2. CHAPTER 2: IMPACTS OF FLOODING AND FLOOD PREPAREDNESS ON SUBJECTIVE WELL-BEING: A MONETISATION OF THE TANGIBLE AND INTANGIBLE IMPACTS[1]

Abstract

Flood disasters severely impact human subjective well-being (SWB). Nevertheless, few studies have examined the influence of flood events on individual well-being and how such impacts may be limited by flood protection measures. This study estimates the long term impacts on individual subjective well-being of flood experiences, individual subjective flood risk perceptions, and household flood preparedness decisions. These effects are monetised and placed in context through a comparison with impacts of other adverse events on well-being. Data from households in flood-prone areas in France is collected. The results indicate that experiencing a flood has a large negative impact on subjective well-being that is incompletely attenuated over time. Moreover, individuals do not need to be directly affected by floods to suffer SWB losses since subjective well-being is lower for those who expect their flood risk to increase or who have seen a neighbour being flooded. Floodplain inhabitants who prepared for flooding by elevating their home have a higher subjective well-being. A monetisation of the aforementioned well-being impacts shows that a flood requires €150,000 in immediate compensation to attenuate SWB losses. The decomposition of the monetised impacts of flood experience into tangible losses and intangible effects on SWB shows that intangible effects are about twice as large as the tangible direct monetary flood losses. Investments in flood protection infrastructure may be under funded if the intangible SWB benefits of flood protection are not taken into account.

[1] This chapter is based on: Hudson, P., Botzen, W.J.W., Poussin, J.K., Aerts, J.C.J.H., 2017. The impacts of flooding and flood preparedness on happiness: A monetisation of the tangible and intangible subjective well-being impacts. *Journal of Happiness Studies, forthcoming, DOI :10.1007/s10902-017-9916-4*

2.1 Introduction

Natural hazards can have large societal impacts. As an illustration, it is estimated that natural hazards caused 7,700 fatalities and $110 billion losses worldwide in 2014 (Munich Re, 2015). Out of the set of natural hazards, flooding is often regarded as having the greatest effect on humanity (UNISDR, 2011). Flood losses are expected to increase in frequency and severity in the future due to a combination of socio-economic development and climate change (IPCC, 2012). It has been argued that in order to optimally manage changing risk, good estimates of flood risks are required, which is often measured as direct property losses, an important input for cost-benefit analysis that guide investments in flood risk management strategies (Mechler, 2016). However, a comprehensive societal cost-benefit analysis should also include intangible losses caused by floods, e.g., psychological damage or anxiety (Lamond et al., 2015) to gain a complete view of welfare. Intangible losses are often neglected in risk assessments, perhaps due to the perceived difficulty of converting intangible losses into monetary values (Prettenthaler et al., 2015), while a range of methods have been developed for assessing tangible flood losses, like property losses (Mochizuki et al., 2014).

Researchers can directly investigate welfare by asking individuals about their happiness also referred to as subjective well-being, henceforth SWB (MacKerron, 2011). SWB scales can be an accurate proxy of the individual's level of overall SWB and can, for example, be applied to valuing negative environmental impacts (e.g., Dietz and Maddison, 2009). Relatively few studies have examined the connection between the impacts of natural hazards, such as flooding, and SWB. An exception is Luechinger and Raschky (2009), who investigate the consequences of droughts and floods, respectively, on SWB and find significant SWB losses.

Our objective is to estimate the long term SWB impacts of experiencing a flood, and how these impacts can be offset by adequate flood preparedness by households exposed to flooding. Data is collected by a survey of about 900 flood-prone households in France. This chapter estimates relations between flood experience, flood risk perceptions and flood preparedness with overall SWB. The results are then monetised to separate tangible and intangible losses, providing a novel contribution to the scarce literature on this topic. Monetisation of well-being impacts is the process of transforming non-monetary impacts of an experience, such as a flood, on SWB into an equivalent monetary value. That way SWB impacts are translated into a readily understood and comparable metric, like money. The monetisation process is conducted by measuring the ratio of the effect of an event on SWB to that of how SWB is related to an income increase. This ratio indicates the change in income required to compensate (equate) for SWB changes caused by experiencing the negative (positive) event. Once a monetary value has been associated to a SWB impact, it is decomposed into parts that correspond to tangible and intangible impacts. Tangible impacts are those with a pre-existing monetary value, such as flood damage suffered or damage prevented from flood preparedness measures. Intangible impacts are the remaining impacts without pre-existing monetary values, such as discomfort and psychological impacts from flooding.

This chapter's results show that the impacts of a flood are negatively correlated with SWB with lasting impacts. Moreover, floods reduce an individual's SWB, even if the individual was not affected themselves. Similarly, worries about future flood risk are correlated with lower SWB. The monetisation process indicates that the total SWB effects are associated with values ranging from €48,000 to €150,000. Decomposing these values into tangible and intangible impacts on SWB indicates that the immediate intangible effects of a flood event on SWB may be twice as large as the direct tangible costs. This suggests that focusing only on the direct tangible impacts of flood events underestimates the total impact on society in terms of SWB losses. Therefore, policy makers invest in socially sub-optimal levels of flood protection when SWB benefits of preventing floods are excluded from risk management decision processes.

2.2 Data and methodology

2.2.1 Survey and data description

A mail survey was conducted in France in 2011 to collect data from a random sample of households in 3 regions (the Var, West, and the Ardennes). These regions are at risk of flooding and differ with respect to: past experiences with floods; the type of floods; the time passed since the last flood; the probabilities of flooding; flood related losses; and the local 'flood cultures'. The sampled areas have been flooded in the past, while not all respondents have been. A mail survey was selected because it is a cost-effective method to obtain a relatively large and geographically spread sample. Furthermore, a mail survey is particularly suitable for answering questions that must be measured via scales (e.g., questions about SWB). The questionnaire has been carefully pretested with 200 respondents. Moreover, in order to increase the response rate, local flood management organizations that operate in the sample areas were involved as well as the employment a professional survey company, IPSOS, to conduct the survey.

The survey response rate was 10.5%, which resulted in 885 returned questionnaires, which is in line with other surveys (e.g., Joseph et al., 2015) regarding flood related topics. A comparison between official statistics of the sampled population and statistics of characteristics of this chapter's respondents shows that the sample is approximately representative with respect to gender and education levels, although very low and very high education levels are slightly under-represented. The sample has a slight over-representation of homeowners and high income households. Moreover, low-age groups are slightly under-represented and high-age groups are slightly over-represented (Poussin et al., 2014).

A selection bias originating from individuals responding to the survey is unlikely, because the resulting sample does not deviate much from what would be roughly representative of the French population as a whole. The results of this chapter's study are not readily generalizable to households outside of flood-prone areas, but research about impacts of floods on SWB is not as relevant for such households who do not face flood risk. Even though the total sample is representative, this may not be the case for the final set of observations used for this chapter's analysis due to missing observations for specific variables. This is why it is checked whether the final dataset used for this chapter's analysis is similar to the total dataset, which turned out to be the case. Details regarding the survey can be found in Poussin et al. (2014). The key variables used in this chapter's analysis are described in Table 2.1 and descriptive statistics that are relevant for this particular application are provided in Table 2.2.

They survey itself was split into 4 sections. The first section focused on (various aspects of) SWB. The second section obtained information on the respondents' risk perception, risk attitude, and worry over floods. The third section focused on the flood experience of the respondents. The fourth section investigated how prepared the respondent was for flood events. The final section investigated the socio-economic characteristics of the respondent. Where possible, questions have closed-ended answers instead of open-ended ones, because open-ended questions can be more easily misunderstood and inadequately replied to.

Following van Praag and Ferrer-i-Carbonell (2008) the survey questions regarding (aspects of) overall SWB were closed-ended on an 11 point scale). The literature regarding SWB argues that overall SWB can be decomposed into several subjective well-being domains, henceforth SWBDs (van Praag et al., 2003). For this reason, the survey asked several questions regarding various important SWBDs, such as family life or living environment. For this chapter's analysis, the SWBDs were converted into dummy variables by setting a SWBD score of greater than 5 with the value 1 and 0 otherwise. An example of the questions asked is provided in Section 9.1.1. Overall, there is a high degree of satisfaction across both SWB and the SWBDs.

Many of the respondents experienced flooding. About 70% of the sample has been flooded in their current home before and many respondents (41%) had experienced a flood within the previous 12

months of being surveyed. Moreover, just over half of the sample has been in a near miss situation in which the community surrounding their current home was flooded, but the respondent was not. For the purposes of this evaluation it is not required that all the individuals experienced the same flood, because the interest is in examining how SWB is related with flood experiences that occurred at different times in the past. For example, recent floods may have a larger impact on current SWB than floods that occurred a long time ago. In this respect, the large number of individuals that have been flooded within 12 months of the survey allows for detecting the more immediate impact of flood events on SWB. According to the availability heuristic, the more recent the flood event, the more focused it is in the minds of the respondents (Tversky and Kahneman, 1973).This variable may also relate to the frequency of flooding since people who are frequently flooded are more likely to have been flooded in the recent past.

Table 2.1 List of variable definitions

Variable name	Definition
Panel A: Subjective well-being (domains)	
Overall SWB	A categorical variable on a scale of 0-10 describing the respondent's degree of overall SWB.
SWB with health	A dummy variable taking the value 1 if a respondent is satisfied with their health and0 otherwise.
SWB with home	A dummy variable taking the value 1 if a respondent is satisfied with their home and 0 otherwise.
SWB with living environment	A dummy variable taking the value 1 if a respondent is satisfied with their general living environment and 0 otherwise.
SWB with financial situation	A dummy variable taking the value 1 if a respondent is satisfied with their general financial situation and 0 otherwise.
SWB with the amount and use of their free time	A dummy variable taking the value 1 if a respondent is satisfied with their free time and 0 otherwise.
SWB with family life	A dummy variable taking the value 1 if a respondent is satisfied with their family life and 0 otherwise.
SWB with social life	A dummy variable taking the value 1 if a respondent is satisfied with their social and 0 otherwise.
Panel B: Flood risk perceptions	
Worries about current and/or future flood probabilities	A dummy variable taking the value 1 if a respondent is worried over their flood probabilities and 0 otherwise.
Expects high damage if flooded	A dummy variable taking the value 1 if a respondent thinks that it is likely high damage will be suffered during a flood and 0 otherwise.
Expects future flood risk to increase	A dummy variable taking the value 1 if a respondent believes it is likely that their person flood risk will increase and 0 otherwise.
Panel C: Flood experiences	
Flooded before	A dummy variable taking the value 1 if a respondent has been flooded in the past either in their current or previous home and0 otherwise.
Flooded within the last year	A dummy variable taking the value 1 if a respondent has been flooded in the past either in their current or previous home within the 12 months previous to completing the survey and 0 otherwise.
Neighbour has been flooded when respondent was not	A dummy variable taking the value 1 if a respondent has had a neighbour flooded while themselves were not and 0 otherwise.
Panel D: Individual flood protection measures	
Has undertaken dry flood-proofing	A dummy variable taking the value 1 if a respondent owns sandbags or other Dry flood-proofing or anti-backflow valves are installed on pipes to stop flood-waters from entering the home through the pipes and 0 otherwise.
Has elevated their building	A dummy variable taking the value 1 if the level of the ground floor is elevated above the most likely flood level and 0 otherwise.

Wet flood-proofing	A dummy variable taking the value 1 if the foundations/ materials have been strengthened to resist water and 0 otherwise.

Table 2.2 Summary of descriptive statistics of key variables

Variable name	Average value	Standard deviation	Range
Panel A: Subjective well-being (domains)			
Overall SWB	7.32	1.79	{0,1,2,3,4,5,6,7,8,9,10}
Happy with health	0.79	0.41	{0,1}
Happy with home	0.85	0.36	{0,1}
Happy with living environment	0.81	0.39	{0,1}
Happy with financial situation	0.68	0.47	{0,1 }
Happy with the amount and use of their free time	0.67	0.47	{0,1}
Happy with family life	0.89	0.32	{0,1}
Happy with social life	0.83	0.38	{0,1}
Panel B: Flood risk perceptions			
Worries about current and/or future flood probabilities	0.60	0.49	{0,1}
Expects high damage if flooded	0.43	0.50	{0,1}
Expects future flood risk to increase	0.45	0.50	{0,1}
Panel C: Flood experiences			
Flooded before	0.71	0.46	{0,1}
Flooded within the last year	0.41	0.49	{0,1}
Neighbour has been flooded when respondent was not	0.56	0.5	{0,1}
Panel D: Individual flood protection measures			
Has undertaken dry flood-proofing.	0.12	0.33	{0,1}
Has elevated their building	0.47	0.50	{0,1}
Wet flood-proofing	0.20	0.50	{0,1}
Number of observations	422		

There is a heterogeneity in answers to the subjective flood risk perception questions, which provides a basis for examining its influence on SWB. The question asked a respondent to rate their belief that damage will be high during a future flood on a 5-point scale that ranges from very likely to not very likely. A similar question asked to rate a respondent's belief that flood risk will increase or not. Answers to these questions were converted into dummy variables in which the answer options very likely and likely were coded with the value 1 and other answers were coded as 0. After this conversion, the proportion of respondents that believe that their flood risk will increase or that they will suffer a high degree of damage in the case of a flood event is approximately 40%. The proportion of people who worry about the current and (or) future flood probability is 60%. Thus, many respondents believe that they will face a worsening problem with flooding, which is in line with several studies that estimate future flood risk in France (Dumas et al., 2013).

Several studies have found that household-level flood preparedness measures are effective at reducing the damage suffered during a flood (e.g., Poussin et al., 2015). This chapter investigates the relation with SWB and implementing the following measures: elevation, whereby households have elevated their building's ground floor above the likely flood water height; dry flood-proofing measures, whereby households employ small scale measures aimed at preventing water from entering the building; wet flood-proofing measures, whereby households employ measures aimed at limiting damage once water has entered a building, for example by using water-resistant construction materials for foundations or flooring.

2.2.2 Methodology

A summary of this chapter's overall methodology is visualized in Figure 2.1. The statistical analysis which is used the estimate the influence of flood experience, flood risk perceptions, and flood preparedness on SWB is explained in detail in Section 2.2.2.1 and the monetisation of these relations is explained in Section 2.2.2.2.

2.2.2.1 Regression models

The literature offers two interpretations of SWB values: ordinal vales, which means that no importance is placed on the number itself, but rather on the position of the number in the scale (Ferrer-i-Carbonell, 2005); cardinal values, which means the number itself matters and the scores can be counted (van Praag et al., 2003). Both interpretations can deliver equally robust results (e.g., Frey et al., 2009). This chapter employs regressions consistent with the cardinal interpretation in order produce regression coefficients that are intuitive to interpret[2].

The framework that assumes that overall SWB can be decomposed into several SWBDs results in eq. (2.1), with possible interactions between the SWBDs (van Praag et al., 2003). To examine the possibility of interactions between the SWBDs, a mediation style analysis is conducted. Mediation occurs when an independent variable has an effect on the outcome variable directly and indirectly through another independent variable (Hayes, 2013). For instance, a flood can affect the SWB directly or indirectly through the SWBD variables. A mediation analysis can be conducted via regression analysis and intervening relationships modelled with covariates (Hayes, 2013). This chapter applies a mediation analysis, which estimates a set of regression models simultaneously via seemingly unrelated regressions. Seemingly unrelated regressions are used in order to model the set of equations with correlated error terms. Accounting for this correlation is relevant since a shock in a single SWBD may be transferred to other SWBDs, because each observation of the SWBD variables is from the same individual.

This is show in eq. (2.1), whereby, ϵ_i is the random error and $FR(.)$ represents the flood risk SWBD that is of particular interest. The parameters to be estimated are β_j, while $\boldsymbol{\gamma}$ is a vector of parameters;$\overline{\gamma_{0,J}}$ and $\overline{\gamma_J}$ are parameters for the j[th] $SWBD_{i,j}$ for individual i and ε_j is the individual SWBD error term, which can be correlated:

$$eq\begin{cases} SWB_i = \beta_0 + \sum_1^7 \beta_j SWBD_{i,j} + FR(Experience_i, Perceptions_i, Flood\ preparedness_i)\boldsymbol{\gamma} + \epsilon_i \\ SWBD_{i,1} = \overline{\gamma_{0,1}} + FR(Experience_i, Perceptions_i, Flood\ preparedness_i)\overline{\gamma_1} + \varepsilon_1 \\ \vdots \\ SWBD_{i,7} = \overline{\gamma_{0,7}} + FR(Experience_i, Perceptions_i, Flood\ preparedness_i)\overline{\gamma_7} + \varepsilon_7 \end{cases} \quad (2.1)$$

In eq. (2.1) FR(.) consists of three elements: previous flood experiences; subjective perceptions of current and future flood risk; household-level flood risk management strategies. These variables are included in this SWBD for three reasons. First, flood events are negative events in an individual's life. Second, the flood risk perception and worry variables are likely to have an effect on SWB because flooding is an endemic risk in the sampled areas. Subjective beliefs regarding the probability and magnitude of flood events are likely to reduce the degree of life satisfaction. Third, the flood preparedness decision variables are included because better preparation for a flood may make an individual less unhappy with living in a flood-prone area, since the risk of living there is lower.

The first element of eq. (2.1) replicates a standard linear regression; however, the standard errors may be different due to an altered structure of the covariance-variance matrix to account for cross-correlations. Mediation analysis via seemingly unrelated regressions allows for calculating the direct effect of FR (.) on SWB and indirect effects through the SWBDs following eq. (2.2). The experience element of FR (.) is used as an example, but it should be realized that the formula is similar for the other elements. In eq. (2.2) $\gamma^{Experience}$ represents the direct effect of the variable on SWB, while

[2] Ordered logit models that are consistent with the ordinal interpretation were also estimated, which provided similar results.

$\sum_1^7 \beta_j \overline{\gamma_1^{Experience}}$ is the total indirect effect of the flood risk SWBD as it acts through the different other SWBDs.

$$Total\ effect_{Experience} = \boldsymbol{\gamma^{Experience}} + \sum_1^7 \beta_j \overline{\gamma_1^{Experience}} \qquad (2.2)$$

2.2.2.2 Monetisation of SWB impacts

Monetisation of the effects of FR (.) on SWB is based on the trade-off between income and SWB. The resulting value is called the compensating value (CV). CVs are calculated via the ratio of the marginal effect of the variable of interest to the marginal effect of income on SWB. This results in the amount of money that equates SWB before and after an event (Clark and Oswald, 2002). For instance, the CV of the effect of flood experience on SWB estimates the amount of money someone would need as compensation for this experience to arrive at the same SWB level before the flood happened.

It would be preferable to generate a relationship between income and SWB from this chapter's own dataset. However, the model already includes the financial SWBD, which means that it is inappropriate to include an income variable[3]. An alternative approach is to model the impact of income on SWB through the indirect effect that income has on the financial SWBD using a mediation analysis. The survey elicited household income via categorical income classes. This variable can be converted to a continuous variable by assuming that each observation takes the value equal to the mid-point value in the income class boundaries[4]. The logarithm of income is used, which results in a semi-elasticity of 0.22 with a standard error of 0.23, suggesting a highly uncertain value for monetisation. To overcome this limitation this chapter employs a meta-analysis, which is a commonly applied method for value transfer (Wilson and Hoehn, 2006). The meta-analysis (described in Section 9.1.2), estimates a value of 0.21, which is very close to this chapter's within sample estimate of 0.22. The meta-analysis value will be used for this chapter's final monetisation[5].

The CV is calculated following eq. (2.3) where the term '$Variable_x$' stands for the explanatory variable of which its effect on SWB will be monetised, which has the regression coefficient β_x. The regression coefficient for the relationship between income and overall SWB is β_{income}. Eq. (2.3) takes its form due to the use of the logarithm of income resulting in a semi-elasticity value[6]. In effect, it estimates the percentage change in income required to compensate for negative life events.

$$CV = -\frac{\beta_x}{\beta_{income}}\ Income \qquad (2.3)$$

A 90% confidence interval of CV is constructed that takes the uncertainty into account regarding both the correlation between income and overall SWB as well as between the flood risk SWBD components and overall SWB.

The monetary value of an intangible effect, such as experiencing a flood or flood preparedness, is estimated following eq. (2.4). The value of intangible impacts is estimated by subtracting the tangible impacts from the monetised value of SWB impacts. For estimating the intangible impacts of flood experience or flood risk perceptions the experienced flood damage is used as tangible flood impact in eq. (2.4), while flood damage avoided is used to estimate intangible impacts of flood preparedness. For instance in the latter case, the intangible benefits of flood preparedness are estimated by subtracting the tangible benefits of prevented flood damage from the total monetised SWB benefits of flood preparedness. The average tangible impacts from Poussin et al. (2015) are used, who have estimated these already for this chapter's sample. As an illustration, suppose that the CV of the total SWB impact for being affected by a flood is equal to €100, while the tangible damage suffered during a flood was €25, then the intangible loss would be estimated as €75.

[3] Other control variables may suffer from similar problems due to the SWBDs acting aggregation sources of SWB.

[4] A drawback of this approach is that, the results are quite sensitive to how the income categories are converted into continuous values.

[5] In the final models income is excluded due to the unclear influence when included in the model that already includes the financial SWBD, and the methodological assumption that its overall impact will have been controlled for by this SWBD.

[6] As eq. (2.4) can also be written as $\frac{\partial \ln(income)}{\partial SWB_x}$, this is approximately equal to the percentage change in income given a one unit change in *x*.

$$Intangible\ Impact = |CV| - Tangibl\ e\ Flood\ Impact,$$

$$\text{T}angible\ Flood\ Impact = \begin{cases} Experiencedflood\ damage \\ Flood\ damage\ avoided \end{cases} \quad (2.4)$$

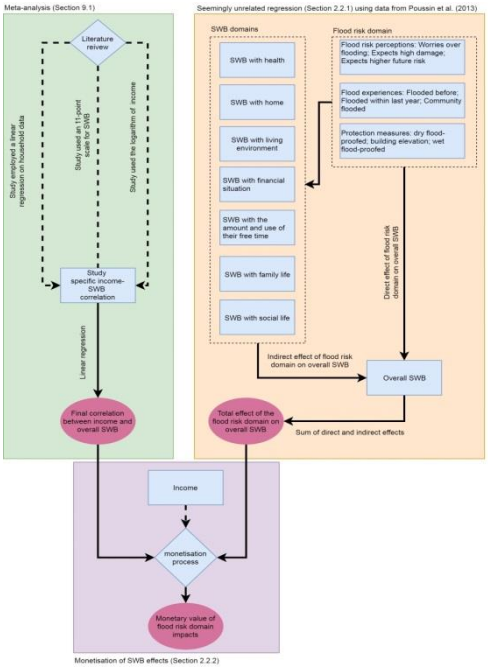

Figure 2.1 Visualization of this chapter's methodology

Notes. Dashed lines represent data flows. Solid lines represent modelling flows. Pink ovals represent objectives. Blue rectangles represent data input variables. A blue diamond represents data input processes.

2.3 Results and discussion

2.3.1 Results and discussion

Table 2.3 displays the results of the main statistical models. The direct effects model in Table 2.3 explains ~48% of the variation in overall SWB, which is mainly due to the SWBDs. The overall fit is quite good since MacKerron (2011) finds that empirical studies of SWB normally explain far less than 50% of the variation in SWB through observed variables, such as socio-economic factors. This chapter's results suggest that using the SWBDs as independent variables may be a suitable methodological choice in future studies. This is because when investigating the overall structure of SWB the various SWBDs capture a fair amount of the variance in overall SWBD as compared to the traditional socio-economic or psychological variables used in such studies.

The estimated SWBD parameters indicate that being happy with their financial situation, health or family are the most powerful explanatory variables to determine overall SWB and are of roughly equal strength. These particular SWBDs are correlated with an increase in overall SWB by about 0.8 (with standard errors of around 0.3 and statistical significance at the 1% level), though satisfaction with their family is the strongest. The variables 'satisfaction with the living environment' or 'social life' are the next most powerful SWBDs, with a positive correlation of 0.6 and 0.5 of a SWB level (both highly significant at the 5% level). The SWBDs act in the expected manner since satisfaction with a single area of life results in a higher overall level of SWB.

The estimated coefficients of the respondents' memory of flood experiences display the expected signs. The effect of the memory of being flooded and being flooded within the last 12 months are each correlated with a fall in overall SWB. The sum of total effects for these two variables is nearly 1.3 (jointly statistically significant at the 5% level). These overall SWB impacts imply a compensation

equivalent to €150,000 for the mean household income or €130,000 for median household income (statistically significant at the 5% level) as shown in Table 2.4. The majority of this impact is driven by the immediate impacts of a flood because after a year the SWB impact is just under half (at €61,000 and only marginally significant at the 10% statistical level). The indirect effects are negative across all the SWBDs; although small in size they have a large combined effect.

Living in a flooded community also reduces the SWB of a respondent even when they themselves have not been flooded. The (direct and total) effect is smaller than when an individual is flooded themselves, perhaps because of the relief from being spared tangible damage.

Out of the set of risk perception variables there are two variables with negative statistically significant total effects, at least the 5% level: worrying about flooding and expecting flood risk to increase. The worry variable is mainly driven by indirect effects since the direct effect was statistically insignificant. The belief that future flood risk will increase has a stronger effect than worrying about flooding because both the direct and indirect effects are statistically significant. Overall, these subjective perceptions may place a larger downward pressure on SWB as compared to flood experiences when they are not attenuated over time.

Table 2.3 Estimated parameters of the regression models

	Direct Effect	Indirect Effect	Total Effect
Constant	4.50*** (0.44)		
Happy with health	0.77*** (0.24)		
Happy with home	0.76*** (0.27)		
Happy with living environment	0.59*** (0.22)		
Happy with financial situation	0.73*** (0.18)		
Happy with the amount and use of their free time	0.25 (0.17)		
Happy with family life	0.85*** (0.30)		
Happy with social life	0.53** (0.26)		
Worries about current and/or future flood probabilities	-0.15 (0.16)	-0.34** (-0.14)	-0.49** (0.19)
Expects high damage if flooded	-0.16 (0.16)	0.01 (0.14)	-0.16 (0.21)
Expects future flood risk to increase	-0.26* (0.13)	-0.40*** (0.12)	-0.66*** (0.17)
Flooded before	-0.51** (0.23)	-0.01 (0.21)	-0.51* (0.31)
Flooded within the last year	-0.48** (0.23)	-0.27 (0.20)	-0.74** (0.31)
Neighbour has been flooded when respondent was not	-0.26** (0.13)	-0.14 (0.11)	-0.40** (0.17)
Has elevated their building	0.2 (0.13)	0.13 (0.12)	0.33* (0.17)
Has undertaken dry flood-proofing	0.44** (0.22)	-0.08 (0.16)	0.36 (0.25)
There is a household plan on how to cope with a flood	0.26 (0.20)	-0.10 (0.16)	0.15 (0.26)
Wet flood-proofing	-0.018	0.173	0.155

	(0.170)	(0.131)	(0.224)
N	422		
R^2	0.477		

Notes: Values within parentheses are standard errors, which are heteroscedasticity corrected. *, **, *** stand for statistical significance at the 10%, 5% and 1% level respectively.

The self-protection measure that is robustly correlated with overall SWB is elevation, which is associated with an increase in overall SWB of a third of a SWB level worth about €39,000. This is a plausible effect because by elevating their ground floor the household has a greater sense of security and protection from flooding. This is confirmed by the total indirect effects, which are positive across the SWBDs and the total effect is statistically significant. The dry and wet flood-proofing measures did not have a robust impact on SWB, even though they may reduce tangible losses indirectly. Dry and wet flood-proofing lack statistically significant impacts as these measures may not offer the same feeling of security and protection from disasters as elevation.

The estimated CVs of floods in Table 2.4 are next decomposed into intangible and tangible effects of floods on well-being. The observed reduction in SWB due to a neighbour being flooded or a perception of increasing flood risk can be considered fully intangible impacts, because neither variable implies a direct costs for the respondent in question. The average damage to household contents and buildings suffered during the most recent flood event by the survey respondents is estimated to be approximately €50,000. Tangible losses of €50,000 result in an estimate of the intangible losses suffered at the time of a flood at the equivalent of €100,000, which is nearly twice as large as the tangible losses.

From the flood preparedness variables, wet flood-proofing did not display significant correlations with overall SWB. Nevertheless, Poussin et al. (2015) estimated that wet flood-proofing may be cost-effective. One reason why cost-effective damage mitigation measures can be uncorrelated with changes in overall SWB is that although they may limit damage, water still enters the building during floods. Poussin et al. (2015) find that dry flood-proofing did not significantly reduce flood damage, which is consistent with the insignificant impact of this measure on overall SWB in Table 2.3. Kreibich et al. (2005) find that these measures are only marginally cost-effective in Germany because they were often overtopped. In contrast, elevation was estimated to reduce flood damage by an average of €8,000 (Poussin et al., 2015), which means that intangible benefits of elevation are €31,000.

2.3.2 Comparison with existing studies

The estimated effects of this chapter's flood risk and preparedness variables on overall SWB are difficult to interpret without being placed in context. Table 2.4 provides a summary of studies that are similar in that they estimated the CV or SWB impacts of flooding or other major life events.

Luechinger and Raschky (2009) estimate a CV value for experiencing flooding in an area for people who may, or may not, have been personally flooded. This value is not directly comparable with this chapter's CV for people who were personally flooded. Luechinger and Raschky (2009) used a US sample that consists of a wider cross-section of society at a higher spatial scale, while this chapter's French sample focuses on individuals exposed to flooding, which can provide more relevant insights for flood risk management policies for the population threatened by floods. This chapter's CV values are higher, which is not surprising given these sample differences. Another basis for the comparison are the studies by Bockarjova et al. (2009) and Brouwer and Schaafsma (2013) who estimate CV values between €2,500-€120,000 for various flood impacts in the Netherlands. This chapter's estimated CV of flood experience of €130,000 is close to the estimates found by these two Dutch studies, despite differences in applied methods, kind of floods, and geographical focus. A third base for comparison are the SWB effects of other major life events than floods.

This chapter's estimated CVs displayed in Table 2.5 vary within the range of estimates found in the literature regarding major life events or problems. Furthermore, the finding that a flood will have lasting SWB impacts is consistent with other findings that individuals do not fully adapt to major life

events. For instance, Oswald and Powdthavee (2008) find an adaptation of SWB to developing disabilities, which is similar to the adaptation of SWB this chapter finds for flood impacts. Overall this chapter's results appear plausible when placed in context with other life events.

The results of this Chapter can also be placed into context with studies from outside of the natural hazard risk domain. An example of such a study is Malmenider and Nagel (2011). Malmenider and Nagel (2011) investigate how a respondent's experience of financial market returns affects their willingness to accept and take risks in the financial market. Malmendider and Nagel (2011) present an analysis that finds in particular that the most recent experiences a respondent experiences has the strongest impact on how the respondent behaves in the financial markets. Additionally, they also find that even though the influence of past experiences on current behaviour decays the further away the experience, such previous experiences can still have impacts on current behaviour (for example those who experienced the Great depression of the 1930s vs the boom years of the 1960s). This is a similar finding to what is presented in this Chapter, that the more recent a flood is the larger its impact on current SWB is. However because floods can be traumatic the past experiences still have lasting impacts for a long time as their influence on current SWB slowly decays.

Table 2.4 Characteristics and results of other studies, which examined the impacts on subjective well-being or compensating variation of floods or other major life events (in 2014 Euro values)

Study	Research objective	Sample	Method	Result
Luechinger and Raschky (2009)	Evaluate the utility impacts of flooding in monetary terms	Cross-section and time series data from 1973-1998 for Europe Cross-section and time series data for the United States from 1993-1998	Regression models of aggregated SWB	CV is 24% of average annual household income to have a 0% chance of flooding
Bockarjova et al. (2009)	To estimate the compensation required for being injured, evacuated, or die during a flood	530 respondents from areas at risk of flooding in the Netherlands (annual probability of 1 in 4000)	Choice experiments	CV is €100,000,€2,500, €7,000,000 respectively
Brouwer and Schaafsma (2013)	To estimate the willingness to accept compensation for controlled floods with an occurrence probability of 0.8%	800 households in the Netherlands across different areas of flood risk. Respondents have experienced either a flood or a near miss within 20 years of the survey.	Choice experiments	CV is €120,000
Blanchflower and Oswald (2004)	To determine the monetary value of a lasting marriage	General Social Surveys of the United States years from 1972 to 1998	A natural experiment of SWB between widows and married women	CV is €108,000
Poudthavee (2008)	To estimate the SWB effects of regularly talking with friends or family	British Household Panel Survey between 1997 and 2003	Panel data regression models of SWB	CV is €61,000
Powdthavee and van den Berg (2011)	To estimate the SWB effects of medical problems ranging from skin conditions to mental illnesses	British Household Panel Survey between 1997 and 2009 for Wales	Random effects models of SWB	CV is €4,000-€330,000
Oswald and Powdthavee (2008)	To determine the rate of adaptation of SWB to (varying degrees of) disability	British Household Panel Survey between 1997 and 2005.	Fixed effects models of SWB	30%-50% of the SWB loss is attenuated over time depending on the severity of the disability
Lucas (2007)	To estimate the degree of adaptation of SWB to major life events such as divorce or the death of a spouse.	German Socio-economic Panel Study and the British Household Panel Study	Estimated trajectories of SWB before and after major life events	There is an overall process of adaptation to major life events, although the degree to which adaptation occurs varies over events and across individuals.

Table 2.5 The estimated compensating value required to compensate for changes in subjective well-being due to flood experiences, risk perceptions, or preparedness decisions

	Expected Value	90% confidence interval lower bound	90% confidence interval upper bound
Correlation between ln(Income) and SWB	0.21	0.17	0.25
	Mean CV	90% confidence interval upper bound	90% confidence interval lower bound
Immediate aftermath of a flood			
Median income	€126,000	€23,000	€235,000
Mean income	€150,000	€27,000	€280,000
12 months after being flooded			
Median income	€51,000	€900	€104,000
Mean income	€61,000	€1073	€124,000
A neighbour was flooded, while you were not			
Median income	€40,000	€30,000	€53,000
Mean income	€48,000	€36,000	€63,000
An individual expects their flood risk to grow			
Median income	€66,000	€53,000	€81,000
Mean income	€79,000	€63,000	€97,000
Elevation			
Median income	-€33,000	-€23,000	-€45,000
Mean income	-€39,000	-€27,000	-€53,000

Notes: Positive values represent compensation for SWB losses, while negative values represent in effect SWB gains.

2.3.3 Policy implications

It must be kept in mind that this chapter's study focuses a specific sub-set of the overall French population and as such the results may not be fully transferable to other regions that are not flood-prone. Nevertheless, this chapter's focus on the average inhabitant of flood-prone areas produces results about the SWB impacts of flooding that are relevant for risk management policies that concern such flood-prone areas. The introduction noted that intangible benefits and costs are often excluded from the decision making process of risk managers. If intangible impacts from flooding would be negligible, then flood risk management decisions based on cost-benefit analysis that only include tangible impacts would be close to the socially optimal decisions. However, the results of this study indicate that the intangible costs of flooding may be between a quarter and twice the size of the tangible impacts. It is clear that intangible impacts are not negligible and should not be excluded from decision-making about flood risk reduction, because otherwise investments in flood risk management strategies are socially sub-optimal.

2.3.4 Sensitivity analysis

When evaluating the robustness of this chapter's results, potential endogeneity of the flood risk SWBD variables must be considered. Endogeneity occurs when an important excluded variable is correlated with one of the included explanatory variables and the dependent variable. The excluded variable causes the estimated model to provide inaccurate parameter estimates. Dolan et al. (2008) note several robust relationships between socio-economic variables and SWB that should be controlled for in a regression model of SWB, which include: (relative) income; health; personal and community relationships; and employment status. For the most part, these variables are key components of this chapter's SWBDs, meaning that they are controlled for in this chapter's regression models. This chapter's respondents were asked to evaluate their level of SWB regarding the specific SWBDs and can be assumed to take into account the relevant subjective or objective factors that relate to the domain in scoring their degree of satisfaction. For instance, an individual may decide to live in a flood-prone area because of cheap housing prices there, implying that individuals with a high flood risk may have a general lower living standard. Such an effect should be capture by this chapter's financial SWB variable, and, hence, not represent a major endogeneity problem.

Dolan et al. (2008) states several further important unobservable variables that may play a role in determining SWB, which include: motivation; intelligence; and family background. One can argue that since one of the control variables is SWB with family life, this element has been controlled. One model run added an explanatory variable reflecting individual motivation to reduce flood risk, which did not affect this chapter's results. Intelligence may not be such a relevant factor for the flood risk SWBD, because the thought processes related with flood preparedness decisions are often determined by simple behavioral heuristics (e.g., Kunreuther and Pauly, 2004). Nevertheless, it was checked whether the results were affected by including education as a proxy for intelligence, which was not the case.

A further source of potential endogeneity can be the introduction of 'bad controls' into the model. These are control variables that are themselves an outcome variable, which leads to the introduction of selection bias (Angrist and Pischke, 2008). This study has attempted to minimize the amount of control variables required through the use of the SWBD variables.

The flood risk SWBD was not directly defined in the survey, which implies that aspects of personality may still have an uncontrolled influence in that domain. However, the respondent's personality can be argued to be uncorrelated with a respondent's flood experience, because floods are random events that occur independently of personality characteristics. This implies that a respondent's personality has no relationship with their history of previous flood experiences. There may be a connection between flood preparedness decisions and personality. Several studies find that protection motivation theory (PMT) can explain household flood preparedness decisions (e.g., Poussin et al., 2014). Personality is a factor that determines a household's PMT evaluation (Maddux and Rogers, 1983). Heller et al. (2005) argue that the most appropriate aspect of an individual's personality in this regard is their tendency to worry about natural hazards. Worry was controlled for in the regression models by including a series of dummy variables of how concerned the respondent is with current and future flood risk.

Even though effects of socio-economic variables, like marital status for example, on overall SWB are in principle already captured by the SWBD variables, they may have effects over and beyond their link with SWBDs. To this end, the sensitivity of the main results to including variables for: age, age squared, gender, income, and marital status are also tested. There is little change in the overall patterns of the magnitude and significance of the regression coefficients, while for the most part these socio-economic variables are statistically insignificant. The inclusion of only statistically significant socio-economic variables (which differ per SWBD) does not substantially affect this chapter's main results about the flood risk and flood preparedness variables.

Furthermore, the sensitivity of the results is also tested by accounting for individual pessimism by including a variable for sadness of the respondent (detailed results not reported here). Including a variable for the overall sadness of the respondent results in small changes in coefficient values of the SWBDs, but does not affect the statistical significance of explanatory variables. Most importantly, including the sadness variable does not affect the main results of the flood risk domain variables.[7]

2.4 Conclusion

Flooding can cause large direct economic impacts, like property damage, which has been extensively researched. However, the consequences of floods or other natural hazards go beyond direct repair costs or production losses, because there are also intangible impacts, such as psychological consequences for individuals or reputational impacts for businesses. These impacts have hardly been studied, which may be due to the perceived difficulty of modelling or converting these intangible impacts in monetary terms for use in cost-benefit analysis. This chapter builds upon this literature in this chapter's study, by estimating both the SWB implications of floods and how these can be limited

[7] An additional sensitivity test is conducted by including a binary variable that indicates if the individual is motivated to further reduce or manage their risk. The rationale is that an individual who is motivated to further manage and control the external issue of flood risk may not be as pessimistic as others who are not as motivated. Including this variable did not affect this chapter's main results.

by flood preparedness. Moreover, these SWB impacts are split into tangible and intangible impacts on SWB. This is done by analysing data collected from a survey of about 900 households in flood-prone areas in France. This chapter estimates relationships between SWB and explanatory variables of flood experiences, perceptions and preparedness decisions. Using these relationships Chapter 2 calculated the monetary value of the intangible impacts of these variables on overall SWB. This provided insight into the relative size of tangible and intangible impacts of experiencing flooding and flood preparedness.

Four main conclusions can be drawn from this chapter's results. First, the immediate impacts of a flood have a large negative effect on overall SWB that is larger than the effects of other individual SWBDs. Moreover, there is a degree of adaptation to flood events since the reduction in overall SWB is nearly halved 12 months after the flood event. The second conclusion is that flood events can have consequences for an individual's overall SWB, even if they themselves are not flooded. Such effects are relatively small; namely about one third of that associated with the immediate effects of being personally flooded. Third, for communities that are prone to flooding the employment of individual flood protection measures can increase the SWB of these households. Elevation of homes increases SWB of flood-prone households. The fourth conclusion is that the intangible benefits or costs of the flood risk SWBD on overall SWB tend to be larger than the tangible damage suffered or the damage prevented. The average total tangible damage suffered during a respondent's previous flood was €50,000, while the implicit intangible loss was an average of €100,000.

Two important lessons for flood risk management policies can be drawn. One lesson is that the SWB impacts of the intangible losses from flooding or the intangible benefits of household preparedness can outweigh the importance of the direct damage and should be integrated into the risk management decision process. Therefore, the failure to take into account intangible benefits in flood risk management decisions will result in a socially inefficient level of flood protection. However, a challenge with accounting for intangible costs and benefits is that their estimates are uncertain and have been hardly quantified. This study has provided a starting point for monetising tangible and intangible impacts of floods on subjective well-being on which future research can develop. The second lesson is this chapter finds that even though the combined tangible and intangible losses due to a flood event or worries over future flood events are large, households can adapt to this loss in SWB over time and through adequate preparedness decisions.

There is a large degree of uncertainty regarding the monetary equivalent values for the effects of flood risk on overall SWB, which highlights the need for future research in other regions. Future research could focus on the development of longitudinal data of flood experience, flood preparedness measures, and SWB in various regions prone to flooding. Such research would allow for obtaining improved insights into how SWB adapts to different kinds of flood events over time as well as the kind of flood risk management policies that are effective in ameliorating SWB losses. Furthermore, the purpose of this chapter's study was to value the SWB effects of flooding and preparedness for the average individual in order to be applicable for risk management decisions. The study of who is most affected by flooding is a question that may require a different approach, but can provide relevant insights for more tailored policy. This avenue of future work is further highlighted by Malmendier and Nagel (2011) who note that not only are different people likely to be differently affected, but such impacts are determined by the sum of their lifetime experiences rather than focusing mainly on the most recent flood events a respondent experiences.