CE

Variable	Definition
Attributes in the CE	
RiskAgri	Annual risk of a significant damage to agricultural production (in %)
RiskDeath	Annual risk of death (in %)
RiskHouse	Annual risk for house and house content to be significantly damaged by a flood (in %)
LevelState	Dummy variable equal to 1 if the flood risk reduction program is implemented at the State level
LevelDistrict	Dummy variable equal to 1 the flood risk reduction program is implemented at the district level
LevelVillage	Dummy variable equal to 1 if the flood risk reduction program is implemented at the village level
Household socio-economic characteristics	
IncomeCap	Annual household income per capita in 2010 (in million VND)
EducHigh	Dummy variable equal to 1 if the household head has attended at least a secondary school
Household flood experience	
Evacuated	Dummy variable equal to 1 if respondent has been evacuated or advised to evacuate from his/her house because of the threat of flood
Injured	Dummy variable equal to 1 if a member of the household has been injured by a flood event in the last 5 years
ProtectDike	Dummy variable equal to 1 if the household is protected by a dike (river or sea dike)
HealthInsurance	Dummy variable equal to 1 if the household has a health insurance
Confidence in institutions	
StateConfidenceHigh	Dummy variable equal to 1 if respondent has a high confidence level in the State for managing in an efficient way flood risks
DistConfidenceHigh	Dummy variable equal to 1 if respondent has a high confidence level in the district for managing in an efficient way flood risks
VillageConfidenceHigh	Dummy variable equal to 1 if respondent has a high confidence level in the village for managing in an efficient way flood risks

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