

The demand for public flood protection under a compulsory private flood insurance scheme

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Abstract

After the 2021 flood events in Germany, the introduction of compulsory flood insurance is debated. However, insurance coverage for private buildings and belongings may undermine the willingness to pay for municipal flood protection. We use a discrete choice experiment (N=5,940 participants) to analyze the effects of compulsory insurance on the preferences for public flood protection. The demand for municipal flood protection is associated with its effectiveness and cost, varies plausibly with numerous covariates, but is unaffected by compulsory insurance. Hence, there is no empirical indication that compulsory flood insurance would undermine citizens' support for public flood risk reduction.

Keywords

Compulsory flood insurance; moral hazard; municipality; flood protection

1. Introduction

Amongst the natural hazards that high-income countries are currently confronted with, flooding causes the highest economic damages and disruptions (Miller et al. 2008). Flood damages are also expected to rise due to climatic and socio-economic developments (Huber & Gulledge 2011; Rojas et al. 2013; Winsemius et al. 2016). Hence, an effective, efficient, and just flood risk management at various governmental levels is key for the transformation to a climate-resilient economy. An important, albeit not sufficient, element of an adequate flood risk management is the design of a functional flood insurance market. Insurance markets are especially important for the financial regulation of medium-sized and large damages. These types of damages will remain, even if governments, communities and private actors invest in structural flood mitigation measures, such as dikes, levees, and household-level measures, or adjust their land use regulations and practices. In case of extreme hydrological events, such risk mitigation measures will not effectively avoid all financial damage, and insurance markets may

provide a welfare-enhancing risk transfer and speed up the reconstruction process (Kousky 2019). In addition, insurance markets are seen as important because they provide price signals of natural hazard risk at certain locations (Bin et al. 2008; Botzen & Van Den Bergh 2009) and, by risk-adjusted premiums, give monetary incentives for risk-reducing behavior (Botzen et al. 2009).

However, in most countries flood insurance markets do not work without some form of governmental intervention. In countries where insurance coverage is voluntary, the demand of private households and businesses is typically below 50% (Hudson et al. 2019), and the market suffers from the so-called “Natural Disaster Syndrome” (Kunreuther 2006; Andor et al. 2020; Tesselaar et al. 2022). The term “Natural Disaster Syndrome” describes the following vicious circle: In case of an extreme flood event, and subject to external factors such as media coverage and the spatial and temporal proximity of events and political elections, governments may provide flood relief payments to affected households who were not insured (Downton & Pielke 2001; Eissensee & Strömberg 2007). This raises expectations regarding future relief payments, resulting in an even more reduced incentive to purchase insurance privately (this effect is also called “charity hazard”, see Botzen and van den Bergh 2012; Landry et al. 2021; Raschky et al. 2013; Raschky & Weck-Hannemann 2007). Furthermore, a decrease in private demand raises transaction costs for insurers, which implies higher prices and, *ceteris paribus*, again declining demand.

One possible way out of the Natural Disaster Syndrome is making flood insurance coverage compulsory. In France, for example, homeowners and tenants are required to purchase flood insurance based on the size of their homes. Similar regimes are in place in Spain, Belgium and parts of Switzerland (Paudel 2012). In Germany, economists and influential politicians proposed a compulsory flood insurance in the aftermath of the extreme flood event of summer 2021 and after major flood events before 2021 (Schwarze and Wagner 2007; Seifert et al. 2013).

While there are several aspects to be considered when introducing a compulsory flood insurance, one potential challenge is that the incentive for investment in and maintenance of structural flood mitigation measures may decline, both for private actors and public entities (e.g., municipalities). In the following, we focus on potential effects for flood risk reduction measures at the municipality level, such as investment and maintenance of dikes, adjusted sewage water systems, and retention basins. Most of these measures are designed to reduce the expected occurrence of critical water levels within the community, although a perfect protection from extreme events is hardly feasible. In the remainder, we call these measures municipal flood protection.

To assess the potential impact of a compulsory flood insurance scheme on municipal flood protection, first imagine a community with voluntary flood insurance, with some inhabitants being insured and others not. In this community, municipal flood protection has three features: First, it reduces non-monetary impacts of flooding for all households. Such impacts may be the loss of memorabilia, the general inconvenience and clean-up efforts after flooding, and possible health impacts. Second, it increases the flood resilience of the municipal infrastructure, including transport and energy networks and sewage systems, and it safeguards the functionality of various institutions, such as businesses, shops, schools and administration. Third, these municipal measures provide additional benefits for non-insured inhabitants, as they reduce the risk of damage at their private homes and contents, which could otherwise result in significant financial hardships for these uninsured flood victims. In a community where every inhabitant is insured against private monetary flood damage and deductibles are low, this latter-mentioned benefit of municipal flood protection is largely obsolete, as private damages will be settled by insurance. Hence, one can hypothesize that the overall perceived utility of municipal flood protection is lower under a compulsory flood insurance scheme than when only a certain part of the population is flood insured.

As a consequence, it is argued that introducing a mandate for flood insurance may be detrimental for a holistic flood risk management, because the universal insurance coverage may undermine incentives for other, equally important and effective risk reduction measures at the municipal level. Opponents of a compulsory insurance scheme repeatedly brought this argument forward (GDV 2016). In economic terms, the argument is based on moral hazard concerns at the side of municipal decision makers.

In the present study, we assess whether the incentives for municipal flood protection are indeed affected by the presence of a compulsory flood insurance scheme, which covers private financial flood damages of the protected households. Following the political economics literature (e.g., Geys et al. 2020; Miller 2005; Potrafke 2013), we approach the incentives of a municipal decision maker for implementing a project or not by the stated preferences of those households who are both the beneficiaries and funders of the project. Moral hazard for households in the flood insurance context has been analyzed, and there is prior literature on the effect of community-level risk reduction on insurance demand (e.g., Andor et al. 2020 and Borsky and Henninghausen (forthcoming), see also next section), but the abovementioned question is not yet assessed empirically. Based on a discrete choice experiment (DCE) in a large-scale online survey conducted in Germany, we elicit the households' preferences and willingness-to-pay (WTP) for municipal flood protection in scenarios with and without compulsory insurance, while controlling for a large set of control variables.

The results robustly suggest that the preferences and hence WTP do not deteriorate when flood insurance is compulsory. This is in contrast to the abovementioned hypothesis, hence there is no empirical indication that the introduction of a compulsory flood insurance scheme would necessarily undermine the incentives for municipal flood protection. Beside the null effect of compulsory insurance, we find several significant associations of flood protection preferences with various covariates. We conclude with some interpretations of these results and derive

preliminary policy implications for the ongoing discussion about possible restructurings of flood insurance schemes.

2. Related Literature

This study ties to two strands of literature: First, we provide additional empirical evidence to a body of recent literature dealing with determinants of WTP – or, more generally, preferences – for municipal flood protection (or public flood protection provision at other governmental levels). Second, the research question at hand inherently raises to the moral hazard issue in the flood insurance and risk mitigation context. Hence we touch upon the question whether the coverage of financial flood damages by insurance is detrimental for the uptake of further risk mitigation measures (indicating these two strategies are perceived as substitutes), or whether these both strategies are rather seen as complements.

Empirical evidence on the demand for public flood protection is very limited. In a recent study, Entorf and Jensen (2020) explore a Germany-wide survey on safety and security, and investigate households' WTP for the reduction of flood risk through public investments. In this survey, the respondents were explicitly asked about their WTP for an improved protection against flood hazard. The authors find a non-linear relationship between WTP and age of respondents, with young and old willing to pay more. According to their further findings, previous flood experience and higher income of respondents are positively related to the WTP for public flood protection. In a similar study amongst households in Central Japan, Zhai et al. (2006) assess the WTP for different public flood control projects under different scenarios. They find, similarly to Entorf and Jensen (2020), that WTP is associated with household income and flood experience. Moreover, they find a positive relationship between preferences for public measures and individual disaster preparedness measures. Using a DCE, Spegel (2017) examines if preferences and WTP for public flood protection schemes differ between citizens and public officials in the Gothenburg region in Sweden. The results suggest only minor

differences in their preference structures; citizens value the reduction of flood-related traffic disturbances higher than public officials do, but preferences for flood damage reduction and drinking water security are very similar.

In the USA, public flood mitigation projects are evaluated by the Community Rating System (CRS) of the US National Flood Insurance Program. Communities pursuing mitigation activities get CRS points, which results in lower insurance premiums for the inhabitants. Fan and Davlasheridze (2016) employ a sorting model to examine residential location choices in response to flood risk and CRS activities, and derive a WTP for different types of damage reduction activities. In a panel study on community-level flood mitigation projects in North Carolina, Li and Landry (2018) find that community mitigation correlates positively with tax revenues and damage experience, and negatively with crime and unemployment rates. In terms of household characteristics, mitigation is higher in regions where median household income and average age are high.

The other strand of literature relevant for our study deals with moral hazard in the flood mitigation and insurance context. While our research focusses on the effect of insurance coverage on public flood protection at the municipality level, there is a large and growing body of literature on the similar effect on private protection measures at the household level (e.g., Andor et al. 2020, Atreya et al. 2015, Botzen et al. 2019, Hudson et al. 2017, Kriesel and Landry 2004, Mol et al. 2020, Oulahan 2015, Osberghaus 2015; Thieken et al. 2006). This research has examined the uptake of flood insurance and risk mitigation measures in different regional contexts (e.g., USA, Canada, Netherlands, Germany) and with different data types and empirical settings (regional insurance penetration rates, household surveys, experiments with and without monetary incentives). Most of these studies find no evidence of moral hazard in the flood mitigation – insurance relationship. Insurance behavior is – if at all – positively associated with the implementation of structural or behavioral measures to reduce the expected

flood damage ex-ante. While the prior literature on moral hazard largely ignores the public dimension of flood protection, we expand these studies by focusing on municipal flood protection instead of household-level flood protection. One notable exception is the recent study of Borsky and Henninghausen (forthcoming), who approach the moral hazard question from another perspective and ask whether insurance decisions are impacted by community-level mitigation efforts. According to their data from the US context, the effect of community-level mitigation depends on its type: flood risk communication can crowd-in private flood insurance demand, while activities that lower the physical flood hazard (hence, the type of municipal protection measures as in our context) crowd-out private flood insurance demand.

We contribute to these two strands of literature by examining the causal effect of introducing a compulsory insurance scheme on the stated preferences for municipal flood protection.

3. Data and Methods

Household Survey

For the empirical analysis we use the 2020 wave of the Green-SOEP panel survey on climate mitigation and adaptation behaviour of households in Germany, collected by the pollster Forsa. The 2020 wave of Green-SOEP was conducted online in early summer 2020, and 6,088 households participated in this wave. The sample is part of the Forsa omninet panel, which includes around 80,000 households which are representative for the German population in terms of household size and regional distribution. The household sample used in our analysis, however, is slightly older and better educated than the average German population, and there are less single occupancy households in the data set than would be in a representative sample. More information on the data set, including descriptive statistics and trends is available in Osberghaus et al. (2020). Germany serves as a prime example for a voluntary flood insurance market, which is potentially moving towards a compulsory-like insurance scheme, which has been shown again by the public discussions in the aftermath of the flood event in summer 2021.

Moreover, the risk of charity hazard – hence the reduced insurance demand due to expectations of public relief – is deemed especially high in Germany, compared to other European countries (Tesselaar et al. 2022).

The Green-SOEP data set contains a number of variables that may serve as potentially important covariates in the regression of flood protection preferences. Beside some basic socio-economic variables such as age, gender, education, income, household size, and homeownership, we use data on political party preferences and locus of control. Flood protection preferences are most probably associated with flood risk perceptions, exposure, and experience; hence we include these variables in the set of covariates. Finally, we also control for the reported flood insurance coverage and implementation of household-level flood protection measures.

Discrete Choice Experiment

The survey included a discrete choice experiment (DCE) on the preferences for municipal flood protection. Before the experiment, the sample was informed about the features of a compulsory flood insurance scheme (see Appendix A1 for a translation of the presented text). The respondents were informed about the general possibilities of municipal flood protection (see Appendix A2 for a translation of the DCE instructions and information treatments). Then, the sample was randomly divided into two subsamples. Sample A was informed that they should state their preferences based on the assumption that compulsory flood insurance is introduced in Germany, hence the largest part of financial flood damages at the household will be compensated by insurance payments. Sample B was informed that flood insurance remains voluntary, i.e. there is no compulsory insurance for private damages.

Finally, one single binary discrete choice question was presented to each respondent. One alternative was labelled “no measure”, representing the status quo of flood protection, with no improvements in flood risk reduction for the community, and no additional costs. The other alternative was labelled “Flood protection measure”, and entailed some positive value of flood

risk reduction (in terms of flood probability in the community), and some costs in terms of additional annual wastewater fees, as this is the typical way how municipal flood protection is financed. An example choice card is depicted in Figure 1, and the attribute levels of risk reduction and costs are summarised in Table 1. The attribute levels for costs were chosen such that they are in a reasonable order of magnitude compared to the current sewage costs. In 2020, the average sewage costs per person was between 100 and 200 € p.a. (depending on consumption, building type, city, etc.).

Insert Figure 1 here.

Insert Table 1 here.

As visible in Figure 1 and Table 1, the survey instrument encompasses a single binary choice task, with two attributes varied across respondents. Since our main objective is to study the treatment effect of interest on preferences, not to put an economic value on flood protection as in a typical CV study, we use the term DCE for our instrument throughout the paper, following the nomenclature of Carson and Louviere (2011). We keep the experiment that simple because our main interest lies in estimating the treatment effect of the randomized information treatment. While the data generally allow for an analysis of the willingness-to-pay (WTP) for flood protection measures, we perceive the issue of potential compulsory insurance effects as more policy relevant in our context than a WTP analysis.

The DCE was pre-tested amongst 109 respondents, who showed reasonable variation in their stated choices and of which 105 rated the questionnaire as “understandable” or “very understandable”. In the debriefing, none of the pre-test participants mentioned the DCE as a critical part. None of the attribute levels was raised as an issue of concern by the participants, or provoked obvious protest responses. Notwithstanding these encouraging pre-test results, we identify those respondents who show to be uncertain on the flood topic by their “do not know”

responses to other flood-related questions, and run a robustness check excluding the sub-sample of “uncertain” respondents.

Given the large number of respondents in the full sample, there is no need to increase the number of choices by eliciting multiple choices per respondent. Choice sequences are often employed to increase the number of choice observations, but come at a cost: As choices may be not completely independent, they bear higher risks of learning effects and untruthful response behaviour (Carson and Groves 2007). In addition, there is the risk of response fatigue (Johnston et al. 2017). Hence, given a sufficient sample size, the elicitation by single binary choice is generally preferred over using choice sequences. In addition, the binary choice approach is less challenging than multinomial choice (i.e., an experiment including more than two alternatives). In multinomial choice situations, participants may respond strategically given their expectations of other respondents’ preferences, thereby not necessarily revealing their true preferences (Carson and Groves 2007).

Based on the large sample size and the parsimonious experimental design (there are only twelve unique combinations of the attribute levels), we are able to administer a full factorial design, including all possible combinations of cost and risk reduction levels in the DCE.

As a potential caveat to our methodology, there is the issue of hypothetical bias involved with stated preferences data. For example, respondents may choose the protection alternative although they would not prefer it in the real world – hence, they could overstate their true willingness-to-pay. However, the elicitation format we use – a single binary choice question – is incentive compatible in many settings (Carson and Groves 2007). In particular, our question asks for the introduction of a new public good with coercive payment (sewage water fee) once it is introduced. As elaborated by Carson and Groves (2007), asking for this type of good using a single binary choice question in a consequential survey is incentive compatible. Regarding the consequentiality of our study, at the beginning of the survey the respondents were informed

that the results of the study “will be communicated to the media, academia, and policymakers”. Also in the introduction to the experiment, the topicality and political relevance of the flood insurance issue was highlighted to the respondents. Hence, the respondents may perceive the study results as potentially influential for real world policy decisions at their local setting, and therefore as consequential. Consequentiality is one important factor for the question being incentive compatible, and for reducing the risk of hypothetical bias (Vossler and Watson 2013, Johnston et al. 2017).¹ Moreover, we highlighted in the choice task that one should respond as if one would really have to bear the costs of the selected measure. Finally, relevant factors such as measure costs and income show expected correlations with the outcome, which further supports the validity of the stated choices.

Data Preparation

As common in household surveys, some variables have missing values, and the share of missings varies between the types of variables, with higher shares in variables on income, perceptions and attitudes. Appendix Table A1 depicts the share of missing values for all used variables in our study. As a consequence, models based on a large set of covariates may suffer from low numbers of observations, and results may be biased by the reporting behaviour of respondents. Therefore, we opted for including the missing observations in the estimation by adding a further category named “missing” for the categorical variables. For household income in € (which is the only continuous variable with missing data), we first grouped the data into four quartiles and then added the missing values as a fifth category “missing”. We did this for variables which are arguably prone to missing responses, such as income, attitudes and expectations. Thereby we treated exactly those variables where the share of missings was larger than 1.5% of the original sample (Appendix Table A1). Based on this procedure, we can keep the number of available observations in the multivariate regressions high, and can clearly assess

the marginal effects of households who provide missing data. All subsequent analyses and estimations are based on the same sample of 5,940 households.

Table 2 provides a summary of the variable definitions, while Table 3 reports the descriptive statistics for the full sample as well as for both subsamples A and B. As indicated in the last column of Table 3, most observable characteristics are not statistically distinguishable between Sample A and Sample B. However, a few variables show significant differences. The respondents randomly assigned to Sample A are somewhat younger, have slightly lower income, and are less exposed to and experienced with flood damage. These variables are, however, included as covariates in the full regression model.

Insert Table 2 here.

Insert Table 3 here.

Estimation Methods

Based on the simple design of the DCE (one choice per respondent, two alternatives available with one being the status quo), we analyse the choice data using logit models with the information treatment and attribute levels used as the main explanatory variables, and with case-specific variables as covariates.

We investigate preferences of individuals regarding flood protection measures based on their choices in the experiment. We assume that an individual n in the experiment derives a utility from choosing an alternative j - ‘flood protection measure’ or ‘no measure’. To allow for an econometric analysis, we partition the utility into two components: an observed part V_{nj} , and a random part e_{nj} :

$$U_{nj} = V_{nj} + e_{nj}$$

Here, $j=1$ if ‘flood protection measure’ is chosen, and $j=0$ if ‘no measure’ is preferred. Furthermore, we model the observed component as a linear function of attributes and individual

characteristics reflected in k parameters to be estimated. Notably, one of these parameters is the indication of the subsample the respondent was assigned to, hence whether compulsory flood insurance shall be assumed or not.

$$V_{nj} = \sum_{k=1}^K \beta_k x_{njk} = \beta' x_{nj}$$

As we normalize the utility derived from ‘no measure’ to zero, a participant chooses a flood protection measure if:

$$U_{n1} = \beta' x_{n1} + e_{n1} > 0$$

$$Y_{n1} = 1 [U_{n1} > 0]$$

Y_n is a dependent variable that takes the value of 1 if an individual n opts for ‘flood protection measure’, and 0 if he prefers the ‘no measure’ alternative.

We employ logit regression model as our main estimation method by further assuming that the unobserved component is independent and identically distributed with type I extreme value distribution. The probability that an individual chooses the flood protection alternative is then given by:

$$P_{n1} = \text{Prob}(U_{n1} > 0) = \frac{\exp(\beta' x_{n1})}{1 + \exp(\beta' x_{n1})}$$

While the probability that he or she chooses ‘no measure’:

$$P_{n0} = \frac{1}{1 + \exp(\beta' x_{n1})}$$

The model is estimated by maximization of the following likelihood function:

$$\text{LogL} = \arg\max_{\beta} [\sum_{n=1}^N (Y_n \text{Log} \left(\frac{\exp(\beta' x_{n1})}{1 + \exp(\beta' x_{n1})} \right) + (1 - Y_n) \text{Log} \left(\frac{1}{1 + \exp(\beta' x_{n1})} \right))]]$$

We estimate this model with different specifications of x_n . In the most parsimonious model, we include only the treatment indicator and the attributes of the proposed flood protection measure

(i.e. cost and risk reduction effectiveness). In another specification, we include respondent-specific socio-economic variables such as income, age and federal state indicators. Following Entorf and Jensen (2020), we allow for non-linear age effects. Finally, in the most comprehensive specification we add flood-related covariates.

We acknowledge that some of these covariates may be endogenous, e.g. because they may be correlated to unobserved variables affecting flood protection. Regarding risk perceptions, Lloyd-Smith et al. (2018) have shown that the effect of risk perceptions on drinking water-related health risk reduction is around three times higher when endogeneity is accounted for. So, for risk perceptions, we expect that coefficient estimates may be biased downwards, when endogeneity is not considered. Importantly, the main research question – whether and how the introduction of a compulsory insurance scheme affects the preferences for communal flood protection – may be assessed without the inclusion of any covariates prone to endogeneity.

To incorporate in the estimations possible unaccounted heterogeneity in responses that are correlated across individuals coming from the same region, we cluster standard errors by district.

As a robustness test for regression results from the logit model, we use a mixed logit model specification, where the coefficient estimates for the DCE attributes are not fixed across individuals, but may vary randomly. Coefficients for *riskred* and *compins* are drawn from normal distribution, and for *cost* from log-normal distribution. The model is estimated with the Stata command `mixlogit` (Hole, 2007), using 500 Halton draws. The likelihood function is maximized with Davidon-Fletcher-Powell algorithm.

Finally, we use the regression results of the most parsimonious model for deriving WTP estimates for municipal flood risk reduction. We do this by dividing the estimated coefficients of risk reduction levels and the treatment indicator by the cost coefficient. As our focus lies on

the treatment effect, we calculate WTP values and their confidence intervals with the delta method for both realisations of the treatment indicator.

4. Results and Discussion

The results of the logit model estimations are presented in Table 4. The most parsimonious model (Model 1) only includes the information treatment about compulsory flood insurance, and the parameters of the municipal flood protection measure. Besides providing first insights into the effects of the information treatment, this model may be seen as a plausibility check regarding the DCE parameter effects on stated choices.

The coefficient of *compins* is statistically non-distinguishable from zero, hence the hypothesis of decreasing preferences for municipal flood protection under a compulsory insurance scenario is not supported. As expected, the propensity to choose the flood protection measure decreases with its annual costs, and increases when it is expected to avoid at least 50 percent of future flood events.

Interestingly, there is no statistical effect of increasing the risk reduction effectiveness beyond 50%, for example to 75 or even 100 percent, compared to 50 percent. The missing effect of the 100 percent risk reduction, compared to 50 or 75 percent, is in contrast to the “certainty effect” derived from Prospect Theory (Tversky and Kahneman 1986), which predicts that a measure that totally prevents a harmful event has additional value just by eliminating the uncertainty of flooding. On the other hand, we also acknowledge that a postulated 100 percent reduction in flood risk may be perceived as less credible than a reduction by 50 percent, which may partly explain the insignificant differences between the risk reduction levels beyond 50 percent. Another possible explanation of this non-monotonic effect may be grounded in a diminishing marginal utility of flood risk reduction. Note that the vast majority of our household sample lives in relative flood safe areas, where the initial flood occurrence interval is higher than 200

years (annual flood probability less than 0.5 percent). Reducing this risk by 50 percent means the flood recurrence interval increases to once in 400 years, approximately. Increasing this recurrence interval further may be of little relevance for a majority of our sample. In other words, there may be a saturation effect in terms of flood risk reduction, and options with 50, 75 and 100 percent flood risk reduction are valued equally. Similarly, Spegel (2017) finds that Swedish citizens and public officials place statistically identical monetary values in different levels of property flood damage reduction. Still, flood protection measures that avoid only a quarter of future expected events are significantly lower valued than more effective options, all else being equal.

Turning to Model 2, we include typical socio-economic, respondent-specific variables, including federal-state-fixed effects. The results of Model 1 remain stable, and the explained variance (pseudo R²) increases from 0.018 to 0.050. Preferences for municipal flood protection are related to age in a u-shaped pattern. This confirms the findings of Entorf and Jensen (2020). One possible interpretation of that u-shape pattern, following Entorf and Jensen 2020, may be that young people have longer planning horizons and higher awareness for environmental issues, while the elderly are highly risk-averse regarding environmental threats, such as flooding. The stated choices for flood protection also relate to household income, with higher income households more often choosing the costly protection measure. This result is in line with a large literature on affordability issues of flood insurance and mitigation measures (e.g., Entorf and Jensen 2020, Osberghaus 2021), and suggests that economic affluence is not only an important factor for household-level flood risk management, but also for the support of public measures which have to be financed by lump-sum fees or communal taxes. Moreover, we control for two important political and psychological covariates – namely the stated voting preferences for a left-wing party and the score of internal locus of control. Both variables correlate with the flood protection decision: The choice for the municipal protection measure

is associated with left-wing party voting and high scores on the internal locus of control indicator. But, as discussed above, these variables may be subject to endogeneity and their correlations should be interpreted with some caution.

In Model 3, we add a set of variables measuring flood exposure, damage experience, risk perceptions, household-level risk mitigation and insurance behavior. The abovementioned relations stay stable, most of the newly added covariates show plausible correlations with flood protection preferences, and the Pseudo-R² increases to 0.074. For example, the estimated probability of choosing the protection option is by 6.5 percentage points higher for households located in flood-prone areas, and it increases by 5.8 percentage points for respondents expecting rather severe or very severe non-financial flood damages. Likewise, the preferences for flood protection are associated with the perceived occurrence probability of riverine flooding. Interestingly, municipal flood protection preferences are positively related to reported private insurance coverage. To some extent, this questions the moral hazard argument that households, who are privately insured, are expected to place lower value in structural protection measures at the municipality level, which incur additional costs to the household. However, we want to highlight again that these coefficient estimates should be seen as indications of correlations at most, given the endogeneity concerns discussed above.

In Models 2 and 3, we have controlled for the effect of reporting missing values in a number of covariates. For most variables, the effect is insignificant which suggests that these choices do not differ significantly from the choice behavior of baseline respondents. However, respondents who refuse to or cannot evaluate the probability of riverine flooding at their premises, the expected financial damage, or their level of household flood risk mitigation, are more prone to choose the protection option. This may be interpreted as a hint towards precautionary behavior in case one cannot properly assess the own flood risk.

Insert Table 4 here.

We use Model 1 to compute WTP estimates and their 95% confidence intervals via the delta method for different effectiveness levels of the protection measure, and for both subsamples. The results are reported in Table 5. The point estimates are in the range of 130 to 159 € p.a.. Consistent with the insignificant coefficient in the regressions, WTP under the mandatory insurance scenario does not differ significantly from WTP under voluntary flood insurance.

Insert Table 5 here.

Compared to prior studies on WTP for public flood protection, our estimated WTP levels seem relatively high. In a contingent valuation study in Germany, Entorf and Jensen (2020) obtain a median WTP of 50 € p.a., and Spegel (2017) finds that Swedish citizens in the region of Gothenburg value a substantial reduction of flood damage at 31 € p.a.. On the other hand, Fan and Davlasheridze (2016) derive a marginal WTP for damage reduction activities of more than 100 USD p.a. per additional CRS point. Note that the mean value of damage reduction points in their sample is 373, hence a single additional point corresponds to a relatively minor improvement in public flood safety.

However, these studies are not directly comparable due to different definitions of protection measures, estimation and elicitation methods. In contrast to costs, which are mostly measured in monetary units per year and household, the definition and quantification of the benefits of a public flood protection scheme is inherently challenging and highly context-specific. Therefore, WTP comparisons over various regional and socio-economic contexts or over differently designed studies may be problematic. We conclude that our results regarding the treatment effect and the heterogeneous preferences of household types (such as presented in Model 3) may be more informative than the mere WTP levels.

As a robustness test, we re-run Model 3 as a mixed logit model (Model 4). In this estimation, we assume that *compins* and *riskred* coefficients are random and normally distributed, and the *cost* coefficient is log-normally distributed. All estimated parameters in mixed logit model are

in line with those in logit regressions. Importantly, the effect of the randomized information treatment on compulsory flood insurance for private financial flood damage remains insignificant.

However, there may be specific sub-groups for which the information treatment has an effect. Therefore, we estimate Model 3 for specific subgroups defined by all the variables used in Model 3 (e.g., male versus female respondents, insured versus non-insured respondents, households within and outside flood-prone areas, households with different assessments of riverine flood probability). In this context, we also test the robustness of the results when excluding those participants who seem to be uncertain in their assessment of flood-related aspects. We define participants as “uncertain” who cannot report their perceived level of flood probability of riverine floods, of flash floods, or on their personal flood mitigation behavior. This applies to 829 participants, or 14 percent of the sample.

For most of the subsample analyses, we do not find any significant treatment effect. The only significant relations of flood protection preferences with the information treatment were found for households with flood insurance for contents. In Table A2 (Appendix A3), we report these results, along with respective results for other subsamples. Hence, there is some evidence that specific sub-groups are more willing to choose the flood protection measure when flood insurance is made compulsory – namely respondents who are already insured (in terms of *inscont*). Some other subgroups characterized by high flood risk (perceptions) also showed relatively high coefficients of *compins*, albeit not significant. We can only speculate on the mechanisms behind these effects. One potential reason is that these households, being already aware of a potential threat of flooding in their community, interpret the introduction of a compulsory flood insurance scheme as a credible signal of a further increasing level of flood risk. Hence, their protection preferences are higher, compared to their counterparts without this additional stimulus.

What is more relevant to the research question, however, is that we find no evidence of decreasing preferences for municipal flood protection in case of compulsory insurance in any sub-group. This also holds for other specifications than Model 3. Moreover, the sub-sample of respondents who were able to report on their flood probabilities perceptions and flood mitigation (used as a proxy for those being familiar with the flood topic) yields almost identical results. Hence, there is no support for the hypothesis of moral hazard effects of compulsory flood insurance on the preferences for structural municipal flood protection.

5. Conclusions

In the aftermath of a major flood event, it is currently debated whether flood insurance should be made compulsory for every homeowner in Germany. While a compulsory flood insurance scheme undisputedly has positive effects on the insurance penetration, its impact on household preferences for municipal flood protection measures remains unclear. This is important as in the worst case a universal insurance coverage for private homeowners would result in lower incentives for non-financial risk reduction measures at the household and municipal levels. For the household level, this moral hazard argument has been assessed empirically, suggesting that evidence for moral hazard is very limited. In contrast, insured households are often employing further risk reduction measures. Preferences for municipal flood protection measures, however, have not been analyzed in relation to a compulsory flood insurance.

We fill this gap by conducting a large-scale household survey and a DCE (N=5,940) targeted at a representative sample of the German household population. By randomly assigning respondents to information treatments, we test the effects of a compulsory insurance scheme on the stated preferences for a municipal flood protection scheme defined by risk reduction effectiveness and annual costs for the household. We hypothesize that households in the compulsory flood insurance setting should exhibit lower preferences for the public flood protection measure as their expected private monetary damages are largely covered by

insurance, hence the utility of the protection measure should be lower compared to a situation where only voluntary (hence for some households no) insurance coverage exists.

While we find several plausible effects of attributes of the available protection measures and of household characteristics, there is no impact of the randomly assigned flood insurance scheme (compulsory or voluntary) on the preferences and WTP for municipal flood protection. In particular, households in the compulsory insurance setting are not less prone to choose the flood protection measure than respondents assuming the status quo of the insurance market. This suggests that, similar to the missing moral hazard effect with regard to private flood protection, the introduction of a compulsory flood insurance scheme may not deteriorate the preferences or WTP for public flood protection measures at the municipality level. Hence, our result may be interpreted as an encouraging finding regarding the currently debated introduction of a compulsory flood insurance scheme.

However, these results are subject to some caveats. First, the employed DCE is not incentivized in monetary terms. Hence, the respondents' choices are completely hypothetical. However, this is in line with large parts of the empirical literature on that topic, and prior methodological studies have shown that stated preferences in non-incentivized experiments are incentive compatible and often a good proxy for real behavior, in particular given our setting and elicitation technique (Carlson and Groves 2007, Vossler and Watson 2013). Second, while our main findings are based on a randomized control and treatment approach, other findings regarding some of the covariates may be subject to endogeneity concerns and should accordingly be interpreted in a correlational sense. Finally, households' preferences for municipal flood protection may differ from the actual implementation of these measures, which is ultimately decided by municipal administrations or policymakers at other administrative levels. In a principal-agent language, we are measuring the preferences of the principal, but do not observe the preferences and decisions of the agent. So our policy-relevant conclusions are

based on the assumption that municipal administrations – at least largely – follow the preferences of their citizens when it comes to flood protection. Whether this is actually the case, and how national flood insurance schemes shape preferences of municipal policymakers, may be two relevant avenues for further research.

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Tables

Table 1: Attribute levels

Attributes	Attribute levels
Flood risk reduction	25%
	50%
	75%
	100%
Costs: Increase of sewage water fees	20 € p.a.
	50 € p.a.
	100 € p.a.

Table 2: Variable definitions and scales

Variable name	Definition	min	max
<i>Dependent variable</i>			
flprot	Municipal flood protection chosen	0	1
<i>Treatment variable</i>			
compins	Compulsory insurance treatment	0	1
<i>Attributes of the flood protection measure</i>			
riskred	Risk reduction in % (four levels: 25, 50, 75, 100 %)	25	100
cost	Cost of flood protection (three levels: 20, 50, 100 EUR p.a.)	20	100
<i>Socio-economic variables</i>			
age	Age in years	20	92
female	Female	0	1
educ	Education at least Abitur	0	1
incomeq4	Monthly household income in 4 quantiles	1	4
homeowner	Homeowner	0	1
hhsiz	Household size in persons (truncated at 4)	1	4
left	Voting for left-wing party	0	1
loc	Locus of control index above median, indicating internal locus of control	0	1
state	Federal state	1	16
<i>Flood-related variables</i>			
flrisk	Living within 200-years floodplain	0	1
damage	Experienced financial damage by flooding	0	1
flprobriv	High perceived probability of riverine flooding (recurrence interval every 200 years or more often)	0	1
flprobprec	High perceived probability of flash flooding (rather likely or very likely, highest two categories on a five-point Likert scale)	0	1
damexpfin	Some financial damage expected in case of a flood	0	1
damexpnfi	Severe non-financial flood damage expected (rather severe or very severe, highest two categories on a five-point Likert scale)	0	1
inshome	Home is flood insured	0	1
inscont	Contents are flood insured	0	1
flmitig	Flood mitigation implemented	0	1

N=5,940

Table 3: Descriptive statistics for the full sample, Sample A and Sample B

Variable name	Full sample		Sample A (compulsory insurance)	Sample B (voluntary insurance)	Sample A- Sample B
	Mean	N ^a	Mean	Mean	Mean difference ^b
<i>Dependent variable</i>					
flprot	0.698	5940	0.702	0.694	n.s.
<i>Treatment variable</i>					
Compins (Sample A)	0.501	5940	1.000	0.000	n.a.
<i>Attributes of the flood protection measure</i>					
riskred	62.555	5940	62.475	62.635	n.s.
cost	56.695	5940	56.757	56.633	n.s.
<i>Socio-economic variables</i>					
age	59.932	5940	59.554	60.311	-0.757*
female	0.332	5940	0.327	0.338	n.s.
educ	0.510	5940	0.512	0.509	n.s.
incomeq4	2.272	5296	2.242	2.301	-0.059*
homeowner	0.635	5940	0.625	0.644	n.s.
hhsiz	2.019	5940	2.007	2.030	n.s.
left	0.396	5761	0.398	0.393	n.s.
loc	0.504	5842	0.496	0.512	n.s.
<i>Flood-related variables</i>					
flrisk	0.076	5411	0.069	0.082	-0.013*
damage	0.123	5940	0.114	0.131	-0.017**
flprobriv	0.562	5203	0.553	0.571	n.s.
flprobprec	0.063	5862	0.064	0.062	n.s.
damexpfin	0.655	5162	0.653	0.658	n.s.
damexpnfi	0.270	5511	0.275	0.266	n.s.
inshome	0.756	3770	0.750	0.762	n.s.
inscont	0.556	5940	0.553	0.558	n.s.
flmitig	0.491	5111	0.484	0.498	n.s.

a) Missing observations are omitted, which explains the varying number of observations. In the regressions, missings values are included as separate categories (see text).

b) Differences are tested for significance using the Wilcoxon ranksum test. The stars *, ** indicate significance levels of 10, 5%, respectively.

Table 4: Regression results. Dependent variable: Choice of municipal flood protection measure

Variable type	Variable	Model 1 Logit	Model 2 Logit	Model 3 Logit	Model 4 Mixed Logit
Treatment variable	compins	0.040 (0.055)	0.053 (0.057)	0.074 (0.057)	0.170 (0.145)
Risk reduction by flood protection measure	riskred: 25%	(baseline)	(baseline)	(baseline)	(baseline)
	riskred: 50%	0.221*** (0.083)	0.236*** (0.085)	0.251*** (0.086)	0.475** (0.217)
	riskred: 75%	0.230*** (0.076)	0.234*** (0.080)	0.239*** (0.081)	0.664** (0.301)
	riskred:100%	0.199** (0.080)	0.215*** (0.081)	0.240*** (0.081)	0.296*** (0.107)
Cost of measure	Cost in EUR p.a.	-0.009*** (0.001)	-0.010*** (0.001)	-0.010*** (0.001)	-0.015*** (0.005)
Socio-economics	age		-0.042** (0.019)	-0.051*** (0.019)	-0.072*** (0.027)
	age squared		0.00026* (0.00015)	0.00035** (0.00015)	0.00049** (0.00022)
	female		-0.025 (0.061)	-0.043 (0.063)	-0.053 (0.089)
	homeowner		0.100 (0.066)	-0.168* (0.093)	-0.219 (0.135)
	hhsiz		-0.029 (0.039)	-0.046 (0.040)	-0.060 (0.056)
	educ		0.069 (0.058)	0.094 (0.059)	0.124 (0.089)
Household income	incomeq4: quantile 1		(baseline)	(baseline)	(baseline)
	incomeq4: quantile 2		0.288*** (0.078)	0.292*** (0.080)	0.385*** (0.125)
	incomeq4: quantile 3		0.410*** (0.093)	0.424*** (0.094)	0.566*** (0.149)
	incomeq4: quantile 4		0.593*** (0.097)	0.637*** (0.098)	0.827*** (0.176)
	incomeq4: missing		0.053 (0.104)	0.047 (0.105)	0.060 (0.141)
Political attitudes	left: yes		0.528*** (0.065)	0.564*** (0.066)	0.760*** (0.134)
	left: missing		-0.135 (0.158)	-0.172 (0.167)	-0.238 (0.226)
Internal locus of control	loc: above median		0.209*** (0.061)	0.243*** (0.063)	0.338*** (0.100)
	loc: missing		-0.018 (0.229)	0.095 (0.230)	0.166 (0.301)
Flood exposure and damage experience	flrisk: yes			0.346*** (0.121)	0.458** (0.180)
	flrisk: missing			-0.084 (0.106)	-0.142 (0.150)
	damage			0.082 (0.098)	0.113 (0.140)
Expected probability of flooding, riverine floods	flprobriv: "Every 200 years or more often"			0.352*** (0.070)	0.468*** (0.107)
	flprobriv: missing			0.360*** (0.093)	0.480*** (0.153)
Expected probability of flooding, flash floods	flprobprec: "rather likely or "very likely"			0.092 (0.128)	0.140 (0.175)
	flprobprec: missing			0.133 (0.261)	0.116 (0.365)
Financial flood damage expectations	damexpfin: yes			0.409*** (0.073)	0.560*** (0.132)
	damexpfin: missing			0.267** (0.103)	0.364** (0.154)
Non-financial flood damage expectations	damexpnfi: "rather severe or very severe"			0.294*** (0.074)	0.400*** (0.126)
	damexpnfi: missing			-0.034 (0.126)	-0.022 (0.172)

Flood insurance coverage and mitigation behavior	inshome: Yes			0.208**	0.280**
				(0.097)	(0.132)
	inscont: Yes			0.140*	0.187**
				(0.074)	(0.091)
	flmitig: Yes			0.087	0.094
				(0.069)	(0.101)
	flmitig: missing			0.257***	0.342**
				(0.088)	(0.134)
S.D. of random coef.	compins				0.737
					(0.560)
	riskred: 50%				0.976*
					(0.548)
	riskred: 75%				1.584**
					(0.657)
	riskred:100%				0.112
					(0.133)
	cost				0.027
					(0.024)
Constant	Constant	1.197***	2.405***	2.010***	2.183***
		(0.092)	(0.609)	(0.610)	(0.800)
	State dummies included	No	Yes	Yes	Yes
	<i>N</i>	5940	5940	5940	5940
	pseudo <i>R</i> ²	0.018	0.050	0.074	

The stars *, **, *** indicate significance levels of 10, 5, and 1%, respectively. Standard errors (in parentheses) are clustered by district in logit regressions (Models 1 to 3), and robust in mixed logit (Model 4).

Table 5: WTP and 95% confidence intervals, based on Model 1

in € p.a.		compulsory insurance		voluntary insurance	
		WTP	95% confidence interval	WTP	95% confidence interval
Flood risk reduction	25%	133.94	(115.52-152.36)	129.65	(111.13-148.17)
	50%	157.84	(133.64-182.04)	153.55	(129.39-177.70)
	75%	158.85	(136.46-181.24)	154.55	(132.21-176.90)
	100%	155.47	(132.02-178.93)	151.18	(127.01-175.36)

Figure titles

Figure 1: Text of the choice task and example choice card.

Notes

¹ As pointed out by Johnston et al. (2017), there is the possibility of eliciting the perceived consequentiality before or after the DCE. We have not done that for reasons of brevity, and because recent research has questioned the utility of such an axillary question: After addressing potential endogeneity, Lloyd-Smith et al. (2019) find that the perceived consequentiality does not affect the voting behavior in the experiment, but the placement of the question in the questionnaire seems to be important. They conclude that “the new trend of including consequentiality follow-up questions in surveys may not be a panacea for SP [stated preferences] validity issues.”






Please tell us whether you would support the municipal flood protection measure shown. Please answer the question as if you would actually have to pay the associated fee increase. If the flood protection measure presented is not attractive to you or you feel the fee increase is too high, please select the "No measure" alternative.

For Sample A:

Important: In your answer, please assume that there would be compulsory insurance for natural hazards in Germany. In the event of a flood, most of the financial damage to your household would then be reimbursed by the insurance company.

For Sample B:

Important: In your answer, please assume that voluntary insurance against natural hazards will continue to exist in Germany in the future.

Flood protection measure	No measure
	
<p>Flood risk reduction by 75%</p>  <p>Meaning that $\frac{3}{4}$ of all future flood events will be avoided</p>	<p>No flood risk reduction</p> 
<p>Increase of sewage water fees by 100 € p.a.</p> 	<p>No increase of sewage water fees</p>
<p><input type="radio"/></p> <p>I prefer this alternative</p>	<p><input type="radio"/></p> <p>I prefer this alternative</p>