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Effectiveness of flood damage mitigation measures: Empirical evidence from French flood disasters

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ABSTRACT

Recent destructive flood events and projected increases in flood risks as a result of climate change in many regions around the world demonstrate the importance of improving flood risk management. Flood-proofing of buildings is often advocated as an effective strategy for limiting damage caused by floods. However, few empirical studies have estimated the damage that can be avoided by implementing such flood damage mitigation measures. This study estimates potential damage savings and the cost-effectiveness of specific flood damage mitigation measures that were implemented by households during major flood events in France. For this purpose, data about flood damage experienced and household flood preparedness were collected using a survey of 885 French households in three flood-prone regions that face different flood hazards. Four main conclusions can be drawn from this study. First, using regression analysis results in improved estimates of the effectiveness of mitigation measures than methods used by earlier studies that compare mean damage suffered between households who have, and who have not, taken these measures. Second, this study has provided empirical insights showing that some mitigation measures can substantially reduce damage during floods. Third, the effectiveness of the mitigation measures is very regional dependent, which can be explained by the different characteristics of the flood hazard in our sample areas that experience either slow onset river flooding or more rapid flash and coastal flooding. Fourth, the cost-efficiency of the flood damage mitigation measures depends strongly on the flood probability faced by households.

1. Introduction

The importance of designing adequate flood risk management strategies has been illustrated by recent global flood events, such as Hurricane Sandy in the USA in 2012, or the large river floods in Germany and the UK in 2013, and 2014, respectively. Climate change may increase flood risks in many places around the world, which requires the implementation of strategies to manage current and future flood risks (IPCC, 2012). Such strategies include the provision of flood protection such as storm surge barriers and dykes as well as measures that reduce flood impacts (Botzen and van den Bergh, 2009). Recent studies have shown that an adequate implementation of flood damage mitigation measures at the household level, with the aim of flood-proofing individual buildings, can decrease the costs of floods (Kreibich and Thieken, 2009; Bubeck et al., 2012). Examples of such measures are installing flood barriers or anti-backflow valves, and elevation of the ground floor. Estimates of the effectiveness of such measures have been obtained by simulating flood risk reduction through flood risk assessment models (e.g. Dawson et al., 2011; Poussin et al., 2012), using expert judgment (ICPR, 2002; ABI, 2003; Defra, 2008), and empirical studies on avoided flood damage conducted after flood events (Kreibich et al., 2005; Kreibich and Thieken, 2009).

The few empirical analyses of flood damage avoided by private mitigation measures find that such savings can be large. After the Meuse floods in The Netherlands in 1993 and 1995, Wind et al. (1999) showed that the implementation of flood damage mitigation measures by households after 1993 decreased their flood losses by 35 per cent during the similar flood of 1995. Bubeck et al. (2012) collected survey data on household flood preparedness during the Rhine floods of 1993 and 1995. They showed that flood damage to households was reduced by up to 50 percent during the 1995 flood as a result of implementing measures. Several studies conducted after the 2002, 2005, and 2006 floods of the Elbe river in

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Germany have also concluded that mitigation measures substantially reduce flood damage (Kreibich et al., 2005, 2011, 2012; Olfert and Schanze, 2008; Kreibich and Thieken, 2009). Kreibich et al. (2005) and Kreibich and Thieken (2009) estimated that the use of flood adaption for buildings and furnishing reduced the flood damage to buildings by between 46 and 53 per cent, and the flood damage to home contents by between 48 and 53 per cent. Installing heating and electrical utilities on higher floors, adapting the structure of the home to floods, and water barriers, respectively reduced the damage to buildings by 36, 24, and 29 per cent (Kreibich et al., 2005; Kreibich and Thieken, 2009).

Although the aforementioned studies provide useful insights into the potential damage savings from flood damage mitigation measures, it is evident that this empirical literature is scarce and focused on a few river basins, which are located in a few countries (mainly Germany). Moreover, few studies examined the cost-effectiveness of these measures. Kreibich et al. (2011, 2012) estimate benefit–cost (B/C) ratios of adapting buildings to floods in Germany, which depend on the type of measures and homes as well as on the probability of flooding. In particular, securing oil tanks and installing water barriers turn out to be very cost effective with B/C ratios between 5.61 and 539.96, and between 1.12 and 61.14, respectively (Kreibich et al., 2011, 2012). These B/C ratios are calculated using values of flood loss reductions that are based on a comparison of means of flood damage suffered between groups of households who have, and who have not, taken flood damage mitigation measures. Applying regression analysis may be more suitable for estimating the independent effect of damage mitigation measures by controlling for other effects on flood damage, such as flood water heights (Wooldridge, 2003).

Further empirical research is needed on the (cost-)effectiveness of individual flood damage mitigation measures. Such information is imperative for policy-makers who are involved in the design of flood risk management policies, insurance companies who are interested in reducing flood vulnerability of their policyholders, and households and businesses who want to reduce the flood risk to their property (e.g. Kull et al., 2013). This study, therefore, aims to provide data on the (cost-)effectiveness of 11 different flood damage mitigation measures. Flood damage savings are estimated using regression models of data gathered by means of a survey of households who have experienced floods. This survey was conducted in three regions of France that face different flood risks. In total 885 households replied to the survey.

The remainder of this paper is structured as follows: Section 2 describes the survey and methodology; Section 3 presents the results of the potential flood damage that can be avoided by the 11 flood damage mitigation measures, and the (cost-)effectiveness of these measures; and Section 4 provides a discussion and conclusion of the main findings of this study and their implications for flood risk management policies.

2. Description of the survey and methodology

2.1. Survey method and description of the sample

A mail survey was conducted in France in 2011 in three flood-prone areas: the French Ardennes; the Var; and the West Coast (Fig. 1). These three areas differ with respect to their flood history, the types of floods they are subject to, their existing regulations against floods, their local "flood cultures" and flood management approaches. The Ardennes are mainly subject to large river floods, which occur regularly and can cause considerable damage, such as €120 million and €240 million in 1993 and 1995, respectively (EPTB, 2011). In the Var, households are regularly threatened by flash floods. In 2010, an extreme event occurred that caused €600 million and 23 deaths (FFSA, 2011). The West region faces coastal floods, which occur rarely. In 2010, the storm Xynthia caused €1.5 billion in damages, including €700 million flood damage, and 47 deaths (Anziani, 2010). More information can be found in Poussin et al. (2013). The survey was conducted in villages and towns that were carefully selected on the basis of having experienced flood event(s) in the past. The survey was pre-tested in the same sample areas that were used for the final survey (Poussin et al., 2013). The final survey was sent by IPSOS, a French professional survey research company, by postal mail to 8201 households, which were equally divided over the 3 regions. In total, 885 respondents returned the mail survey, of which 530 have been personally flooded at least once in their home.

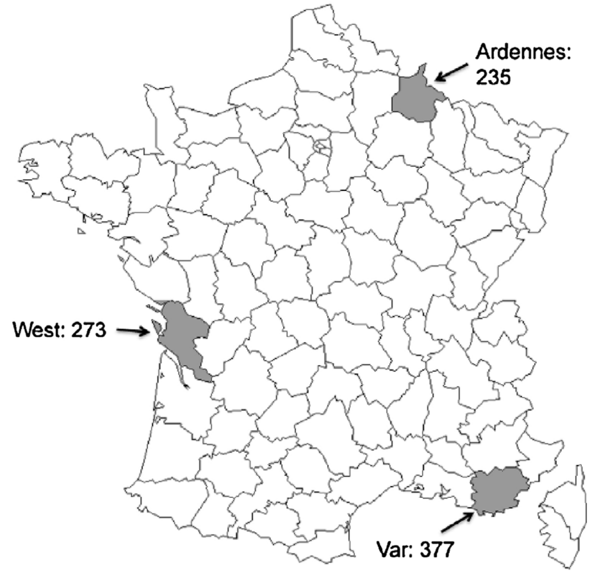

Fig. 1. Geographical location of the three French regions surveyed and the respective number of respondents to the survey.

A comparison between the demographic statistics from the actual population of the three regions, and the socio-economic characteristics of the respondents who experienced flood damage can be found in Poussin et al. (2013). The sample is approximately representative with respect to certain characteristics, such as gender and education, while it slightly under-represents home-owners and over-represents high income and older households. Most age groups of adults are well represented in our sample, but higher age groups are slightly over-represented. As an illustration, the percentages of our regional samples that fall in the age group 60–74 years are 28%, 24% and 37% in the Ardennes, the Var and the West, while in the actual population these percentages are 14%, 18% and 17%. In general, older individuals in France tend to take more flood risk mitigation measures (Poussin et al., 2014). But, there is no reason to suspect that age affects the flood damage avoided per mitigation measure, which is the main focus of this paper.

2.2. Overview of the main variables included in the regression models

A variety of variables have been used to assess the effectiveness of the mitigation measures in reducing flood damage. The effects of several variables that potentially influence the level of flood damage are estimated using ordinary least squares (OLS) regression models. Linear regressions are calculated in a stepwise manner, thus excluding explanatory variables (Table 1) that are insignificant.

Table 1 contains a description of the dependent and explanatory variables that are included in the final regression models. The two