The determinants of household's flood mitigation decisions in France - evidence of feedback effects from past investments

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Abstract

In this paper, we investigate the determinants of private flood mitigation in France. We conducted a survey among 331 inhabitants of two flood-prone areas and collected data on several topics, including individual flood mitigation, risk perception, risk experience, and sociodemographic characteristics. We estimate discrete choice models to explain either the presence of precautionary measures implemented by the household, or the intention to take such measures. We test the robustness of the Protection Motivation Theory in France, discuss its scope and investigate the existence of feedback effects from past investments on people's protection intentions. Our results confirm that the Protection Motivation Theory is a relevant framework to describe the mechanisms of private flood mitigation in France, highlighting in particular the importance of threat appraisal, threat experience appraisal, and coping appraisal. Some sociodemographic features are also significant to explain private flood mitigation. Our results also give evidence for feedback effects as they suggest that implementing precautionary measures reduces perceptions of the risk of flooding. The existence of these feedback effects implies that intended measures, rather than implemented ones, should be examined to explore further the determinants of private flood mitigation.

JEL Classification: Q54; D81; R22
Keywords: flood; risk; mitigation; risk perception; France

1 Introduction

In 2014, floods accounted for more than a third of the total estimated damage caused by natural disasters worldwide, which amounted to 100 billion US dollar.[1] Thus, they already represent a major source of concern. In addition, the frequency and

[1] `http://www.emdat.be/disaster_trends/index.html`

magnitude of extreme events such as floods are expected to be modified due to climate change (Patwardhan et al., 2007). As a result, adaptation to natural disasters, and to floods in particular, is one of the key challenges humans will have to face to build and maintain sustainable societies. France is largely affected by floods. Indeed, these phenomena generate over one billion Euros of annual costs in this country (OECD, 2014) and one in four inhabitants is exposed to this risk (DGPR, 2011). Yet very few studies have so far investigated flood prevention measures in France (Poussin et al., 2014, 2015).

The measures aimed at protecting people from flood risks or mitigating their negative consequences can be classified into public and private actions. Among public responses are zoning policies, solidarity and compensation schemes, and collective protection measures, like dykes or flood retention basins (Erdlenbruch et al., 2009, Picard, 2008). On the other hand, individuals themselves can take actions. In many countries, they can subscribe to private insurances aimed at compensating monetary losses after a natural disaster. In France, since there is a compulsory national compensation system (Catnat), individuals do not take the decision to buy an insurance or not, but they can decide to set up precautionary measures aimed at mitigating the consequences of floods in their home, such as pumps or openings on the roof to facilitate evacuation. This can be seen as an auto-insurance (Carson et al., 2013). One interesting question is thus to understand why people adopt precautionary measures and how public actions could support these decisions.

Several points can be raised to underline the paramount importance of private precautionary measures for the sustainability of socio-ecological systems. First, large structural flood defences such as dams, storage reservoirs and embankments lack reversibility and can provide a misleading feeling of complete safety among populations exposed to floods (Kundzewicz, 1999). Thus, they may hinder the adaptation to changing risks of flooding and are poorly suited within the context of climate change. Moreover, they can harm ecosystems (Werritty, 2006). On the contrary, since private precautionary measures are more localised and can be designed for specific household's situation and exposure, they may be more flexible and may have less impact on the environment than public flood defences. Moreover, by implementing precautionary measures, individuals take responsibility for their own safety. Hence, the use of such measures can help maintain a certain awareness of the risk of flooding among exposed populations. Finally, several studies suggest that individual precautionary measures have great potential to reduce the consequences of natural disasters. For instance, Poussin et al. (2015) showed that elevating buildings could reduce the ratio of total damage to total building values by 48% in three different areas in France. Similar results were found in Germany (Kreibich et al., 2005) and in the Netherlands (Botzen et al., 2009).

This paper recognizes the importance of private initiatives and investigates the mechanisms at stake when people decide whether to implement precautionary measures or not. We combine economic approaches, stressing the importance of individual decision making in terms of self-insurance on their properties (Carson et al., 2013) and psychological approaches, highlighting the importance of perceptions and emotions to explain people's motivations to take actions in order to reduce their risk

vulnerability (Rogers, 1975).

Several studies on individual flood preparedness have identified the Protection Motivation Theory as a relevant framework to explain the implementation of precautionary measures (Grothmann and Reusswig, 2006, Poussin et al., 2014, Reynaud et al., 2013). However, in spite of the overall adequacy of this framework, and as highlighted by Bubeck et al. (2012), most studies are cross-sectional and may thus neglect possible feedback effects from already adopted precautionary measures on explanatory factors.

The main objective of this article is twofold: i) to test the relevance of the Protection Motivation Theory in France, and to expand its framework, if necessary, by including the effects of local social interactions and other socio-demographic variables, ii) to investigate whether past decisions have an impact on people's perceptions and intentions, and how these feedback effects in turn affect the robustness of the Protection Motivation Theory.

To examine these questions, we conducted a survey among households living in flood prone areas in the South of France, which were hit by major floods at different points in time during the last 20 years. We collected data on exposure, attitudes, risk perception, experience of floods, characteristics of housing, social interactions, and socio-demographic features from 331 households. We explored possible feedback effects by asking the respondents not only to indicate which precautionary measures they took, but also which ones they considered implementing at the time of the survey. We used discrete choice decisions models (Train, 2009) to compare the adequacy of the Protection Motivation Theory to explain implemented and planned measures and compared the perceptions and emotions of people who had already implemented measures with those of respondents who still considered taking actions.

In line with the existing literature, we confirm the relevance of the Protection Motivation Theory to explain private flood mitigation. Our results highlight in particular the importance of threat appraisal, coping appraisal, and threat experience appraisal. In addition, they are compatible with the assumption of a feedback effect of the implementation of precautionary measures on risk perceptions. Finally, we provide some evidence on the positive role of social interactions in private flood mitigation.

In the remainder of the paper, we first describe the Protection Motivation Theory and highlight its strengths and weaknesses in section 2. In section 3, we present the survey designed to investigate the drivers of private flood mitigation and the data collected. Then, we explain how we statistically analysed the gathered information. Results are exposed in section 4 before being discussed in section 5. Finally, section 6 is devoted to the conclusion.

2 Literature on Protection Motivation Theory

The Protection Motivation Theory has first been proposed by Rogers (1975) and applied in the health domain. It has been further developed by Milne et al. (2000) and

adapted to the context of floods by Grothmann and Reusswig (2006). According to this framework and as presented in Figure 1, the higher an individual's appraisal of the threat caused by floods, the more likely he will respond to this risk by adopting either non protective responses, such as a fatalist position, or precautionary measures. The individual's coping appraisal will influence the type of response: the more a person thinks that she is able to protect herself against the consequences of floods, the more she will tend to implement a precautionary measure rather than a non protective response. Moreover, people who have already experienced a flood should be all the more likely to take precautionary actions that the event that affected them was severe. On the other hand, the reliance on public flood protection and actual barriers, such as a lack of monetary resources, are expected to negatively affect the implementation of precautionary measures.

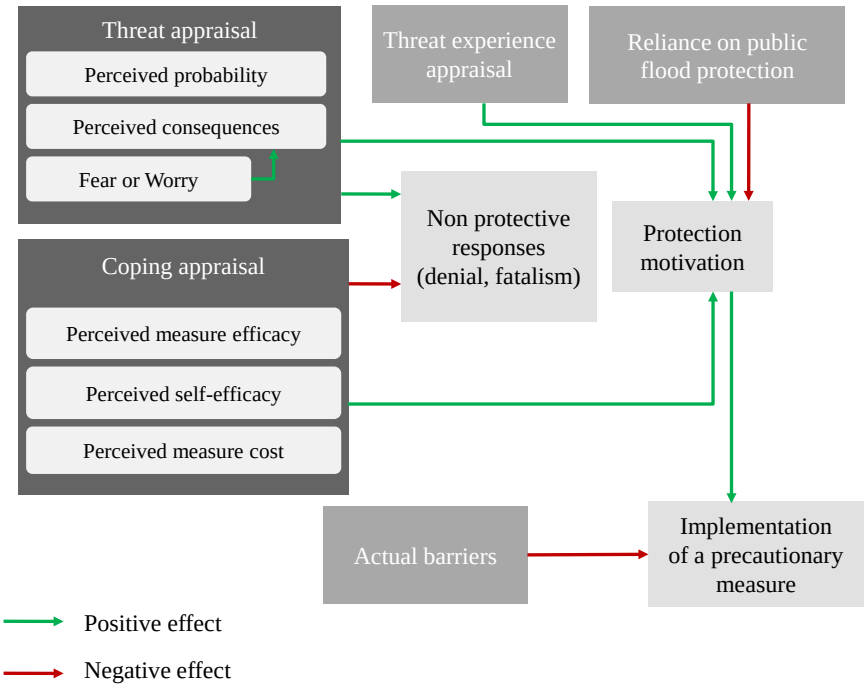

Figure 1: The Protection Motivation Theory.
Source: adapted from Grothmann and Reusswig (2006)

The Protection Motivation Theory has been successfully applied to explain private flood mitigation in several countries (Grothmann and Reusswig, 2006, Poussin et al., 2014, Reynaud et al., 2013). Thus, it appears to be quite robust and flexible. However, since most studies are cross-sectional, they examine the links between perceptions, emotions, and flood mitigation at one point in time. As a result, they may neglect possible feedback effects from already adopted precautionary measures (Bubeck et al., 2012). Moreover, unlike health risks which can affect isolated individuals, natural hazards, such as floods, result necessarily from the interaction between natural phenomena and social systems settled in specific geographic areas (Burton et al., 1993). Consequently, members of communities facing the same risks can communicate about solutions to mitigate them. Indeed, good social interactions have already been identified as a factor of private mitigation in the context of vol-

canic hazards (Paton et al., 2008). Thus, it seems relevant to explore the effects of local social interactions on private flood mitigation.

3 Method

3.1 Sample

Figure 2 presents the geographical location of the two departments surveyed: the Aude department and the Var department. They are both subject to flash floods. The Aude department was severely impacted by such a phenomenon in November 1999. Thirty-five people died during this event and it caused an estimated loss of €771 million (Vinet, 2008). As for the Var department, it was hit by a major flash flood in June 2010 that killed 26 people. The estimated damage due to this disaster lies between 1,000 and 1,500 million euros (Vinet et al., 2012). The respondents were selected so that approximately 80% of the sample had already experienced at least one flood. This sampling decision insures that the survey targets a majority of people concerned by the risk of flooding while still allowing to examine the effect of flood experience on private mitigation.

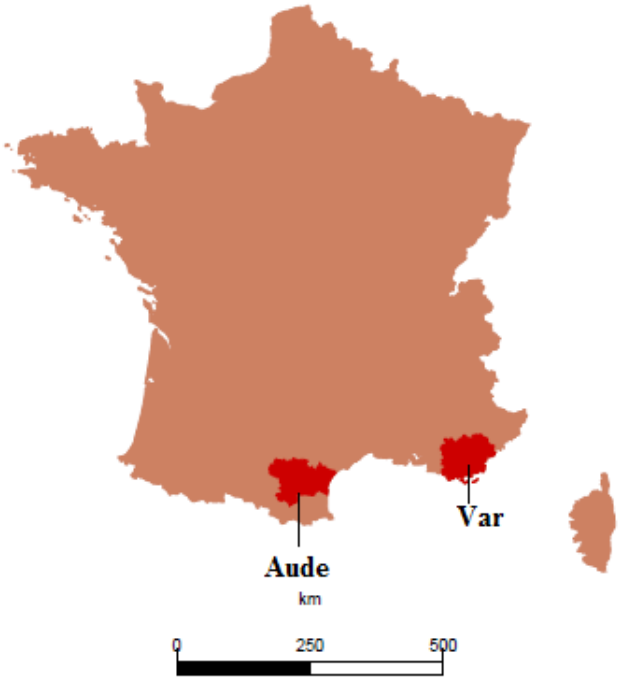

Figure 2: Geographical location of the French departments surveyed.

In total, 331 people participated in the survey during face-to-face interviews conducted in summer 2015. Among them, 272 respondents completed all the questions used in the analyses exposed here. As presented in Table 1, approximately half of this final sample is composed of women and half of men. Moreover, half of the respondents lived in the Aude department and half in the Var at the time of the survey. Similarly, half of the respondents lived in cities of more than 10,000 inhabitants and half in municipalities where the population size is lower than 10,000 inhabitants. Half of the sample has less than a high school diploma and two third are home owners. Finally, all age categories are represented. Since only 58% of the respondents indicated their revenue, this variable was not taken into account to describe the sample and for subsequent analyses.

Table 1: Sociodemographic variables distribution of the sample

Variable	**Category**	**Sample distribution**
Department	Aude	49.3%
	Var	50.7%
Gender	Male	46.7%
	Female	53.3%
Age	<30	17.6%
	30-44	21.3%
	45-59	25.0%
	60-74	26.5%
	>74	9.6%
Education level	Less than a high school diploma	51.1%
	High school diploma or higher diploma	48.9%
Ownership of the home	Home owners	63.2
	Others	36.8
Size of the municipality of residence	Resident of a municipality of less than 10,000 inhabitants	52.6%
	Resident of a municipality of more than 10,000 inhabitants	47.4%

N=272

3.2 Questionnaire design

The design of the closed questionnaire used for the survey was inspired from the literature on Protection Motivation Theory (Grothmann and Reusswig (2006), Poussin et al. (2014), Reynaud et al. (2013)) and from an exploratory phase during which semi-directive interviews were conducted with 11 inhabitants of the Aude department. Main types of precautionary measures and potential drivers of private flood mitigation were identified during the literature review and the exploratory phase. The questionnaire was reviewed by 5 experts in the field of floods before being completed by the respondents. It is aimed at investigating individual flood mitigation

and its relationships with perceptions, emotions, experience, and sociodemographic characteristics.[2]

3.3 Data

Private flood mitigation

The semi-directive interviews led to the identification of 11 main measures that are exposed in appendix A and that we classified in two groups: structural and non-structural measures. Structural measures are features of the structure of homes, such as raised ground floors or raised crawl spaces, which aim at hindering the negative consequences of floods. On the other hand, non-structural measures are all the other devices implemented in order to avoid damage caused by floods. Pumps and watertight doors are two examples of such measures.

For each of the 11 measures selected, the respondents indicated whether it was present or not in their home and whether they intended to implement it. In case a precautionary measure was present in a respondent's home, he had to specify whether this measure had been implemented by the household or by someone else.

Among the 272 households, 78% disposed of at least one precautionary measure, 42% implemented at least one measure by themselves, and 25% considered taking at least one measure at the time of the survey.

The potential drivers of private flood mitigation examined in this article are the components of the Protection Motivation Theory and local social interactions. These variables are presented more thoroughly below and in Table 2. We also investigated the effect of the sociodemographic features exposed in Table 1.

Components of the Protection Motivation Theory

Threat appraisal

The threat appraisal component of the Protection Motivation Theory comprises two variables related to the respondents' perceptions, their perceived probability of floods and their perceived consequences, and one emotion variable, which is the worry floods generate for people who feel exposed to them. Hence, we estimated these three variables during the survey.

The perceived probability was measured by asking the respondents to indicate their perceived likelihood that their municipality will be flooded within 10 years from the moment of the survey. For this question, people had to give a score on a qualitative scale from "a: impossible" to "k: certain" and also to directly provide a probability in terms of percentages. Qualitative perceived probabilities are used in the subsequent analyses because the response rate was higher with this method than when people had to estimate probabilities (84% vs. 64% for the initial sample of 331 respondents). The qualitative perceived probabilities were recoded from 0, which

[2]Data on attitudes towards risk, housing characteristics, and exposure to floods were also collected during the survey but are not included in subsequent analyses because they were not significant to explain individual flood mitigation

corresponds to "a: impossible", to 11, which is equivalent to "k: certain". On average, the perceived probability is rather high within the sample since it rates at 6.9 out of 11.

Furthermore, the respondents were told that it was considered in the survey that a municipality is flooded when the water accumulates in its streets. According to this definition, all inhabitants are not necessarily affected when a flood occurs in their municipality. Thus, the respondents estimated the likelihood that the water would reach their street in case of floods in order to provide insights into their perceived consequences of such events. This question was rated on the same scale as the qualitative perceived probability and was recoded in a similar way. Its average score of 7.0 suggests that the respondents tend to believe that they can be personally affected by floods.

Finally, the respondents indicated the extent to which they worried about floods on a scale from "0: not at all" to "3: a lot". The mean value for this question is 1.6, which means that the respondents are on average between "not really" and "a little bit" worried about the risk of flooding.

Coping appraisal

The coping appraisal results from the combination of the perceived self-efficacy, the perceived precautionary measure efficacy, and the perceived cost of the measure. We only used information regarding perceived self-efficacy and perceived measure efficacy.

Perceived self-efficacy was estimated by asking the respondents to indicate their agreement with the following statement: "I do not believe that I am able to avoid the consequences of floods in my household. I have no hold in this matter." The respondents could rate this statement between 0 ("strongly agree") and 6 ("strongly disagree"). The average score for this item is 2.28. This indicates that the respondents in general feel rather helpless in the face of floods.

Then, for each of the 11 measures selected, the respondents assessed its efficacy to protect a household against floods from 0 ("not at all effective") to 4 ("very effective"). The mean score among all measures is 2.57, that is to say between "moderately effective" and "effective". The 3 precautionary measures considered the most effective are the measures to improve the water flow, raised ground floors or raised crawl spaces, and the storage of valuables upstairs. All these measures are seen on average as "effective".

Threat experience appraisal and reliance on public flood protection

Threat experience appraisal was estimated in two steps: first, the respondents indicated whether they had already experienced at least one flood or not. If they had, they answered questions related to a reference event.[3] In particular, they assessed

[3]The reference event is the flood which occurred in 1999 for the inhabitants of the Aude department who have experienced it, the flood of 2010 for people living in the Var department who have experienced this event, or the flood which had the greatest impact on the respondents who were neither present during the flood of 1999 nor during the one of 2010.

the seriousness of this flood for their household on a scale from 0 ("not serious at all") to 10 ("extremely serious"). The threat experience appraisal variable consists of the scores given to this question for the respondents who had already experienced a flood and is set at 0 for the others. Among the 272 respondents, 81% had already experienced a flood at the time of the survey. Moreover, the average score of the threat experience appraisal is 3.93.

The reliance on public flood protection was estimated by asking the respondents to rate their satisfaction regarding the public management of floods in their municipality on a scale from 0 ("not at all satisfied") to 4 ("very satisfied"). The average value of this variable is 2.21. In other words, the average reliance on public flood protection lies between "neither dissatisfied nor satisfied" and "satisfied".

Local social interactions

Local social interactions are not included in the Protection Motivation Theory framework, as described by Grothmann and Reusswig (2006). However, the semi-directive interviews conducted with inhabitants of the Aude department suggested that they could play a role in private flood mitigation. Indeed, the only two respondents of the exploratory phase who did not dispose of any precautionary measure lived alone and one of them had poor relationships with the other inhabitants of her village. On the other hand, another respondent implemented several precautionary measures after his neighbours advised him to do so. Moreover, the positive effect of good local social interactions for coping with natural disaster has already been highlighted by Adger (2010) who suggests that social capital within communities can substitute the state to inform and advise the populations exposed to such risk.

In order to evaluate the local social interactions, we used 2 different pieces of information. First, the respondents indicated how often they exchange with their entourage about floods on a scale from 0 ("never") to 3 ("often"). This question provides an indication regarding the quantity of local social interactions. Then, a second question was aimed at assessing the respondents' well-being in their municipality and was rated between 0 ("I do not feel good at all") and 4 ("I feel very good"). Since a strong and positive relationship has been identified by Helliwell (2006) between well-being and social capital, and more particularly its trust component, we used the well-being variable as an indicator of the quality of the respondents' social interactions.

On average, the respondents talk about floods with their entourage between "rarely" and "sometimes" (mean value of 1.50) and they feel between "good" and "very good" in their municipality (mean value of 3.30).

Table 2: Data summary

Variable	Mean (Std dev.)	Question	Scale
Perceived probability	6.94 (3.07)	"How do you assess the following scenario: 'your municipality will be flooded at least once within 10 years'?"	From 0 ("impossible") to 11 ("certain")
Perceived consequences	7.01 (3.73)	"In case of flooding, how do you assess the following scenario : 'the water will reach your street'? "	From 0 ("impossible") to 11 ("certain")
Worry	1.60 (1.02)	"Are you worried regarding the risk of flooding in you municipality ?"	From 0 ("not at all") to 3 ("a lot")
Perceived self efficacy	2.28 (1.67)	"To what extent do you agree with the following statement: 'I do not believe that I am able to avoid the consequences of floods in my household. I have no hold on this matter.'?"	From 0 ("strongly disagree") to 6 ("strongly agree")
Perceived measure efficacy	2.57 (0.81)	"For each measure listed below, how do you feel regarding its efficacy to hinder the negative consequences of floods?"	From 0 ("not at all effective") to 4 ("very effective")
Threat experience appraisal	3.93 (3.67)	"How do you assess the seriousness of the consequences of the reference flood for your household?"	From 0 ("not serious at all" or for people who have not experienced a flood) to 10 ("extremely serious")
Reliance on public flood protection	2.21 (1.06)	"Are you satisfied with the public management of floods in your municipality?"	From 0 ("not at all satisfied") to 4 ("very satisfied")
Importance of floods in social interactions	1.50 (1.00)	"How often do you exchange with your entourage about floods?"	From 0 ("never") to 4 ("often")
Well-being within the municipality	3.30 (0.79)	"How do you feel in your municipality?"	From 0 ("not good at all") to 4 ("very good")

N=272

3.4 Statistical treatment

Two binary dependent variables were created. The first one, "implemented" takes the value 1 if at least one precautionary measure present in the respondent's home has been implemented by the household and 0 otherwise; the second dependent vari-

able, "planned" takes the value 1 if the household was considering implementing at least one precautionary measure at the time of the survey and 0 otherwise.[4]

First, two logistic regressions (Train, 2009) were performed to compare the adequacy of the Protection Motivation Theory for each dependent variable. We then investigated potential feedback effects by comparing the perceptions of people who already implemented at least one precautionary measure and did not plan to increase their protection level with the perceptions of respondents who had not implemented any measure yet but considered doing so at the time of the survey. Since the data are not normally distributed, Mann-Whitney-Wilcoxon tests (Mann and Whitney, 1947) were used to compare the two samples.

Finally, we focused on the variable which is the best explained by the Protection Motivation Theory ("planned") and examined the role of local social interactions and sociodemographic features in order to expand this framework.

To do so, simple logistic regressions were used to first study the effect of each variable of interest on private flood mitigation. The variables whose coefficients were significant at the level 0.1 were selected and used in a multiple logistic regression. The least non-significant independent variables were then progressively excluded from the regression one by one until only variables with a coefficient significant at the level 0.1 remained in the model. To avoid multicollinearity, we checked that the Spearman coefficients of correlation are all inferior to 0.80 (Bryman and Cramer, 1990). Actually, the highest correlation found is 0.46 between perceived consequences and perceived probability (see Appendix B).

4 Results

4.1 Scope of the Protection Motivation Theory

Table 3 summarizes the results of two logistic regressions. Model 1 explains the implementation of at least one precautionary measure whereas Model 2 explains the willingness to implement at least one measure. The two model specifications contain the Protection Motivation Theory variables presented above. The fit of Model 2 is way better than the one of Model 1 (Nagelkerke R^2 of 0.376 versus 0.117). Furthermore, only two variables, perceived self efficacy and threat experience appraisal, are significant at the level 0.1 in Model 1 whereas only perceived probability and satisfaction in public flood management are non significant in Model 2.

In Model 2, as expected according to the Protection Motivation Theory, perceived consequences, worry, and threat experience appraisal positively influence the willingness to implement precautionary measures. However, the effects of the two variables used to assess coping appraisal, perceived self-efficacy and perceived measure efficacy, are non linear. Indeed, for each of these variables, the probability to consider implementing a measure increases first before decreasing.

[4]The number of measures taken or planned could have been used as dependent variables. However, since some measures could be regarded as substitute (Osberghaus, 2015), their accumulation is not relevant to explore the willingness to mitigate flood consequences.

Table 3: Comparison of the adequacy of the Protection Motivation Theory for implemented and planned precautionary measures

	Model 1: Implemented	**Model 2: Planned**
Variable	Estimate (Std dev.)	Estimate (Std dev.)
Intercept	-0.97 (0.86)	-7.91*** (1.69)
Perceived probability	0.01 (0.05)	-0.02 (0.06)
Perceived consequences	0.07 (0.04)	0.25*** (0.06)
Worry	0.13 (0.16)	0.46** (0.22)
Perceived self-efficacy	-0.45* (0.24)	0.95*** (0.34)
(Perceived self-efficacy)^2	0.10** (0.04)	-0.18*** (0.06)
Perceived measure efficacy	-0.17 (0.60)	2.37** (1.19)
(Perceived measure efficacy)^2	0.04 (0.13)	-0.54** (0.24)
Threat experience appraisal	0.08* (0.04)	0.13** (0.05)
Satisfaction in public flood management	-0.02 (0.14)	0.18 (0.17)
Nagelkerke R^2	0.117	0.376

N=272. Significance levels: * p<0.1; ** p<0.05; *** p<0.01.

These results have two main implications. First, already implemented and planned measures cannot be used equivalently to explore private flood mitigation mechanisms for the considered sample. Secondly, the Protection Motivation Theory explains better the willingness to take precautionary measures than the presence of already implemented measures in the household in this case.

4.2 Feedback effect of the presence of precautionary measures

To explore possible feedback effects of the presence of precautionary measures and its mechanisms, the scores on the Protection Motivation Theory variables of respondents who had already implemented precautionary measures were compared with those of people who planned to take at least one measure. To do so, we first isolated two groups within the sample: Group 1 consists of respondents who considered implementing at least one measure and did not take any precautionary measure at the time of the survey and Group 2 consists of respondents who did not consider implementing any supplementary measure but had already taken at least one measure. Then, Mann-Whitney-Wilcoxon tests were performed between the distributions of the Protection Motivation Theory variables in Group 1 and Group 2.

Table 4: Comparison of the Protection Motivation Theory variables between respondents who had already taken precautionary measures and respondents who intended to implement measures at the time of the survey.

Variable	**Group 1** N=34	**Group 2** N=82
Mean perceived probability	8.27	7.39
Mean perceived consequences	9.38***	7.16***
Mean worry	2.06**	1.65**
Mean perceived self-efficacy	2.06	2.33
Mean perceived measure efficacy	3.30	3.11
Mean reliance on public flood protection	2.15	2.09
Mean threat experience appraisal	5.91**	4.21**

Group 1: People who considered implementing at least one precautionary measure and did not take any precautionary measure at the time of the survey; Group 2: People who implemented at least one precautionary measure and did not consider implementing any additional measure at the time of the survey. In this table, the perceived measure efficacy is the mean perceived efficacy of all planned measures for respondents in Group 1 and the mean perceived efficacy of all implemented measures for respondents in Group 2. The significance levels indicated come from Mann-Whitney-Wilcoxon tests between group 1 and group 2. Significance levels: * $p<0.1$; ** $p<0.05$; *** $p<0.01$.

On average, people who had already implemented at least one measure assigned a lower score to the perceived consequences, worry, and threat experience appraisal variables than the respondents who planned to implement at least one measure. These results support the assumption of a feedback effect of the implementation of precautionary measures on perceptions and emotions relating to flood risks.

Hence, it seems more relevant to focus on the planned measures than on those which are already implemented to explore the mechanisms of private flood mitigation. Thus, the variable "planned" was used to broaden the Protection Motivation

Framework by exploring the effect of local social interactions and to examine the role of several sociodemographic features in private flood mitigation.

4.3 Effect of sociodemographic features and local social interactions

Following Grothmann and Reusswig (2006), we define the threat appraisal variable as the joint measurement of perceived probability and perceived consequences. More specifically, the perceived probability was normalized to lie between 0 and 1 before being multiplied by the normalized perceived consequences. As a result, the threat appraisal variable takes its values between 0 and 1. We combined the perceived self-efficacy and the perceived measure efficacy in a similar way in order to construct the coping appraisal variable. The use of normalized variables to define threat appraisal and coping appraisal ensures that their components have the same weight.

The threat appraisal and coping appraisal variables are used as explanatory variables in Model 3, which is presented in Table 5. Only variables significant at the level 0.1 remain in this model. Compared to Model 2, threat experience appraisal has the same sign and similar magnitude and coping appraisal has the same parabolic effect as when perceived self-efficacy and perceived measure efficacy are included separately. Moreover, threat appraisal has a positive and significant effect, such as perceived consequences in Model 2. However, worry is no more significant at the level 0.1. As for the sociodemographic variables, the respondents who have at least a high school diploma, those who live in the Var department and in municipalities of more than 10,000 inhabitants, and home owners are more likely to consider implementing at least one precautionary measures than the others. Finally, the better the respondents feel in their municipality, the more they tend to be willing to mitigate the consequences of floods.

Table 5: Multiple logistic regression of the variable "planned"

Model 3

Variable	**Estimate**	**Std dev.**	**Marginal effect**
Intercept	-12.64***	2.14	
Block 1: Socio-Psychological variables from the Protection Motivation Theory			
Threat appraisal	1.84***	0.59	
Coping appraisal	7.80**	3.20	
(Coping appraisal)^2	-13.70***	5.26	
Threat experience appraisal	0.18***	0.06	
Nagelkerke R^2 for this block	**0.311**		
Block 2: Socio-economic variables			
Education level	1.44***	0.42	0.17
Department (0: Aude; 1: Var)	1.37***	0.41	0.15
Municipality size	1.32***	0.44	0.15
Ownership of the home	0.82*	0.44	0.08
Nagelgerke R^2 change	**+ 0.197**		
Block 3: Social interactions			
Feeling of well-being in the municipality	0.58*	0.31	
Nagerkerke R^2 change	**+0.014**		
Nagelkerke R^2 final	**0.522**		

N=272. The marginal effects represent the partial effect for the average observation. Significance levels: * p<0.1; ** p<0.05; *** p<0.01.

Marginal effects at the means are provided only for sociodemographic variables. Indeed, since other factors are ordinal, the effect of a change of one unit of these variables on the probability to be willing to take precautionary measures does not have concrete meaning. All marginal effects of the sociodemographic variables lie between 0.08 and 0.17. Having at least a high school diploma increases the probability of considering to implement measures by 17% when all variables are at the mean, which is the greatest marginal effect. On the other hand, the smallest marginal effect is associated to ownership of the home: home owners have a probability 8% higher than the others to be willing to implement measures when all other factors are at the mean.

5 Discussion

5.1 The dynamics of adaptation and the Protection Motivation Theory

Our results suggest that the Protection Motivation Theory explains better the willingness to mitigate floods than the presence of precautionary measures implemented by the household. Two potential reasons to clarify this finding were identified.

First, as shown in Figure 1, there might be actual barriers which, according to the Protection Motivation Theory, hinder the implementation of precautionary measures. Since we did not control for these actual barriers, their effect might be included in the error terms of Model 1 and be greater for people who did not implement any precautionary measure than for the others. In that case, the key assumption of independence of error terms would be violated and the parameters' estimation distorted (Train, 2009). In contrast, Model 2 aims to describe the protection motivation, which does not depend on actual barriers according to the Protection Motivation Theory (see Figure 1).

Secondly, the perceptions and emotions which induced the decision to take precautionary measures can change over time. Thus, the collected data may not accurately depict the state of mind which led the respondents who implemented precautionary measures to take action to mitigate the consequences of floods. According to Bubeck et al. (2012), these changes can occur due to feedback effects following the implementation of a precautionary measure.

We explored this possibility by comparing the perceptions and emotions of the respondents who had already implemented precautionary measures and those of the respondents who intended to take measures at the time of the survey. Indeed, under the assumption that the Protection Motivation Theory is a generalizable framework, the same pattern of perceptions and emotions as the one observed for people who intended to implement measures should have induced the respondents who had already taken precautionary measures to do so. Nevertheless, it appears that people who adopted measures perceive that it is less likely that the water will reach their street in case of a flood, but are also less worried and have a lower threat experience appraisal on average than people who intended to take mitigation actions. This observation supports the assumption that risk perception and worry tend to decrease after the implementation of precautionary measures. As a result, it would be more relevant to ask for planned measures instead of already implemented ones in order to investigate the relationships between socio-psychological variables and private flood mitigation.

More generally, our results highlight the importance of considering the dynamic aspect of adaptation to floods. Indeed, since explanatory factors (such as threat appraisal) may change over time, particular care should be taken to distinguish between the variables which may evolve and those which are more stable (e.g., gender] while designing a survey to explore private flood mitigation and interpreting its results. Besides, if a factor affects only temporarily the willingness to implement precautionary measures, advised policies which target this factor to foster flood mitigation should be timed accordingly.

5.2 Determinants of private flood mitigation in France

Threat appraisal, experience, coping appraisal, and reliance on public flood protection

Looking more specifically at the drivers of private flood mitigation, threat appraisal

and threat experience appraisal have the expected positive effect. These results are in line with those of Grothmann and Reusswig (2006).

More surprising is the non-significance of the perceived probability of floods in the municipality when perceived probability and perceived consequences are included as separate explanatory variables in the same model (see Model 2 in Table 3). This finding suggests that the most important component of threat appraisal to trigger private mitigation is the awareness of the possibility of being affected by a flood. Similar results are presented by Poussin et al. (2014) who found no significant effect of the perceived probability. In the survey conducted by Reynaud et al. (2013) in Vietnam, the perceived probability of floods has an ambiguous effect: its relationship with floor elevation is significant and positive but it is not significant to explain the presence of a pumping set. To compare these results with ours, it is worth highlighting that the inhabitants surveyed in Vietnam faced very frequent floods (1.50 a year on average) whereas half of our sample had experienced no more than one flood at the time of the survey. Thus, the perceived probability could be taken into account by people who are used to floods in order to adjust their adaptation but is not necessarily an important factor to explain the willingness to take precautionary actions. Another assumption to explain the non-significance of the perceived probability when it is included as explanatory variable along with perceived consequences lie in the high level of correlation between these two variables.

The positive effect of experience also appears in the wider literature (e.g. Grothmann and Reusswig (2006), Osberghaus (2015)). However, our study also has the particularity of examining the situation in two areas: the Aude department, in which an over 100-year flood took place in 1999, and the Var department, which was affected by an over 100-year flood in 2010. Because of this contrasted distance to major events, we can isolate the importance of recent experience to explain intentions to implement precautionary measures. We found that living in the Var department raises the intention to implement measures, compared to living in the Aude department whereas the decision to actually implement measures, on the contrary, is not explained by the geographical variable. Thus, there seemed to be still an ongoing process of adaptation to floods 5 years after the most recent striking event in the Var department, whereas the situation appeared more stable in the Aude department, 16 years after the 100-year flood. In other words, the department variable could be a proxy for the distance to the most recent major flood in our survey and its effect on private flood mitigation might evolve over time.

The non-linearity of the two components of coping appraisal is another striking result. Indeed, the Protection Motivation Theory predicts that people with very low coping appraisal will be less likely to take mitigation actions than the others. In our sample, respondents with very low but also very high coping appraisal tend to be less willing to implement precautionary measures than the others. Two different explanations for this result can be provided. First, since perceived self-confidence has been identified as a factor that increases risk-taking (Krueger and Dickson, 1994), a person with a high coping appraisal, who by definition has a high confidence in her ability to avoid being harmed by floods, could be more likely than the others to believe that she is able to face the risk without implementing precautionary mea-

sures. Secondly, respondents with a high coping appraisal could have taken measures faster than the others since this task seems easy for them. As a result, these people could have already implemented measures at the time of our survey and thus not be willing to take additional precautionary actions. This assumption is supported by Model 1 and by the results of Grothmann and Reusswig (2006) according to which respondents with a high perceived self-efficacy were the most likely to have already implemented precautionary measures at the time of the surveys. Nevertheless, to explore further the hypothesis that coping appraisal is an accelerator rather than a necessary condition for adaptation to floods, the long term evolution of its effect on the implementation of measures should be examined to study if it decreases over time.

Finally, reliance on public flood protection has no significant effect on private flood mitigation in our sample. However, according to the Protection Motivation Theory and as supported by the results of Grothmann and Reusswig (2006), this variable should reduce the willingness to take precautionary actions. On the other hand, Reynaud et al. (2013) found a positive relationship between the confidence level in the city to efficiently manage flood risks and the presence of a pumping set in the household. Similarly, Poussin et al. (2014) found a positive effect of the feeling of being protected by public measures on the number of structural measures implemented. Thus, the relationship between reliance on public flood protection and private mitigation is still unclear and needs to be further investigated.

Social interactions

The well-being in the municipality has a positive and significant effect on the willingness to implement precautionary measures. This could suggest that good local social interactions foster private flood mitigation. Such relations have been described by Kunreuther et al. (1985) in a theoretical framework. Moreover, Carson et al. (2013) show that mitigation in the neighborhood has a positive impact on individuals' own flood mitigation decisions. Nevertheless, the effect of social interactions on private flood mitigation needs to be investigated more in depth since the variable used in this study, the well-being in the municipality, could be related to many other elements rather than good local social interactions, such as amenities or the natural environment. Besides, Reynaud et al. (2013) extend the idea that social interactions can encourage flood mitigation by considering social networks as fully-fledged precautionary measures because they can provide informal insurance against floods. However, it is unlikely that social interactions play such a role in France since people in this country already take part in a compulsory national compensation system.

Sociodemographic variables: education level, department, municipality size, and ownership of the home

The respondents who have at least a high school diploma, those who live in the Var department or in municipality of more than 10,000 inhabitants, and home owners have a higher probability of considering to implement precautionary measures. The

positive effect of the education level has been found in other studies (Poussin et al., 2014, Reynaud et al., 2013). Moreover, as discussed above, the department variable could be a proxy of the temporal distance to the most recent major event. As for the effect of the municipality size, it could be explained by the fact that the need for private protection is greater in big than in smaller cities. Indeed, 85% of the respondents who live in municipalities of less than 10,000 inhabitants have at least one measure in their household whereas that proportion drops to 71% in the municipalities of more than 10,000 inhabitants. Finally, the positive effect of ownership of the home is in line with the results found by Grothmann and Reusswig (2006) and Poussin et al. (2014).

Other potential determinants: risk aversion, revenue, and solidarity schemes

One common hypothesis in the economic literature on mitigation is that higher levels of risk aversion lead to higher likelihoods of mitigation and to more extensive mitigation investments. Carson et al. (2013) found evidence that supports this hypothesis in a study on 173,000 individuals participating in a public program on mitigation measures in Florida. Building on the domain-specific risk-attitude approach of Weber et al. (2002), we collected data from which we constructed an indicator of risk aversion with respect to flood risks. However, too few respondents answered this question and we preferred not to reduce our sample size.

A similar problem arose with the data on income: only half of our sample indicated their revenue so we decided not to include this variable in our analyses. However, the impact of income (or wealth) on risk aversion is largely discussed in the literature (see for example Brunnermeier and Nagel (2008), Cohn et al. (1975)). Moreover, income might also directly influence mitigation decisions as mitigation investments can be costly. For instance, in our survey, among the respondents who had implemented no measure and did not intend to do so (63 people out of 331), 24% explained this decision by the fact that precautionary measures are too costly. Similarly, Carlson et al. (2014) found in a qualitative survey conducted in the United States that the most often cited constraints to explain the difficulty of adapting storm water management to climate change were economic concerns. Nevertheless, empirical evidence on the income effect is mixed, as discussed by Carson et al. (2013).

Finally, private precautionary measures can also be seen as self-insurances (Carson et al. 2013). As a result, they can be substitutes to market insurances or governmental relief programs, in which case the latter might crowd out the former as has been shown in several countries (Raschky et al., 2013). In other words, individuals would refrain from investing in self-insurances and rather count on market insurances or public support. Because there is a compulsory insurance system for home owners in France (Erdlenbruch et al., 2009, Grislain-Letrémy and Peinturier, 2010), we could not thoroughly investigate the relationship between self-insurances and market insurances. However, over two thirds of the considered sample dispose of at least one precautionary measure and nearly half of the respondents implemented themselves at least one measure in their home. This means that the public solidarity scheme does not completely crowd out individual measures. This is in line with findings by

Carson et al. (2013) and Osberghaus (2015) , who did not find any substitutability between individual mitigation and market insurance.

6 Conclusion

The main findings of our study are summarized in Figure 3. In particular, our results suggest that the Protection Motivation Theory is a relevant framework to explain private flood mitigation in France if feedback effects from past investments are taken into account. Considering these feedback effects could improve the assessment of the determinants of household's flood mitigation and thus guide the design of policies aimed at fostering these private actions. For instance, it could be efficient to help people who intend to take measures shortly after major floods, when risk perceptions are still high, and then try to maintain flood awareness and preparedness.

To design policies to support those who intend to take precautionary measures, additional issues that are not addressed in our study could be examined. In particular, we did not take into account potential actual barriers. However, according to the Protection Motivation Theory, they explain the difference between intentions and decisions to mitigate. Actual barriers could consist in high costs for investing in mitigation measures or high information costs to know what behaviour should best be adopted. Findings from Poussin et al. (2014) support the assumption that a lack of financial resources could hinder private mitigation. They indeed suggest that incentives from the state or municipalities have a positive impact on the intentions to mitigate in France.[5] Moreover, even if the state does not provide financial aid, it could give information on the cost-effectiveness of mitigation investments for different hazard zones (see Kreibich et al. (2011) for data in Germany). As a result, policies aimed at increasing self-insurance should probably work toward removing actual barriers for those individuals who are motivated to invest. Our study can help to identify this group. Subsequent research might investigate more in depth the nature of actual barriers, which would facilitate the design of public support for individual precautionary measures.

Finally, one interesting question is whether adjusting the public CatNat insurance system might lead to increased individual mitigation investments. This implies to measure the elasticity of substitution of the two insurance tools in order to investigate how much more investment in precautionary measures could be triggered by a reduction in the CatNat premium (see Botzen et al. (2009) and Wouter Botzen and Van Den Bergh (2012)). To extend this idea, it is worth highlighting that some private precautionary measures can even improve the situation of larger communities in the face of natural hazards, as discussed by Carlson et al. (2014) in the context of storm water management. Thus, it could be useful to identify such measures in the context of floods and foster their implementation in order to increase the efficiency of private mitigation compared to public protection, which can be harmful to the environment.

[5] We asked the respondents to indicate whether they have been subsidized or not but only very few of our respondents (4 people in the whole sample) got public support for their investments. As a result, we could not investigate this issue.

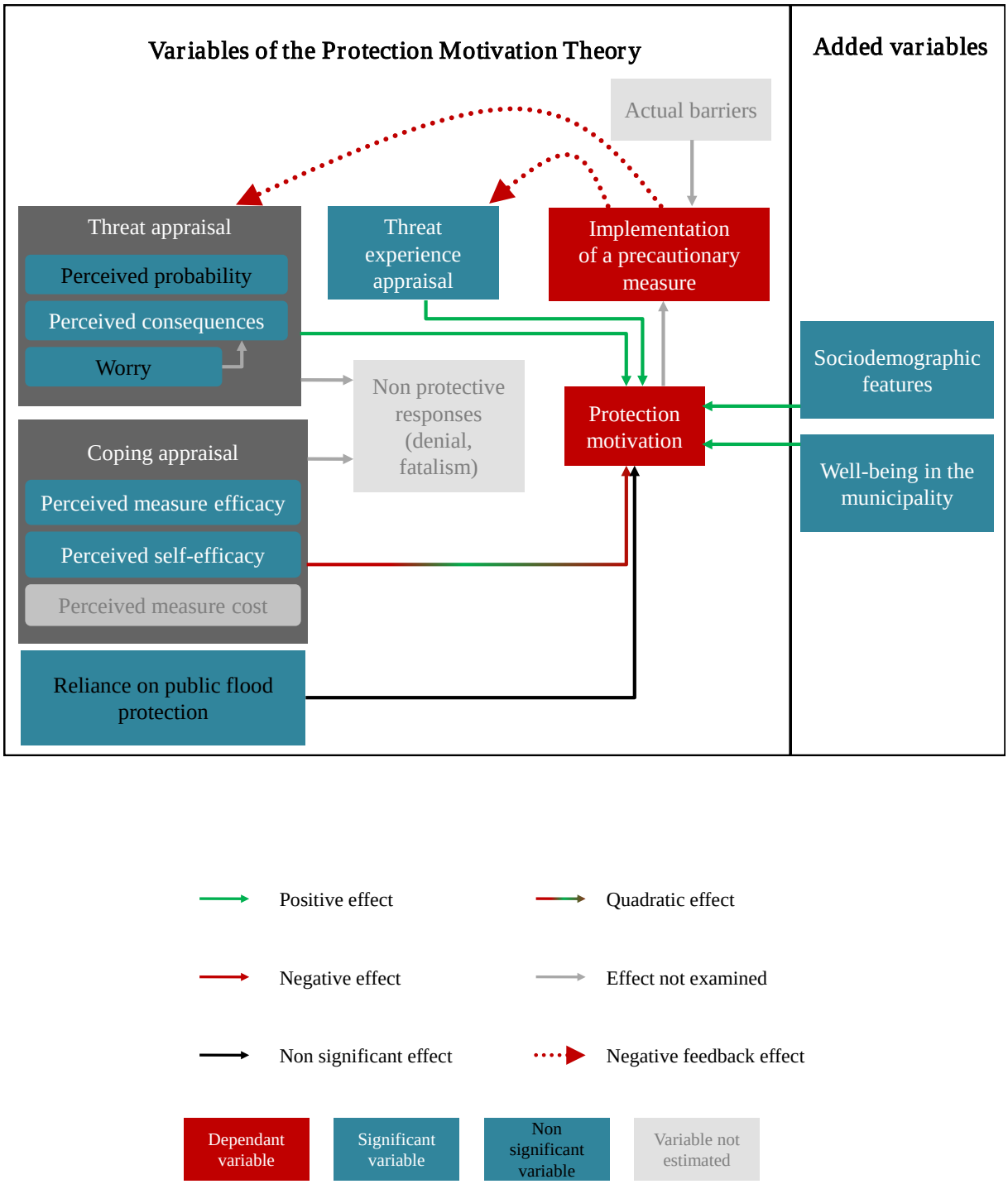

Figure 3: Summary of the factors of private flood mitigation highlighted in the analyses.

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Appendices

A Precautionary measures

Structural measures	Non structural measures
Raised ground floor, raised crawl space	Watertight doors and windows
Opening on the roof to facilitate evacuation	Sewer non-return valves
Use of water resistant materials (for the floor and/or the walls)	Slot-in flood barrier(s)
Electrical wiring and systems and/or boiler installed higher up in the walls	Pump(s)
	All main rooms (kitchen, bedrooms, living-room) installed upstairs
	Measures to improve water flow
	Valuables stored upstairs

B Correlations

Table 6: Spearman correlations between the variables

	1	2	3	4	5	6	7	8	9	10	11	12
1: Perceived probability	1	0.46***	0.42***	-0.05	0.01	0.27***	-0.28***	-0.19***	0.02	-0.16**	0.13**	0.01
2: Perceived consequences		1	0.40***	-0.01	0.15**	0.45***	-0.17***	0.02	0,12*	0.06	0.21***	0.11*
3: Worry			1.00	-0.07	0.19***	0.44***	-0,37***	-0.11*	-0.05	-0.06	0.38***	0.09
4: Perceived self-efficacy				1	-0.01	0.08	0.06	-0.01	-0.09	0.14**	0.07	-0.03
5: Perceived measure efficacy					1	0.08	0.08	0.10*	-0.05	0.22***	0.19***	-0.03
6: Threat experience appraisal						1	-0.25***	0.02	-0.01	0.11*	0.06	0.06
7: Reliance on public flood protection							1	0.32***	0.12*	0.13**	-0.18***	-0.04
8: Well-being in the municipality								1	0.14**	0.28***	-0.24***	0.14**
9: Education level									1	0.21***	0.01	0.11*
10: Department of residence										1	-0.05	0.09
11: Size of the municipality of residence											1	-0.15**
12: Homeownership												1,00

N=272. Significance levels: * p<0.1; ** p<0.05; *** p<0.01