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Insurance, Public Assistance, and Household Flood Risk Reduction: A Comparative Study of Austria, England, and Romania

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In light of increasing losses from floods, many researchers and policymakers are looking for ways to encourage flood risk reduction among communities, business, and households. In this study, we investigate risk-reduction behavior at the household level in three European Union Member States with fundamentally different insurance and compensation schemes. We try to understand if and how insurance and public assistance influence private risk-reduction behavior. Data were collected using a telephone survey ($n = 1{,}849$) of household decisionmakers in flood-prone areas. We show that insurance overall is positively associated with private risk-reduction behavior. Warranties, premium discounts, and information provision with respect to risk reduction may be an explanation for this positive relationship in the case of structural measures. Public incentives for risk-reduction measures by means of financial and in-kind support, and particularly through the provision of information, are also associated with enhancing risk reduction. In this study, public compensation is not negatively associated with private risk-reduction behavior. This does not disprove such a relationship, but the negative effect may be mitigated by factors related to respondents' capacity to implement measures or social norms that were not included in the analysis. The data suggest that large-scale flood protection infrastructure creates a sense of security that is associated with a lower level of preparedness. Across the board there is ample room to improve both public and private policies to provide effective incentives for household-level risk reduction.

KEY WORDS: Climate change adaptation; flood insurance; moral hazard; public incentive; risk reduction

1. INTRODUCTION

Floods are the most devastating disasters globally, accounting for 43% of all recorded natural disasters between 1994 and 2013. In this period, floods affected almost 2.5 million people, causing more damage to infrastructure than any other natural hazard, and USD 636 billion of economic losses worldwide.(1) This is due mainly to an accumulation of assets in flood-prone areas.(1) Reducing losses and damages from floods and other natural disasters is thus of utmost importance "to enhance the economic, social, health, and cultural resilience of persons, communities, countries, and their assets."(2) However, despite evidence of their high economic returns, public and private stakeholders throughout the world fail to implement sufficient risk-reduction measures.(2)

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To date, research has focused mainly on the cognitive drivers of risk-reduction behavior, most importantly on factors such as risk perception, risk attitudes, previous experience, and socioeconomic factors. More recently, researchers designed protection motivation theory to include coping capacity as an important explanation.[3,4] Reviews of these drivers show how in comparison institutional drivers are less broadly covered.[5,6] With the increasing relevance of public and private institutions in designing comprehensive risk management strategies, the potential to foster household-level risk reduction, but also to inadvertently discourage it, is becoming increasingly relevant.

Much of the ongoing discussion on insurance reform focuses on the argument that moving from undifferentiated to risk-based insurance schemes will further risk reduction.[7–11] If premiums reflect the actual risk in terms of hazard, exposure, and vulnerability, i.e., locating in lower-risk areas means lower premiums, and if private risk-reduction measures were to be rewarded by reduced premiums, overall risk reduction could be encouraged and potential effects of moral hazard would be reduced. Moral hazard, assuming asymmetric information, refers to policyholders' low willingness to implement risk-reduction measures or even relocate out of flood-prone areas when expecting insurance payouts. The same claim is made for public postdisaster assistance and compensation schemes, which in this narrative crowd out insurance and reduce private risk-reduction behavior,[12–14] sometimes referred to as charity hazard. Despite arguments for reducing public disaster assistance in favor of risk-based insurance programs, no country in Europe can claim full risk-based insurance pricing, and many countries, including the Netherlands, Austria, and the United Kingdom, have experienced difficulties in implementing reforms in this direction.[15] At the same time, in only a few countries do citizens rely exclusively on public *ex post* assistance.

In this study, we investigate how existing insurance programs and public assistance architectures are associated with risk reduction at the household level. We compare Austria, Romania, and England, each with fundamentally different risk management approaches. In Austria, *ex post* public compensation has been institutionalized for two decades, unlike in England where people can only rely on market insurance. Romania is the only selected country where disaster insurance is mandatory, but the communist legacy of government responsibility for flood risk is difficult to cast off and market penetration for insurance remains low (see also Section 3). Our findings are crucial for identifying whether and how risk management schemes can be usefully redesigned in order to better foster risk-reduction behavior at the household level.

2. BACKGROUND

In light of the complex drivers of human behavior, research on private risk reduction, including flood preparedness and risk reduction, has increased considerably over the past two decades. This also applies to the context of disaster preparedness and risk reduction in general and to flood risk in particular. Comprehensive literature reviews have illustrated the importance of risk perception, past experience, risk attitudes, and coping capacity, although the direction of any associations may vary across studies, depending on contextual factors and research design.[5,6] Incentives from private and/or public insurance and other government risk management efforts feature less prominently, but receive increasing attention. This section summarizes existing literature on theoretical reasoning and empirical findings of incentive mechanisms for risk-reduction behavior.

In the absence of appropriate incentives, economic theory states that insurance may lead to moral hazard. Stiglitz described the fundamental conflict of moral hazard as "the more and better insurance is provided against some contingency, the less incentive individuals have to avoid the insured event, because the less they bear the full consequence of their actions."[16] Economic theory on pure moral hazard suggests that risk-based pricing is impossible or unfeasible due to high transaction costs, but moral hazard should be counteracted by means of deductibles and indemnity limits, i.e., not fully insuring risk, and thereby setting an incentive. It also states that any government insurance not specifying risk-reduction measures is detrimental to market efficiency.[16]

The problem of moral hazard also applies to postdisaster public aid and compensation, also known as the Samaritan's dilemma,[17] referring to a situation where beneficiaries expecting aid have less incentive to improve their own situation by reducing their risk, but rely on external compensation. For natural disasters, Browne and Hoyt[18] substitute the term "Samaritan's dilemma" with *charity hazard* to denominate a crowding-out effect of public *ex post* compensation on insurance. Raschky and Weck-Hannemann as well as Deryugina and Barrett

expand the definition to include risk mitigation efforts on behalf of the potential recipient.[19,20]

At the same time, there is limited evidence on which mechanisms insurers use in practice that can be associated with risk reduction. Lorant *et al.* list those incentive mechanisms available to insurers: insurance limits and deductibles, i.e., the part of an insurance claim to be paid by the insured; warranties, i.e., terms and situations when an insurance policy applies; risk engineering, referring to direct support determining suitable risk-reduction measures; and awareness raising and persuasion by means of information sharing. While these measures are effective in theory, the practice falls far short of their potential.[21] Indeed, empirical evidence on successful risk-based pricing is scarce. While insurers increasingly implement partially risk-based premiums using improved hazard risk mapping, they rarely include warranties, or provide premium or deductible discounts, for the implementation of risk-reduction measures.[15] In Germany, for example, where insurance premiums are calculated based on risk zones, mitigation behavior in insured households is slightly higher compared to uninsured households.[22] One reason may be that some German insurers attach warranties for backflow valves to their policies.[23] In the French NatCat system, insurers' incentives are positively associated with risk-reduction measures taken by households. However, information provided by insurers was not associated with risk-reducing behavior.[5] Despite this limited evidence for incentive mechanisms from insurers, particularly studies for Germany find no evidence for the existence of moral hazard in practice.[22–24]

Several studies, however, provide empirical evidence for the existence of charity hazard based on respondents' intention to purchase insurance and/or implement other risk-reduction measures, if compensation could be expected. Raschky *et al.*, using stated preference, found that in the Austrian province of Tyrol even partial public *ex post* compensation discouraged the willingness to pay for insurance policies.[13] Similar results are available for Taiwan,[14] England and Wales,[25] and the Netherlands.[26] These studies, however, do not provide evidence whether charity hazard in practice is salient enough to outweigh other drivers of risk reduction.

Governments have a range of tools at their disposal that may encourage private risk reduction. These can be regulatory, such as building codes; financial, such as subsidies, tax breaks, or loans for risk-reduction measures; the provision of in-kind assistance, such as mobile barriers; and the provision of information about risks and risk-reduction measures. Empirical evidence on the effectiveness of such measures is increasingly available, but not always decisive. Poussin *et al.* found that people in the French NatCat insurance system who looked for government-provided information on flood protection implemented more structural and avoidance measures.[5,27] "Incentives from the municipality" were positively associated with the number of preparedness measures, as well as with the intention to take measures in the future. Also, information provided by local authorities and insurers was found to play a significant role. This is in line with findings from Thieken *et al.* and Sims and Baumann in their case studies for Germany[28] and the United States,[29] where information did affect risk-reduction behavior positively. Contradicting these findings, Miceli *et al.* found that communication by public authorities in Italian communities had no influence on households' risk-reduction behavior.[30] Similarly so, Osberghaus and Philippi report that provincial campaigns for disaster risk reduction did not influence household behavior.[23] Several authors highlight the positive impact of building codes.[7,31,32] Findings are not uniform, however, as others find no impact of building codes on risk-reduction behavior.[27]

Generally, governments focus more on large-scale flood protection opportunities than on incentivizing private risk-reduction behavior. Keating *et al.* highlight how the levee effect may result from the public provision of flood protection infrastructure without considering human, social, and environmental dynamics:[33,34] the main purpose of a levee is to protect against flooding, and at the same time it may create a false sense of security, increasing development and thus exposure of people and assets in its catchment. When the levee fails, the disaster will be much bigger as more is at stake and people are less prepared.[34–37] This has been documented in Germany and Austria as contributing to the extent of losses in the 2013 floods.[38]

Ultimately, a growing discourse shows how insurance and assistance schemes could contribute to enhancing risk reduction, but little knowledge exists on how unstylized design features pan out in reality. This is where we see the contribution of this study. Since practices vary not only across countries, but also across individual insurers and local jurisdictional levels, a bottom-up perspective is useful to gain

further insight on the risk-reduction behavior of households in the light of different public and private (dis-)incentives from insurance, *ex post* compensation, *ex ante* assistance, and public flood protection infrastructure.

3. INSTITUTIONAL DESCRIPTION OF COUNTRY CASES

The three selected European case study countries—Austria, Romania, and England—have strongly differentiated risk compensation and insurance systems. We describe each, in turn.

Austria is one of the few countries that provides institutionalized *ex post* compensation for disaster losses to its residents. The national budget includes a catastrophe fund (Katastrophenfonds) capitalized from income, capital yields, and corporate income taxes. The fund is primarily used to finance large-scale protection infrastructure (*ex ante* risk management), but also serves to compensate private households for damages from natural catastrophes, among which floods feature most prominently. Disbursements from the fund are matched at the provincial level, which also distributes the payouts based on provincial rules. Typically, the fund compensates losses above EUR 1,000, and up to 20–50% of damages, with exceptions for cases of extreme distress, in which up to 100% of damages have been refunded. Flood victims are not legally entitled to compensation from the fund. Often, insured losses are exempt from compensation, which is a disincentive for purchasing insurance, contributing to low flood insurance market penetration.

Flood insurance in Austria is available from the private market, although often denied for properties in high-risk areas. Recently, it has become more common to include coverage for natural catastrophes, including floods, in homeowners' property insurance contracts. Most policies have indemnity limits of only a few thousand Euros,[39] although extension of coverage may be possible. This recently introduced coverage, which often is not optional, makes it difficult to assess market penetration, previously reported as being low at 10–25%.[40]

England, in stark contrast to Austria, relies on private insurance with a market penetration of over 75%.[41] This high penetration rate is in part due to homeowners being obliged to purchase flood insurance as a condition for a mortgage. The British government is not legally bound to provide *ex post* compensation for disaster damages, and there is no tradition of providing *ad hoc* aid on a significant scale.

Until recently, England relied on a "gentlemen's agreement" between insurers and the government, by which insurance was offered at affordable premiums for the entire population at flood risk, as long as the government provided flood protection infrastructure in those same areas. According to the insurance industry, this agreement was insufficiently adhered to by the government, and thus a comprehensive reform effort was initiated in 2014.[42] Insurers are increasingly setting their premiums partially on risk, by differentiating premiums according to postal zones. However, this is not directly communicated to consumers. Some insurers set or increase deductibles after a property has suffered from flood damage.

Romania's communist history creates a special case for this study. The state played a very paternal role in providing comprehensive flood protection infrastructure between 1960 and 1990, with the overall aim to eliminate all major flood risk. These exclusively technical solutions (i.e., canals, levees, pumping stations, etc.) are today often considered maladaptations, as they negatively influence river ecosystems and have even increased flood intensity, for example, along the Danube.[43,44] At the same time, flood insurance was compulsory, especially for agricultural areas. After this system was abolished, due to unclear regulations, the government occasionally paid relief to flood victims.

Romania introduced a compulsory insurance system with law nr. 260/2008 and law 191/2015. This scheme, backed by a national insurance pool (PAID), obliges all Romanian citizens to purchase bundled multihazard insurance, with the option of cover for either EUR 10,000 or EUR 20,000, depending on the quality of the building. Thus, premiums depend only on the construction type and, quite exceptionally, not on hazard probability or exposure. This law also states that no compensation will be paid to uninsured households.[45] Market penetration in the new scheme reached 18% in mid 2015, with higher penetration rates in urban than in rural areas.[46,47] This low penetration despite the compulsory nature of the system reflects difficulties to enforce the law, particularly in rural areas. Armaş *et al.* found the lack of insurance uptake to be related to a lack of trust in insurers as well as missing information on how to buy insurance.[43] We only have anecdotal evidence for other reasons explaining the low penetration rate. For example, the fact that people in rural areas often

have difficulties proving the ownership of their home, which is a prerequisite for buying insurance.

All three countries have publicly accessible flood risk maps available online, and flood risk management plans in the final stages of preparation in line with E.U. regulations. With the exception of the province of Lower Austria, the countries lack building codes that prescribe risk-reduction measures. Even in the case of Lower Austria, the regulations regard only one measure, mandating that floor levels be raised above certain flood levels. Emerging regulation and guidance on new developments and drainage in England are unlikely to influence the outcome of this study.

4. METHOD

4.1. Sampling and Data Collection

Data were collected by a professional survey company (IMAS), which conducted 1,849 computer-assisted telephone interviews (CATI) in flood risk areas in Austria (600), England (600), and Romania (649) among the voting-age population. In order to reduce the probability of rented homes in the sample, the focus was on rural communities, assuming that rural residents have higher home ownership and that renters tend to be less aware and take less action in relation to risk mitigation than homeowners.[4,28,48]

The sampling process for flood risk studies is complicated, as flood risk areas usually do not correspond with administrative entities, and data protection laws do not allow us to determine the addresses of respondents and thus the identification of objective flood risk for each household. Data on flood risk areas are also not harmonized across countries, and require different criteria for determining the sample. We selected communities using the public flood risk information available in each of the three countries. For Austria, we used the flood risk zones provided by the public online tool HORA in combination with APSFR (Areas of Potential Significant Flood Risk) information provided by the provinces for setting up the E.U.-mandated flood risk management plans. The sample frame included all postal codes where at least 30% of addresses are in flood-risk areas, and where, according to the APSFR, 500–5,000 inhabitants have been affected at least by a 100-year flood. We selected postal codes for the provinces of Vorarlberg, Tyrol, Salzburg, Lower Austria, and Burgenland. For England, we selected communities based on the National Flood Risk Assessment 2011.[49] The sample frame is limited to postal codes fulfilling the following conditions: (1) 80% of residential properties are at high (up to 1 in 30 chance) or medium (up to 1 in a 100 chance) flood risk; (2) less than 40% of homes are rented; and (3) the most recent floods in the respective post district occurred after 2000. For Romania, we selected communities directly from the interactive flood risk and hazard map of Romania,[50] activating the flood risk layer for 1 in 10 year events in order to identify communities that include areas of high flood risk.

4.2. Questionnaire Design and Sample Description

In designing the questionnaire, we took into account recent studies on flood risk. Qualitative interviews with experts and stakeholders in Austria, England, and Romania served as a first reference for determining content standards. The questionnaire master was developed in English and then translated to German and Romanian. It was tested for cognitive and usability standards as well as duration in a small subset of informal interviews and a pretest of 25 interviews. Overall, the questionnaire consisted of both closed and open-ended questions. The interviews were conducted in July and August 2015. In terms of response rate, the number of contact attempts in order to complete one successful interview was 44 in Austria, 40 in Romania, and 11 in England. This stark difference resulted in part from the different sampling approaches used. Interviews took an average of 16 minutes; this included questions for other purposes than this analysis.

We included two preselection questions at the beginning of the questionnaire, inquiring about the perceived level of flood risk on a five-point scale and about the decision-making capacity of the respondent (Table S2, Supporting Information), aborting interviews where respondents reported no flood risk, or no decision-making competences. Although the unit of analysis is the household, we acknowledge that questions relating to perceptions are tied to individual respondents. For this analysis, we assumed that perceptions and opinions are shared across the household. We thus use household and respondents as being semantically appropriate in the text, but referring to the same unit of analysis.

Table I lists the median age of the sample population as 57 years and thus above the national median age of each country, although less so in

Table I. Median Age and Gender Balance for Each Sample Region Compared to National Numbers[51]

	Median Age (Years)		Gender (Women per 100 Men)	
	Sample	Country	Sample	Country
Austria	56	42.9	121	104.7
Romania	59	40.8	163	103.2
England	54.5	39.9 (U.K.)	127	104.7 (U.K.)
Total	**57**	–	**137**	–

England and Austria than in Romania. This may be because our sample frame was mostly restricted to rural areas, where the population is on average older than in urban areas. Interviewing times, although covering weekends, mornings, and evenings as well as throughout the day, may lead to older people and women being overrepresented. Finally, women are generally more likely to respond to phone surveys than men,[55] which may account for some of the gender bias in our sample compared to national distribution of sex.

We collected information on income using country-specific categories for the monthly net household income. In order to achieve some kind of comparability, we created income groups with the categories low, middle, and high, where middle includes those two income categories closest to the national mean household income as reported by EUROSTAT for 2015. This shows that higher-income households are overrepresented compared to low-income households, which may again be explained by homeowners being the main target of this survey.

The largest proportion of the sample population in each country state high school and technical or vocational training as their highest complete level of education. The Austrian subsample has a lower number of university graduates, but a high number of respondents who had completed technical or vocational training compared to England and Romania.

4.3. Analytical Framework

For the purpose of identifying ways insurance and public assistance efforts may be associated with household risk-reduction behavior, we explored the variables shown in Fig. 1. Our analytical framework is inspired by Poussin *et al.*, who expanded protection motivation theory for additional variables that had been identified in the literature as potentially relevant drivers of private risk-reduction behavior.[5] We collected information on risk-reduction behavior as the outcome variable differentiated for structural (SMs) as well as avoidance and preparedness measures (APMs). SMs are often costlier and more complicated to implement than APMs; some may only be implemented when building a house, such as using flood-resistant materials for foundations; others may need expensive retrofitting, such as fitting new waterproof windows, or moving wiring or piping. Only a few SMs are comparably inexpensive, such as installing a pump and/or backflow valves. APMs, such as emergency plans, moving expensive appliances, and keeping sandbags ready, are considerably less expensive and usually easier to implement. Indeed, they do not require structural changes, and less advance preparation. Unlike many other studies, we did not predefine measures or categories of measures. We account only for measures respondents took explicitly as SMs or APMs in order to avoid two kinds of bias: (1) focus on a predetermined set of measures, or toward measures people feel they should have taken; and (2) we avoid missing measures that are specific to a certain area due to certain landscape features or cultural heritage. We acknowledge that this approach might to some extent underrepresent the actual number of measures implemented. It also may create a bias due to systematically different capabilities to remember the implementation of the measures. Respondents dealing more frequently with floods may more easily recall the measures implemented than others who have installed the same measures based on a recommendation, but have no experience with floods.

The predictor variables are (1) the availability of public *ex post* relief, which should negatively influence risk-reduction behavior in the case of Austria. We were only able to assess this by means of a country dummy variable. This is insufficient to prove or disprove charity hazard as the scope of our study does not allow us to control for other important factors that may systematically differ across countries. Also, in practice we rarely find an ideal setup to test charity hazard. In Austria, relief payments are not covering 100% of damages and are not legally binding. Moreover, at least some level of insurance is available for most households. Thus, it will be impossible to dissect any actual charity hazard. The only conclusion we may infer is about whether any disincentive will manifest in less risk-reduction measures taken by Austrian compared to Romanian and English households, despite other drivers not explicitly included. (2) Public measures at

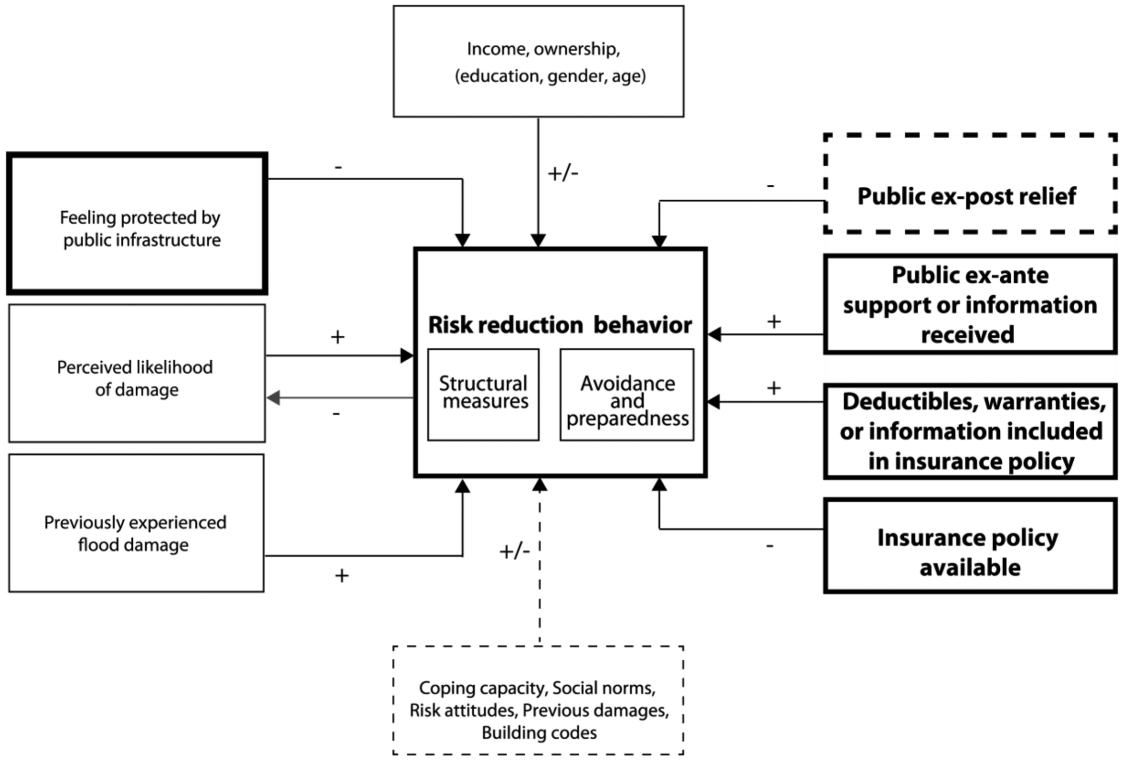

Fig. 1. Dependent and independent variables and their assumed positive and/or negative associations. Thick lines indicate the main variables. The thinner solid lines indicate the control variables, whereas the thin dotted lines highlight relevant variables that we were not able to address in the regression model.

the municipal, provincial, and national scales, such as financial and in-kind assistance (e.g., sand bags) or the provision of information, which can be associated positively with risk-reduction behavior. (3) Being insured for investigating whether insured households tend to implement less risk-reduction measures because of moral hazard should be more visible in the case of England and Romania, where indemnity limits are considerably higher than in Austria. (4) In the case of insurance, we also try to dissect any associations of deductibles, warranties, and whether respondents have received information on risk-reduction measures from insurers. (5) We include the extent to which households feel protected by large-scale flood protection infrastructure, which we assume will be negatively associated with risk-reduction behavior. We control for the anticipated positive effects of (6) previous flood experience, and (7) perceived likelihood of flood damages in the next 10 years. Finally, we control for socioeconomic variables household income and highest level of education, demographic variables income and gender, and in the case of SMs, for ownership. We did this under the assumption that most APMs may be also in the interest of renters, whereas SMs are mostly relevant for homeowners.

The dotted box indicates other relevant variables, including social norms, coping capacity, and risk attitudes, that we could not include in the analysis for lack of adequate data. We accounted for some of these aspects indirectly, through the institutional background, and an open question for households that did not take SM and/or APM. An overview of the questions asked to elicit these variables, and any transformation of variable levels, can be found in Table S2 of the Supporting Information.

Most respondents (95%) specified no or only one measure in each category of risk-reduction measures. We thus coded the outcome variables to be binary with 0 = no measure installed and 1 = one or more measures installed. In the next section, we use descriptive statistics to compare each variable across countries. Due to the binary coding of our dependent variables, we then use logistic regression analysis to identify associations between risk-reduction behavior and our predictors.

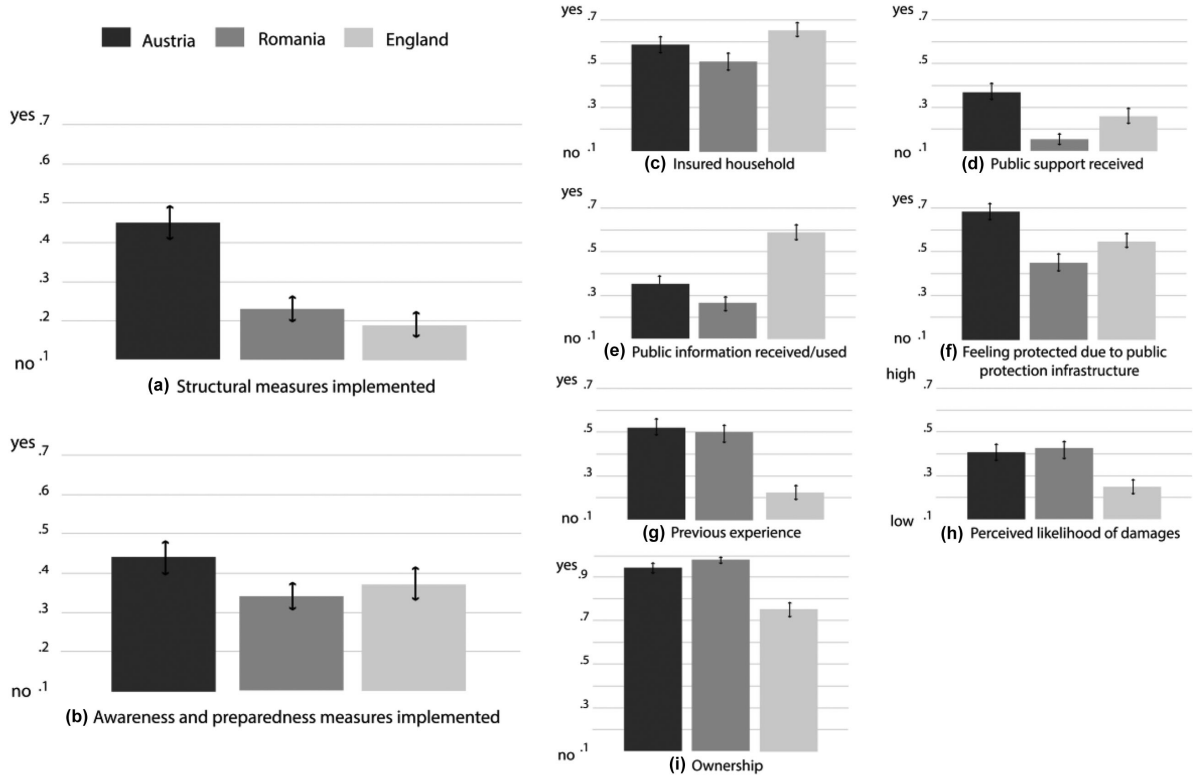

Fig. 2. Overview of outcome and explanatory variables (mean and 95% confidence interval) by country. The respective numbers are summarized in Table S3 in the Supporting Information.

5. RESULTS

5.1. Descriptive Statistics

Fig. 2 compares the means and 95% confidence intervals for all variables for the three countries. Due to the binary nature of the variables, the mean equals the proportion of observations with a positive outcome. Fig. 2(a) shows that there was a significant difference in the number of households that have SMs implemented versus those that have no measures across Austria (45%), Romania (23%), and England (19%). This difference was much less pronounced for APMs, with 44%, 35%, and 38%, respectively (Fig. 2b).

The share of households reporting to hold flood insurance was generally high, but somewhat higher among English households—65%, compared to 58% and 51% in Austria and Romania (Fig. 2c). Thirty-seven percent of Austrian households reported having received financial incentives or material support for risk-reduction measures from public authorities, compared to 26% in England and 15% in Romania (Fig 2d). In terms of awareness of public information, England stood out with 58%, compared to Austria (35%) and Romania (26%) (Fig. 2e). Almost 70% of Austrian respondents felt protected due to publicly provided flood protection infrastructure, as do 45% of Romanian and 54% of English respondents (Fig. 2f).

The share of respondents who perceived the likelihood of damages from floods to be from medium to very high was much lower in England (25%) than in Austria (41%) or Romania (42%) (Fig. 2h). This difference was reflected in the share of households that had previously suffered damages from floods: 23% in England, 53% in Austria, and 51% in Romania (Fig. 2g).

Fig. 2(i) shows that our aim to reach mostly homeowners was best achieved in Austria (93%) and Romania (98%), and less so in England (75%).

5.1.1. Direct Public Incentives

We further explored public authorities at different administrative levels as sources of support and

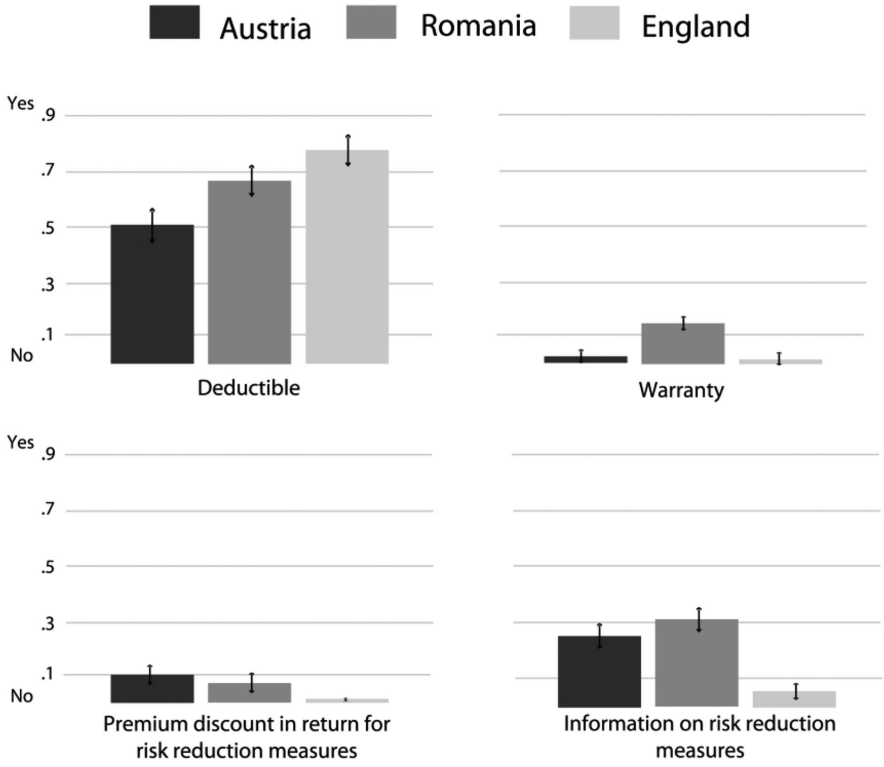

Fig. 3. Different insurance mechanisms that may be positively associated with the implementation of risk-reduction measures. Means and 95% confidence intervals.

information. We acknowledge that our data reflect the source only as perceived by respondents, which may not be identical with the actual provider of the incentive. The respondents report that most public incentives, including financial, material, and informational support, originate from local authorities: 74% and 75% of all public incentives in Austria and England, respectively, and 85% in Romania. For the provision of information on risk-reduction measures, this means 68% of all information received in Austria, 63% in Romania, and 61% in England was perceived to originate from local authorities. Respondents reported other public support as being most often in-kind, and also received locally. Few respondents reported public financial support for the implementation of risk-reduction measures, but, if so, it was reported more often in Austria than in England or Romania.

5.1.2. Incentives from Insurers

With insured households we followed up on the availability of certain incentives for risk reduction that may be included in an insurance policy, in particular, deductibles, warranties, premium discounts, and information on risk reduction (Fig. 3). Over 70% of English, over 60% of Romanian, and about 50% of Austrian respondents were aware of deductibles in their insurance policies. Warranties and premium discounts were mentioned by only a few percent of respondents in all countries: Romania stands out with more than 10% of respondents having had to fulfill certain risk-reduction–related conditions in order to purchase a flood insurance policy. About 30% of Romanians also reported having received information on risk-reduction measures from insurers. Also in Austria, over 20% of respondents reported such a service, whereas only about 5% of English respondents did.

5.2. The Logistic Regression

We ran logistic regressions for SMs and APMs independently, including the predictor variables described in Fig. 1. A previous analysis had included additional variables such as age, gender, income, and education, as well as perceived responsibility for flood protection and flood damages. We excluded

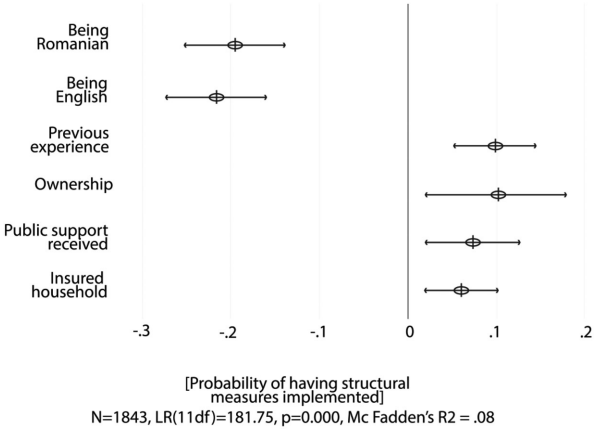

Fig. 4. Variables significantly associated with the implementation of structural flood protection measures. Average marginal effects and 95% confidence intervals.

these variables from the analysis here for a clearer presentation of results, as we found no significant associations and no major increase in the significance of the overall model. We acknowledge that our income variable was barely insignificant for SMs. A more differentiated analysis with respect to different SMs might have rendered the variable more salient.

Figs. 4 and 5 summarize the average marginal effects of the variables significantly associated with risk-reduction behavior (the complete regression can be found in Table S4 of the Supporting Information). The low values for R^2 and the small marginal effects reflect the low explanatory power, despite the model being significant overall. This is not unexpected, as neither of the insurance and compensation schemes investigated provide strong incentives and disincentives for private flood risk mitigation.

Fig. 4 shows how Romanian and English respondents are about 20% less likely to have SMs compared to Austrian respondents. This result is robust, accounting for the national differences in the other variables. The difference between Romania and England is only 3%. Fig. 4 also shows that insured households were 6% more likely to have SMs in place than uninsured households. Households that had received public support *ex ante* were 7% more likely to reduce their risks compared to households that had not received such support.

Control variables significantly associated with risk-reduction behavior are previous experience and ownership; both increased the probability of having implemented SMs by 10%.

Fig. 5 shows that the significant associations for APMs were different from those for SMs. We find that insurance increases the probability of households implementing APMs by 9%. Public support and the provision of information were also positively associated with having APMs in place at 9% and 11%, respectively. At the same time, public action may be negatively associated with risk-reduction behavior, as feeling protected from floods because of public protection infrastructure reduced the probability of having APMs in place by 8%. Unlike for SMs, where risk perception was not influential, respondents with a high perceived likelihood of damages were 15% more probable to have avoidance or APMs implemented.

We investigated a subsample of households that had previously experienced flood damage in Fig. 5, indicated in gray, as the level of experience with floods varied particularly for the English population compared to the other countries. Also, a preliminary association analysis showed a strong correlation of experience and risk perception (Table S5, Supporting Information). The analysis of the subsample shows how mitigation behavior with respect to APMs is similar across countries; indeed, no significant difference can be found between England and Austria. The difference in experience did not affect the results for SMs, and is therefore not included here. The analysis of the subsample shows that there is an independent effect of risk perception on risk-reduction behavior. Other variance of independent variables across countries was tested using interaction terms, and subsamples, and did neither increase model fit, nor yield additional insights.

In order to determine the extent to which insurers' incentives are associated with risk-reduction behavior, we ran regressions on a subsample of only insured households (Table S6, Supporting Information). We found households were more likely to have SMs in place if they also reported having received any or several of the following incentives for risk reduction from insurers: information on risk reduction, a premium discount for having implemented risk-reduction measures, a warranty specifying certain risk reduction as a precondition. Being aware of one's deductibles made no difference in risk-reduction behavior for SMs. This was the opposite for APM, where a small, but positive, association was established with deductibles, but not for other incentives.

In order to assess the robustness of the regression model, as well as to gain insight on associations at the country levels, we ran the logistic regression for each of the country samples (Table S7,

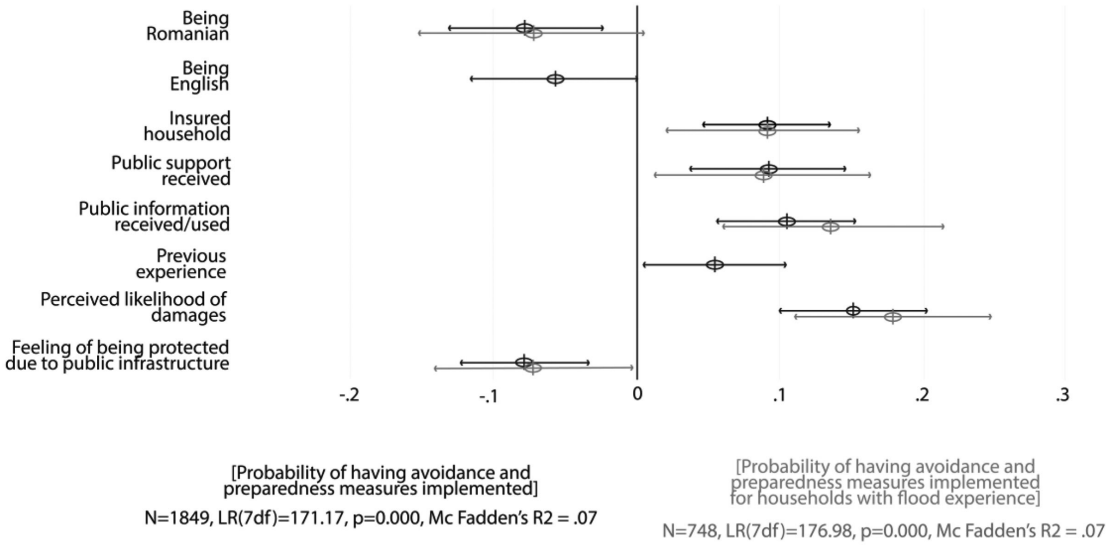

Fig. 5. Variables significantly associated with the implementation of APMs: average marginal effects and 95% confidence intervals. In gray is the analysis repeated only for households reported to have experienced flood damage before.

Supporting Information). We found that the regression model using *SMs* as the dependent variable was only significant in Austria and England, but not for Romania, whereas the model for *APMs* was significant for all three countries. The variables related to public and private incentives and the indirect effects of large-scale flood protection were not significant for Romania. Other differences to the main sample are the fact that feeling protected was indeed weakly, but positively, associated with the implementation of SMs in Austria. This finding is somewhat surprising. It indicates that Austrians who feel protected from floods are somewhat more likely to have structural measures in place. We can only speculate about the reasons for this: it might have to do with the fact that the SMs implemented predate the public protection infrastructure. Finally, in the English case, public support was not associated with the implementation of APMs.

5.3. Other Drivers of Risk-Reduction Behavior

We acknowledge that in the absence of strong public and private incentives there are other drivers that play an important role in determining risk-reduction behavior (see Fig. 1). Although resource constraints did not allow for a detailed analysis, we are able to provide some context based on an open-ended question on the reasons for not taking any measures, which we asked those households that had no measures implemented. While around 50% of respondents in this subsample did not have SMs and/or APMs in place due to low risk perception, 15% argued that high costs were the reason for not taking private risk-reduction measures. More than 70% of Romanian respondents considered risk-reduction measures to be too expensive. Eleven percent of respondents expressed the view that the implementation of any measure was too complicated or that they lacked the necessary knowledge to make the right decision. In less than 5% of responses, the blame landed on insurance, public protection, and lack of time; less than 1% gave public compensation as a reason for not taking measures. These findings highlight that apart from risk perception, coping appraisal indeed seems to be an important consideration in many households in the absence of stronger incentives from public authorities and insurers.

6. DISCUSSION

Our data yield important insights conducive to designing and reforming flood risk management with the aim to increase their potential to enhance private risk reduction. Here, we discuss them first for insurance, and then for public incentives resulting from different aspects of risk management more broadly.

We found no support for moral hazard in insured households. Indeed, households holding flood insurance were somewhat more likely to have risk-reduction measures in their homes. This is in line with findings by Thieken *et al.* and Osberghaus for

Germany[28,52] and Hudson *et al.* for Germany and the United States.[24] While we could not associate deductibles with the implementation of SMs, which corresponds with findings for hurricane insurance in the United States,[24] warranties, premium discounts, or information on risk reduction were positively associated. This is the opposite for APMs, where deductibles are positively associated with APMS, but not warranties, premium discounts, or information on risk reduction. In practice, it is these mechanisms that are rarely part of insurance policies.

Our data suggest that Austrians, who have partial postdisaster relief at their disposal, are more (SMs) or equally (APMs) protective of their homes than Romanians and the English. If there is charity hazard, it seems not to be salient and strong enough to overcome other drivers of risk reduction. One possible explanation for this could also be the tendency in Austria to build one's own home rather than buy professionally developed homes, which is more common in England and Romania. This would make it easier to implement structural measures from the beginning, and/or explain the fact that Austrians are more aware of the measures implemented. Another reason could be that in Austria, compared to Romania and England, more *ex ante* incentives for risk reduction-financial and in-kind—are available.

Dominant flows of this kind of public support and information were local, and positively associated with private risk-reduction behavior, particularly for APMs. This was strongest in England, and in line with other research findings for France,[5] but with contradicting findings for Italy.[30] Compared to insurers' incentives, both financial and in terms of information, public incentives were mentioned more frequently in the survey, and showed a stronger association with risk-reduction behavior. However, overall, also households that reported having public *ex ante* incentives received, particularly financial ones, were rare.

According to our data, public flood protection creates a feeling of safety, which was negatively associated both with risk perception and risk-reduction behavior. The country analysis reveals that this is true for Austria, and England individually in the case of APMs. The association was strongest in Austria, where it was also significant for SMs. This means that a significant number of respondents who are protected by public measures such as flood dams actually feel safer and thus tend to invest less in property-level prevention. This could be seen as a rational behavior, but it can become problematic if the perception of safety is overstated. Such a "false sense of security" may inadvertently increase the chance of flood damage due to an underinvestment in private measures. Considering the potential effectiveness of local provision of information, we consider more targeted awareness raising in the catchment of large-scale flood protection through local channels a useful task for public authorities and insurers.

Some of these overall associations cannot be reproduced for the Romanian case by itself. For Romania neither public nor private incentives were significantly associated with private risk-reduction behavior. The reasons may be related to insufficient effort and enforcement on the side of public authorities and insurers, or to a lack of trust and reliance in the population toward the support provided.[53] Other behavioral drivers related to coping capacity may thus be more relevant and warrant further investigation.

We excluded the effect of latent variables and mediated effects, which are likely to exist and deserve further attention. This provides room for additional research. Future work could also address the need for better integrating behavioral, cognitive, and institutional drivers, and the distribution of burdens and benefits between households and private and public actors. Furthermore, we did not explore inadvertent effects that may be caused by other public risk management efforts, such as efficient postdisaster help and rescue efforts, and social capital.[54]

In summary, we can say that insurers' incentives for risk reduction are even less common than public efforts to improve property-level risk reduction. However, if available these incentives were positively associated with risk-reduction behavior at the household level. This means that both insurers and public authorities have ample room to improve their policies on that account. Our model does not show any negative effects for risk reduction from charity hazard. In the light of existing economic theory this is somewhat surprising, and given the limitations of our study, should be interpreted with caution. Further work would be required to investigate the relationship between public *ex post* assistance and private risk-reduction efforts in more detail. As they stand, our findings suggest that completely abolishing public *ex post* disaster aid, which is politically difficult, might not always be an essential ingredient for strengthening private actions of households to reduce flood losses. Considering the costs and difficulties associated with comprehensive risk-based pricing in insurance practice, it may be worth

considering different avenues of incentivizing risk reduction at the household level, such as local information campaigns, stricter spatial planning, and building regulations.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Table S2: Questions collecting the data used for the analysis in this article. The right-most column indicates any transformations from the initial variable level.
Table S3: Descriptive statistics for all variables included in the regression analysis. N=number of observations; μ=mean; σ=standard deviation.
Table S4: Logistic regression with structural and preparedness measures as the dependent variables. The regression for preparedness measures in the subsample including households that previously experienced flood damage led to no important significant changes from the main model run and was thus not included here.
Table S5: Nonparametric test of associations (Spearman's Rho) for each of the dependent and independent variables in the regression.
Table S6: Logistic regression with structural and preparedness measures as dependent variables for a subsample including only insured households—investigating the influence of deductibles and other insurer's incentives.
Table S7: Logistic regression with structural and preparedness measures as dependent variables for each of the three case countries.