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# 9. APPENDIX

## 9.1 Appendix A: Supplementary material for Chapter 2

### 9.1.1 Example SWB questions

Shown below are examples of the SWB questions employed in the questionnaire.

A – CURRENT QUALITY of LIFE

Q1. First, on a scale from 0 to 10, where 0 means totally unhappy and 10 means totally happy, how satisfied are you with your life as a whole?

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |

Q2. Similarly, on a scale from 0 to 10, where 0 means totally unhappy and 10 means totally happy, how satisfied are you with the following domains of your life?

| **Domains** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Your health | | | | | | | | | | | |
| Your home | | | | | | | | | | | |
| Your environment of living | | | | | | | | | | | |
| Your financial situation in general | | | | | | | | | | | |
| Your amount of free time | | | | | | | | | | | |
| The use of your free time | | | | | | | | | | | |
| Your family life | | | | | | | | | | | |
| Your social life | | | | | | | | | | | |

### 9.1.2 Meta-analysis of studies investigating the relation between income and overall SWB

A literature review was conducted to establish the relation between income and overall SWB which is needed for calculating the compensating values.

The literature review was conducted by searching for relevant publications in Google Scholar between 23rd March and 25th March 2015. The search was based on finding the following text strings in the titles of papers: SWB income; Life satisfaction income; Subjective well-being income; Subjective well-being income. These search strings resulted in a total of 470 hits once the searches have been refined to papers published between 2000-2015, excluding patents and citations.

The selection of papers was further refined based on the following four initial conditions. First, SWB was measured on an 11 point scale over the range 0-10 which is the range used in our SWB survey question. Second, the paper estimated at least one linear regression between overall SWB and income. Third, the studies were conducted at a micro-economic level. Fourth, the income variable is continuous rather than discrete. Once the papers were collected it was observed that the majority of papers used the natural logarithm of income as an independent variable and so this condition was added as an additional criterion to further improve the consistency of the final set of papers (only two of the identified papers did not meet this condition).

The following papers met our conditions: Vendrik and Woltjer (2007); Pouwels et al. (2008); Knabe and Pätzel (2010); Di Tella et al. (2010); Sekulova and van den Bergh (2013); Stutzer (2004);Headey et al. (2008); Ball and Chernova (2008); Bartram (2010);Gilbert and Paul (2009);Boyce et al. (2009) ; FitzRoy et al. (2011); Boes and Winkelmann (2004); Wunder (2008); Knies (2010); Powdthavee et al. (2013); Plaff (2013); Di Tella and MacCulloch (2008).

In order to arrive at an estimated value for the partial correlation between income and overall SWB, each regression model estimated in the above papers was treated as a separate observation resulting in 73 observations. These observations are used as inputs into the following linear regression:

$$(\mathrm{A1}):\ \mathrm{Paramater}_i = \vartheta + u_i$$

Where $\mathrm{Paramater}_i$ is a value corresponding to a single parameter estimate;$u_i$ is a random error term that represents the deviation of a

particular estimated parameter from the 'true' parameter value $\vartheta$. The estimated value of $\vartheta$ and its standard deviation are used as inputs for our CV calculations. A regression consisting of only a constant and error term has been deemed suitable for an analysis of a variable where there is a single parameter value of interest (e.g., van Houwelingen et al., 2002; Osborne, 2008). The estimated value of $\vartheta$ is 0.21 (with a standard error of 0.02), which indicates a strongly inelastic relationship between income and overall SWB. This is because it implies that a doubling of income increases SWB by $1/5^{th}$ of a SWB level.

Nelson and Kenndy (2009) argue that in certain applications of meta-regressions the non-independence of observations, i.e. several observations from the same study, should be controlled for. However, Nelson and Kenndy (2009) also argue that this is not required if the purpose of the study is to only estimate the average effect size, i.e. regression coefficient size. Nonetheless, a multi-level regression model was also estimated, but as it resulted in similar coefficient estimates, we use the OLS regression results.

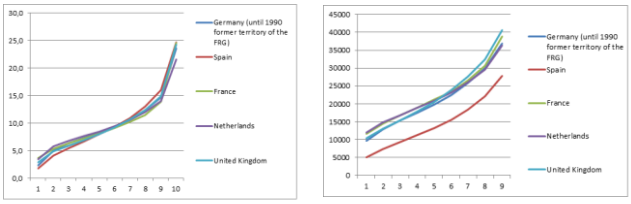


**Figure 9.1 Share of total national income earned by the $n^{th}$ quantile of income (left); Income of the $n^{th}$ quantile (right)**

The value for the relationship between income and subjective well-being used within the main text of the paper is in effect an application of the value transfer method. We believe that the value is suitable because of the relatively small spread of estimates in the literature for countries similar to France. Moreover, the income distributions of the countries used for our meta-analysis have important similarities, which give confidence in our approach. This is apparent from Figures 9.1, which show, respectively, the share of total income earned by each quantile and the highest income point in a quantile for the countries used in our meta-analysis. The figures show that in effect the income distributions are vertically identical across the countries within the meta-analysis. The value of Spanish income is lower than the other countries within the sample, but follows a very similar shape

which implies that also this observation is a useful input for establishing our relation of interest which is based on the logarithm of income.

### 9.1.3 Systematic differences between sample sub-groups and possible endogeneity

An additional method of investigating the presence or potential of endogeneity or sample bias is by checking for systematic differences within our sample between important explanatory variables. There is not a single variable of interest in our study rather a series of variables, which is why we test for differences in the means of the sub-samples created by the explanatory variables. For instance, the variable indicating that a household has employed dry flood-proofing measures can split the sample into two groups, and we then test if there are statistically significant differences in the means of the two sub-samples for each explanatory variable. The results of this investigation show that there are few statistically significant differences between the various sub-samples. The main sample differences occur in expected patterns: those that have been flooded in the past have a higher tendency to worry about future flood risk or impacts and are more likely to employ flood-protection measures.

**Table 9.1 Results of mean comparison tests, which examine differences between sample sub-groups in relation to key explanatory variables (in columns)**

| | Flooded before | Flooded within the last year | Neighbour has been flooded when responde | There is a household plan on how to cope | Has under taken dry flood-proofi | Has under taken wet flood-proofi | Has elevated their buildin g | Expects future flood risk to grow | Expects high damage if flooded | Worries about current and/or future flood |
|---|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **nt was not** | **with a flood** | **ng** | **ng** | | | | **probabilities** |
| **Happy with health** | No sig. diff | No sig. diff | No sig. diff | No sig. diff | No sig. diff | No sig. diff | No sig. diff | Yes:9% | Yes:8% | Yes:10% |
| **Happy with home** | No sig. diff | No sig. diff | No sig. diff | No sig. diff | No sig. diff | No sig. diff | No sig. diff | Yes:13 % | No | Yes:10% |
| **Happy with living environment** | No sig. diff | No sig. diff | Yes:8% | No sig. diff | No sig. diff | No sig. diff | Yes: 8% | Yes:13 % | Yes: 8% | Yes:14% |
| **Happy with financial situation** | No sig. diff | No sig. diff | No sig. diff | No sig. diff | No sig. diff | No sig. diff | Yes:10 % | No sig. diff | No | Yes:16% |
| **Happy with the amount and use of their free time** | No sig. diff | No sig. diff | No sig. diff | No sig. diff | No sig. diff | No sig. diff | No sig. diff | Yes:13 % | Yes:10 % | No sig. diff |
| **Happy with family life** | No sig. diff | No sig. diff | No sig. diff | No sig. diff | No sig. diff | No sig. diff | No sig. diff | Yes:9% | No sig. diff | No sig. diff |
| **Happy with social life** | No sig. diff | No sig. diff | No sig. diff | No sig. diff | No sig. diff | No sig. diff | No sig. diff | Yes:11 % | No sig. diff | No sig. diff |
| **Worries about current and/or future flood probabilities** | Yes: 19% difference | Yes:30% difference | No sig. diff | Yes:22% | No sig. diff | No sig. diff | Yes:14 % | Yes:25 % | Yes: 45% | |
| **Expects high damage if flooded** | Yes: 15% difference | Yes: 25% difference | No sig. diff | No sig. diff | No sig. diff | No sig. diff | Yes:15 % | Yes:22 % | | |
| **Expects future flood risk to increase** | No sig. diff | Yes: 12 % difference | No sig. diff | No sig. diff | No sig. diff | No sig. diff | Yes: 11% | | | |
| **Has elevated their building** | No sig. diff | No sig. diff | Yes:13% | No sig. diff | No sig. diff | Yes:20 % | | | | |
| **Has under taken wet flood-proofing.** | No sig. diff | No sig. diff | No | No sig. diff | Yes: 20% | | | | | |
| **Has undertaken dry flood-proofing** | No sig. diff | Yes: 9% | Yes: 6% | No sig. diff | | | | | | |
| **There is a household plan on how to cope with a flood** | Yes: 11% | Yes:11% | No | | | | | | | |
| **Neighbour has been flooded when respondent was not** | No sig. diff | No | | | | | | | | |

**Notes:** No sig. diff. indicates that the sample means do not differ at the 5% significance level. Values after 'Yes' indicate the absolute difference in means.

## 9.2 Appendix B: Variable number, name, and description for Chapter 3

The variables in italics below have been included in every PS function, and are otherwise referred to as the core variables. The variables presented in standard type are included in models where they improved performance while maintaining the balancing assumption. The Table 9.2 below lists the variables included in each PS model. The possible variables to be included in the PS function:

**Table 9.2 Included confounders**

| | |
|---|---|
| **Flood adapted use (contents damage)** | **3-28,35-37,39-40,43** |
| **Flood adapted use (building damage)** | 3-29, 33, 35, 36, 38, 43 |
| **Wet flood-proofing (contents damage)** | 3-28,35,36,38-41,43 |
| **Wet flood-proofing (building damage)** | 3-15,17-32, 35, 36, 38, 43 |
| **Adapted building structure (contents damage)** | 3-8, 11-28, 35-37, 39-43 |
| **Adapted building structure (building damage)** | 3-8, 10-28, 30-32, 35-43 |
| **mobile water barrier (contents damage)** | 3-8, 10-28, 30-32, 35-43 |
| **mobile water barrier (building damage)** | 4-8, 10-27, 29-33, 35-37, 39 |
| **Notes: The confounders are referred to by their identifying numbers, which are listed above.** | |

1. Household Contents Damage: damage to household contents, where contents are all moveable items in the home. Measured in euros, and as replacement costs.
2. Household Building Damage: Damage to the building – repair costs. Measured in euros.
3. Household Contents Value: The value of all moveable items within the home. Measured in Euros.
4. Flood Duration: The length of time the building was flooded in hours. Measured in hours.

5. Flow Speed One: low water speed (stationary water is the base group). From a 0-4 scale based on the scale developed by the Bureau of Reclamation (Thieken, 2005). This is a dummy variable taking the value of 1 if the respondent provided a value of 1, and 0 otherwise.
6. Flow Speed Two: medium water speed (stationary water is the base group). From a 0-4 scale based on the scale developed by the Bureau of Reclamation (Thieken, 2005).This is a dummy variable taking the value of 1 if the respondent provided a value of 1, and 0 otherwise.
7. Elbe: A dummy variable taking the value of 1 if the respondent lived along the Elbe River, and 0 otherwise.
8. Urban Area: A dummy variable taking the value of 1 if the respondent lived in an urban area (greater than 50,000 residents), and 0 otherwise
9. House Age (1948): A dummy variable taking the value of 1 if the respondent's building was constructed between 1948-64, and 0 otherwise.
10. House Age (1964): A dummy variable taking the value of 1 if the respondent's building was constructed between 1964-90, and 0 otherwise.
11. House Age (1990): A dummy variable taking the value of 1 if the respondent's building was constructed between 1990-2000, and 0 otherwise.
12. House Age (2000): A dummy variable taking the value of 1 if the respondent's building was constructed after 2000, and 0 otherwise.
13. House Quality 2: A dummy variable taking the value of 1 if the respondent said that the quality of their building was 2 on a 6-point scale (1 is highest quality)
14. House Quality 3: A dummy variable taking the value of 1 if the respondent said that the quality of their building was 3 on a 6-point scale (1 is highest quality)
15. House Quality 3 Plus: A dummy variable taking the value of 1 if the respondent said that the quality of their building was 4,5 or 6 on a 6-point scale (1 is highest quality)
16. Flood Risk 1: A dummy variable taking the value of 1 if the respondent said that a flood had only affected them once before.
17. Flood Risk 2: A dummy variable taking the value of 1 if the respondent said that they have suffered twice from flooding before.

18. Flood Risk 3: A dummy variable taking the value of 1 if the respondent said that they have suffered three flood events before.
19. Flood Risk 4: A dummy variable taking the value of 1 if the respondent said that they have suffered from 4 flood events before.
20. Flood Risk 5: A dummy variable taking the value of 1 if the respondent said that they have suffered from more than 5 floods before.
21. Water height: The height of floodwaters entering the house in meters.
22. Contaminated Water: A dummy variable taking the value of 1 if the respondent's house was contaminated by sewage or oil, and 0 otherwise.
23. Warning Duration: The length of time before a flood that a warning was issued in hours.
24. Return 1: A dummy variable taking the value of 1 if the flood recorded at the nearest gauge was between 1 in 10 years to 1 in 50 years, and 0 otherwise.
25. Return 2: A dummy variable taking the value of 1 if the flood recorded at the nearest gauge was between 1 in 50 years to 1 in 200 years, and 0 otherwise.
26. Return 3: A dummy variable taking the value of 1 if the flood recorded at the nearest gauge was over 1 in 200 years, and 0 otherwise.
27. Cellar: A dummy variable taking the value of 1 if the building has a cellar, and 0 otherwise.
28. Floor size: The total floor space of the home, including the size of the cellar if present. Measured in $m^2$.
29. House price: An estimate of the house price based on the M1914 criteria. Measured in euros.
30. Warning Quality: A dummy taking on the value of 1 if the perceived quality of the flood warning is given a value of 1, 2 or 3 on a scale of 0-11, and 0 otherwise.
31. Warning Quality Two: A dummy taking on the value of 1 if the perceived quality of the flood warning is given a value of 4, 5 or 6 on a scale of 0-11, and 0 otherwise.
32. Warning Quality Three: A dummy taking on the value of 1 if the perceived quality of the flood warning is given a value larger than 7 on a scale of 0-11, and 0 otherwise.
33. Renter: A dummy variable taking the value of 1 if the resident rents their residence, and 0 if they own their place of residence.

34. Detached house: A dummy variable taking the value 1 (0 otherwise) if the building is a detached house (this variable is the core base category for housing type)
35. Semi-detached house: A dummy variable taking the value 1 (0 otherwise) if the building is a semi-detached house.
36. Town house: A dummy variable taking the value 1 (0 otherwise) if the building is a detached house.
37. Multi-family house: A dummy variable taking the value 1 (0 otherwise) if the building is a multi-family house.
38. Commercial Building: A dummy variable taking the value 1 (0 otherwise) if the building is a commercial building.
39. Secured documents: A dummy variable taking the value 1 (0 otherwise) if the responded secured their documents before the flood.
40. Move Cars: A dummy variable taking the value 1 (0 otherwise) if the respondent moved their car to a flood safe-area before the flood.
41. Move Animals: A dummy variable taking the value 1 (0 otherwise) if the respondent moved animals to a flood safe location.
42. Turn off gas/electric: A dummy variable taking the value 1 (0 otherwise) if the respondent turned off the mains electric and gas.
43. Evacuation: A dummy variable taking the value 1 (0 otherwise) if the respondent had to vacate their building due to the flood.

## 9.3 Appendix C: Variable number, name, and description for Chapter 4

A list of the variables included in the PSM analysis for Chapter 4 is given below. The variables conditioned upon in the PSM follow the guidelines set out in Chapter 3. The data are trimmed in two respects. First, observations with over €100,000 (€300,000) of contents (building) damage are removed as these are outlying values. Second, sample is trimmed to only observations within the common support.

List of variables included in the PSM analysis

1. Household contents damage: damage to household contents, where contents are all moveable items in the home (in € as replacement costs).
2. Household building damage: Damage to the building as repair costs (in €).

3. Household contents value: The value of all moveable items within the home (in €).
4. Flood duration: The number of hours the building was flooded.
5. Flow speed one: Dummy variable of low water speed (stationary water is the base group).
6. Flow speed two: Dummy variable of medium water speed (stationary water is the base group).
7. Elbe: Dummy variable of the respondent living along the Elbe River.
8. Urban area: Dummy variable of the respondent living in an urban area.
9. House age (1948): Dummy variable of the building being constructed between 1948-64.
10. House age (1964): Dummy variable of the building being constructed between 1964-90.
11. House age (1990): Dummy variable of the building being constructed between 1990-2000.
12. House age (2000): Dummy variable of the building being constructed after 2000.
13. House quality 2: Dummy variable of a building quality of 2 on a 6-point scale (1 is highest quality).
14. House quality 3: Dummy variable of a building quality of 3 on a 6-point scale (1 is highest quality).
15. House quality 3 plus: Dummy variable of a building quality of 4, 5 or 6 on a 6-point scale (1 is highest quality).
16. Flood risk 1: Dummy variable of being affected by a flood once.
17. Flood risk 2: Dummy variable of being affected by a flood twice.
18. Flood risk 3: Dummy variable of being affected by a flood thrice.
19. Flood risk 4: Dummy variable of being affected by a flood 4 times.
20. Flood risk 5: Dummy variable of being affected by a flood 5 times.
21. Water height: The height of floodwaters entering the house in meters.
22. Contaminated water: Dummy variable of contaminated flood waters
23. Warning duration: The length of time before a flood that a warning was issued in hours.
24. Return 1: Dummy variable of a recorded return period of 1 in 10 years to 1 in 50 years.
25. Return 2: Dummy variable of a recorded return period of 1 in 50 years to 1 in 200 years.
26. Return 3: Dummy variable of a recorded return period of over 1 in 200 years.

27. Cellar: Dummy variable of a cellar.
28. Floor size: The total floor space of the home, including the size of the cellar if present in $m^2$.
29. House price: An estimate of the house price based on the M1914 criteria (in €).
30. Warning quality 1: A dummy variable for if the perceived quality of the flood warning is given a value of 1, 2 or 3 on a scale of 0-11.
31. Warning quality 2: Dummy variable of the quality of the flood warning being 4, 5 or 6.
32. Warning quality 3: Dummy variable of the quality of the flood warning being larger than 7.
33. Detached house: Dummy variable of a detached house (this is the base category).
34. Semi-detached house: Dummy variable of a semi-detached house.
35. Town house: Dummy variable of a detached house.
36. Multi-family house: Dummy variable of a multi-family house.
37. Commercial building: Dummy variable of a commercial building.
38. Secured documents: Dummy variable of securing documents.
39. Move cars: Dummy variable of moving cars.
40. Turn off gas/electric: Dummy variable of turning off the mains electric and gas.
41. Evacuation: Dummy variable of evacuating their building.

# 10. SUMMARY

## 10.1 English summary

Extreme weather events are a pressing global concern due to the devastation that they can cause. This thesis focuses on flooding, which is the natural disaster with the greatest effect on humanity. Europe as a whole has suffered an annual average loss of $14 billion between 1980 and 2010 due to the effects of extreme weather events. The increasing trend over time in flood risk has resulted in a growing interest in flood risk management, and financial mechanisms such as insurance to deal with increasing flood risk. The main research question of this thesis is: How can insurance and household-level risk reduction be combined to create a flood-resilient society? This can help to meet the Sendai framework's call for increasing investments in disaster risk reduction. To answer this question this thesis consists of five content chapters that answer different aspects of this core question.

Chapter 2 finds that there are large both tangible and intangible welfare impacts from flooding and that the intangible impacts may be twice as large as the tangible impacts, highlighting the need for increased effort in reducing flood risk. Moreover, Chapter 2 showed that there are substantial welfare benefits from individual risk reduction measures (~€39,000), which provides a rationale for exploring how the implementation of such measures can be improved using insurance. Chapter 3 offers empirical evidence that household-level disaster risk reduction measures can have a substantial impact on the damage suffered during a flood if a household is suitably prepared. For example, ~25% of the average monetary flood loss can be prevented by implementing certain wet flood-proofing measures. The thesis provides a clear rationale to examine the ability of insurance to promote the use of such household-level risk reduction measures, and Chapter 4 finds that the German and U.S. natural disaster insurance markets are likely free of moral hazard, showing that voluntary insurance purchase may not have acted as a disincentive to prepare for risk. Moreover, Chapter 4 shows that in the case of the U.S. only the presence of very large deductibles incentivised household risk reduction, indicating that other incentive mechanisms are required.

Chapter 5 shows that premium discounts could strongly incentivise and promote the use of some of the risk reduction measures studied in Chapter 3 in the case of Germany and France. However, even though risk based premiums could promote risk reduction, they often remain potentially

unaffordable for low-income households in high-risk areas. Chapter 6 reconfirms this finding when using an EU wide insurance model, which estimates that on average 18% of those at high flood risk would find premiums unaffordable by 2055. This unaffordability can be corrected via means-tested insurance vouchers in order to facilitate an adjustment to risk-based premiums.

Chapter 6 also presents six stylized insurance market structures for the EU and shows that, as society moves forward in time and risk increases, the general structure of insurance markets will have to adapt. While there is not a uniform optimal market structure, the common traits of desirable flood insurance systems are: a sufficiently strong connection of premiums with risk reduction measures; a limited premium cross-subsidization between higher and lower risk households, and the presence of a public-private partnership through a government reinsurer to cover losses from extreme events. Moreover, strengthening requirements to buy insurance may be required in order to maintain high insurance penetration rates. The research presented in this thesis indicates that as flood risk develops into the future, a stronger partnership across stakeholders focusing on risk reduction is required.

There are four main policy recommendations drawn from this research. The first is that floods can have large intangible impacts, which should not be ignored when assessing risk. The second is that while moral hazard may not be present in natural disaster insurance markets adverse selection is potentially present, and the suggested policy mix to overcome this issue is based on risk zoning and compulsory insurance purchases, which increases solidarity. The third is that risk-based pricing and premium discounts are likely to be more effective at promoting risk reduction than relying on the common current practise of deductibles alone. The fourth is that while risk-premiums may be unaffordable for low-income households in high risk areas, this can be eased by introducing income support mechanisms from outside the insurance market, such as temporary vouchers.

## 10.2 Nederlandse samenvatting

Extreem weer leidt wereldwijd tot groeiende bezorgdheid vanwege de grote verwoesting die het kan veroorzaken. Dit proefschrift richt zich op overstromingen, de natuurramp met het grootste effect op de mensheid. Alleen al in Europa heeft extreem weer gemiddeld $14 miljard per jaar aan kosten veroorzaakt tussen 1980 en 2010. De tendens van toenemende overstromingsrisico's heeft geresulteerd in meer interesse in het beheersen

van die risico's en in financiële arrangementen voor het vergoeden van overstromingsschade zoals verzekeringen. De hoofdvraag van dit proefschrift is: hoe kunnen verzekeringen en risicobeperking op huishoudensniveau worden gecombineerd om een samenleving te creëren die beter bestand is tegen overstromingen? Deze combinatie kan helpen om de oproep van het Sendai Framework voor toenemende investeringen in risicobeperkende maatregelen te realiseren. Dit proefschrift bestaat uit vijf inhoudelijke hoofdstukken die ieder een verschillend aspect van deze hoofdvraag beantwoorden.

Hoofdstuk 2 laat zien dat overstromingen grote materiële en immateriële effecten hebben op het welzijn van huishoudens en dat de immateriële effecten tot wel twee keer zo groot kunnen zijn als de materiële. Dit benadrukt de noodzaak van meer inspanningen om overstromingsrisico's te beperken. Daarnaast laat hoofdstuk 2 zien dat er substantiële welzijnsvoordelen zijn van individuele risicobeperkende maatregelen (± €39.000), wat een reden is om te onderzoeken hoe de implementatie van deze maatregelen kan worden verbeterd via verzekeringen. Hoofdstuk 3 biedt empirisch bewijs dat risicobeperkende maatregelen op huishoudensniveau een substantiële impact kunnen hebben op de geleden schade gedurende een overstroming. Zo kan bijvoorbeeld ± 25% van de gemiddelde financiële schade door een overstroming worden voorkomen door de implementatie van bepaalde 'natte' voorzorgsmaatregelen die schade beperken als water een gebouw binnendringt. Het is dus belangrijk om te onderzoeken hoe verzekeringen het gebruik van risicobeperkende maatregelen op huishoudensniveau kunnen bevorderen.

Hoofdstuk 4 toont aan dat de Duitse en de Amerikaanse verzekeringsmarkt voor natuurrampen waarschijnlijk geen moreel risico kennen, wat betekent dat vrijwillige verzekeringen waarschijnlijk niet gezorgd hebben voor een ontmoediging om zich voor te bereiden op risico's. Daarnaast laat hoofdstuk 4 zien dat, in het geval van de Verenigde Staten, alleen de aanwezigheid van zeer grote eigen risico's huishoudens heeft gestimuleerd om risico's te beperken, wat aantoont dat andere financiële prikkels voor risicoreductie nodig zijn.

Hoofdstuk 5 laat voor Duitsland en Frankrijk zien dat premiekortingen een effectieve prikkel zijn voor huishoudens om een aantal van de risicobeperkende maatregelen te nemen. Ondanks dat op risico gebaseerde premies zulke maatregelen kunnen aanmoedigen, zijn deze premies onbetaalbaar voor veel huishoudens met lage inkomens in gebieden met

een hoog risico. Een toepassing van een EU-breed verzekeringsmodel in hoofdstuk 6 bevestigt dit. Het model schat dat de premies onbetaalbaar zijn voor gemiddeld 18% van huishoudens met een hoog overstromingsrisico in 2055. Compensatie is mogelijk door op risico gebaseerde premies aan te passen via inkomensafhankelijke subsidies op verzekeringen.

Hoofdstuk 6 presenteert tevens zes aangepaste arrangementen voor de overstromingsverzekeringsmarkt voor de EU en laat zien dat verzekeringsmarkten hervormd moeten worden als risico's toenemen door klimaatverandering en sociaaleconomische ontwikkelingen. Ook al is er geen uniforme optimale marktstructuur, de gemeenschappelijke kenmerken van gewenste systemen van overstromingsverzekeringen zijn: een voldoende sterke verbinding van premies met risicobeperkende maatregelen; een gelimiteerde premie-kruissubsidiëring tussen huishoudens met een hoog en een laag risico, en publiek-private samenwerking door middel van een overheidsgestuurde herverzekeraar die schades veroorzaakt door extreme rampen dekt. Bovendien is het nodig om de vereisten om een verzekering af te sluiten aan te scherpen om een hoge dekkingsgraad te kunnen waarborgen. Het onderzoek in dit proefschrift wijst erop dat als overstromingsrisico's veranderen in de toekomst verschillende publieke en private organisaties beter moeten samenwerken om risico's te beperken.

Uit dit onderzoek volgen vier belangrijke beleidsaanbevelingen. De eerste is dat overstromingen grote immateriële welvaartseffecten kunnen hebben die niet moeten worden genegeerd in risicoanalyses en kosten-batenanalyses van overstromingsbescherming. De tweede is dat, alhoewel moreel risico waarschijnlijk niet aanwezig is in verzekeringsmarkten voor natuurrampen, antiselectie wel voorkomt. De voorgestelde beleidsmix om dit probleem op te lossen bestaat uit risicozonering waarmee premies worden aangepast aan de hand van het lokale risico en eventueel verplichtingen instellen voor het afsluiten van verzekeringen waardoor solidariteit en risicospreiding toenemen. De derde is dat op risico gebaseerde premies en premiekortingen voor risicoreductie waarschijnlijk meer effect hebben op het bevorderen van risicobeperking dan alleen het eigen risico. De vierde is dat mogelijke problemen met de betaalbaarheid van op risico gebaseerde premies voor huishoudens met lage inkomens in gebieden met een hoog risico kunnen worden opgelost door subsidies, zoals tijdelijke vouchers waarmee deze huishoudens een verzekering kunnen aanschaffen.

# 11. ACKNOWLEDGEMENTS

From a review of the various theses I have seen over the years this is the part that most resembles an Oscar's speech thanking everyone from their co-stars down to the hamster of their hairdresser. However, I shall keep this brief as I am less likely to make a mistake with my English (a bane of putting this thesis together).

Much like Rome a thesis is not completed overnight nor can a thesis be completed in isolation. This thesis took nearly 4 years to write up in the book that you are currently looking at either in print or on a screen and received the input of a village. The village in question is the Institute for Environmental Studies, a lovely collection of people. It was a pleasure to spend 3.5 of those years there, more so given my apparent love of change and travel, one of which happened more than the other.

The folks I spent my time with in Amsterdam were thanked in the second paragraph of this section and as you were all equal there is no need to call you out individually. However, there are also those co-authors spread across the world whose help created different aspects of this thesis and the work within. Jeroen helped to plan out the strategic nature of how to approach and disseminate the work in this thesis (as well as running the ENHANCE project along with Ralph that provided the funding and a new job), Wouter helped spectacularly with all of his advice on the actual writing of this thesis, Jennifer, Heidi, Jeff and Luc all helped contribute data and advice that allowed the work in this thesis to be as good as it could. Literally without your help and contributions this thesis would not be here today. Also, thanks to Nadia for translating the summary in return for a stamp.

At this point, I would care to remind you what I said in the second sentence of this Chapter.

# 12. ABOUT THE AUTHOUR

## 12.1 A short biography

Paul was born in Birmingham, the United Kingdom where he spent the following 18 years until he moved to Manchester to study for an Undergraduate degree in economics, where he graduated with a first class degree in economics. Shortly after graduating from the University of Manchester, Paul started his international career by moving to the South Korean countryside to teach English in an elementary school. After which he returned to Europe in order to complete two Master degrees in Economics from Tilburg University (NL, Msc) and the Université catholique de Louvain (BE, MA).

After the completion of these degrees Paul was fortunate to be offered a place to complete his PhD studies at the Institute of Environmental Studies at the VU University Amsterdam, before leaving for a new country once again to work at the University of Potsdam.

## 12.2 List of publications

1. Insurance of weather and climate-related disaster risk: Inventory and analysis of mechanisms to support damage prevention in the EU, August 2017, Consultation for the European Commission Directorate-General for Climate Action, Unit A.3 – Adaptation, Partnership between IVM (**Paul Hudson**, Marleen de Ruiter, Lars de Ruig, Onno Kuik) and Ramboll (Xavier Le Den, Matilda Persson, Audrey Benoist)
2. **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, DOI **:** 10.1007/s10902-017-9916-4
3. Surminski, S., **Hudson, P.** 2017. Investigating the risk reduction potential of disaster insurance across Europe. The Geneva Papers on Risk and Insurance - Issues and Practice, 42 (2), 247-274.
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10. **Hudson, P.,** Botzen, W.J.W., Kreibich, H., Bubeck, P., Aerts, J.C.J.H. 2014. Evaluating the effectiveness of flood damage mitigation measures by the application of propensity score matching. Natural Hazards and Earth System Sciences, 14, 1731-1747, DOI: 10.5194/nhess-14-1731-2014