Ecological Economics 156 (2019) 153–163

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

Future Public Sector Flood Risk and Risk Sharing Arrangements: An Assessment for Austria

Christian Unterberger[a,b,c,*], Paul Hudson[d], W.J. Wouter Botzen[e,f,g], Katharina Schroeer[a,b], Karl W. Steininger[a,h]

[a] Wegener Center for Climate and Global Change, University of Graz, Austria
[b] FWF-DK Climate Change, University of Graz, Austria
[c] Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland
[d] Institute of Earth and Environmental Science, University of Potsdam, Germany
[e] Institute for Environmental Studies, VU University, Amsterdam, the Netherlands
[f] Utrecht University School of Economics, Utrecht University, the Netherlands
[g] Risk Management and Decision Processes Centre, The Wharton School, University of Pennsylvania, USA
[h] Department of Economics, University of Graz, Austria

ARTICLE INFO

Keywords:
Climate change
Adaptation
Flood risk
Insurance
Public sector
Risk reduction

ABSTRACT

Climate change, along with socio-economic development, will increase the economic impacts of floods. While the factors that influence flood risk to private property have been extensively studied, the risk that natural disasters pose to public infrastructure and the resulting implications on public sector budgets, have received less attention. We address this gap by developing a two-staged model framework, which first assesses the flood risk to public infrastructure in Austria. Combining exposure and vulnerability information at the building level with inundation maps, we project an increase in riverine flood damage, which progressively burdens public budgets. Second, the risk estimates are integrated into an insurance model, which analyzes three different compensation arrangements in terms of the monetary burden they place on future governments' budgets and the respective volatility of payments. Formalized insurance compensation arrangements offer incentives for risk reduction measures, which lower the burden on public budgets by reducing the vulnerability of buildings that are exposed to flooding. They also significantly reduce the volatility of payments and thereby improve the predictability of flood damage expenditures. These features indicate that more formalized insurance arrangements are an improvement over the purely public compensation arrangement currently in place in Austria.

1. Introduction

Floods account for a major share of natural hazard losses experienced in the European Union between 1980 and 2016 (European Environment Agency, 2017). Socioeconomic development combined with ongoing climate change will further increase flood risks, due to worsening flood conditions and more people and assets being placed in harm's way (Alfieri et al., 2018; Rojas et al., 2013; Winsemius et al., 2016).

For governments, the projected increase in flood damages carries the risk of significantly burdening public budgets (Unterberger, 2018). In the aftermath of floods, governments must restore public infrastructure and often provide compensation to people and affected businesses for non-insured losses. For example, the German federal government created a special ad-hoc fund of €7.1 billion to provide support to those affected by the 2002 flood event. The role of governments as emergency risk managers exposes the public sector to significant risk. The responsibility to respond to the consequences of floods creates a large public contingent liability, which must be managed. This liability increases if the state is the only actor to bear this expenditure. Importantly, floods strike regardless of the economic circumstances or governments' fiscal position. Therefore, governments should consider implementing mechanisms that protect their budgets from the impacts of floods, including strategies that ensure the adequate provision of funds for post disaster relief and reconstruction and incentives that limit flood damages (Cevik and Huang, 2018).

Insurance has emerged as an important player in flood risk management (Botzen and van den Bergh, 2008; Schwarze et al., 2011; Steininger et al., 2005; Surminski et al., 2015a, 2015b). Insurance coverage guarantees contractually specify ex-post compensation, while

* Corresponding author at: WSL Swiss Federal Institute for Forest, Snow and Landscape Research, Zürcherstr. 111, 8903 Birmensdorf, Switzerland.
E-mail address: christian.unterberger@uni-graz.at (C. Unterberger).

https://doi.org/10.1016/j.ecolecon.2018.09.019
Received 13 December 2017; Received in revised form 19 September 2018; Accepted 20 September 2018

contract designs can be used to incentivize ex-ante risk reduction (Botzen et al., 2009; Kunreuther, 1996; Surminski and Hudson, 2017). Several studies have shown that mitigation measures at the building level can effectively reduce the damage of natural disasters (Hudson et al., 2014; Kreibich et al., 2005; Poussin et al., 2015). Therefore, insurance contracts that offer risk-based premiums and reward the installment of mitigation measures with a discount are a possible approach to deal with increasing flood losses (Hudson et al., 2017; Michel-Kerjan and Kunreuther, 2011). Moreover, such actions can aid and support other policies aimed at stimulating risk reduction through say building code alterations or regulations by providing positive rewards for these actions. Risk-based insurance premiums charge policyholders a premium in line with the total flood risk they face. Therefore, those at higher risk will tend to pay more for an insurance policy, while those who reduce their risk, pay less. This allows insurance to act as a price signal of risk, which can stimulate adaptation to changing flood risks.

Most of the literature focuses on private household flood insurance (Botzen and van den Bergh, 2008; Hudson et al., 2016; Osberghaus, 2015). However, flood risk to public infrastructure and the insurance implications have received less attention. The impacts of floods on public infrastructure can have more profound ramifications than on private property. Any delay in restoring public infrastructure causes indirect effects since many people rely on and require the services of public infrastructure in the fields of education, health, transportation, and culture. Additionally, the value of public infrastructure can exceed that of individual private property, since schools and hospitals are often large facilities and equipped with high-tech installations (Aerts et al., 2013). In order to address the gap in the literature, this article seeks to analyze the future development of riverine flood risk faced by the public sector in Austria in terms of exposed public infrastructure and the potential implications that different financial risk sharing arrangements can have on the total financial burden on public budgets.

Austria provides an interesting case study due to its high income and its capacity to implement adaptation strategies, and whose existing public sector risk management strategy is increasingly challenged to improve its effectiveness (Prettenthaler et al., 2015; Steininger et al., 2015). In Austria, flood risk is currently primarily borne by the Austrian disaster fund (*Katastrophenfonds*), financed by 1.1% of the federal share on income taxes, taxes on capital yield, and corporate taxes (Holub and Fuchs, 2009). The fund can hold reserves of up to €30 million from unspent resources; surpluses beyond that are redistributed back into the general budget (Austrian Ministry of Finance, 1996). If needed, additional funds can be appropriated from the federal budget (Gruber, 2008). The fund's primary role is to implement, and conduct maintenance of, large-scale disaster prevention measures. These investments account for ~70% of the fund's expenditure (Austrian Ministry of Finance, 2018). The remainder can be used to compensate disaster related damage. The damage to public infrastructure in municipalities tends to be compensated at a rate of ~50% (Austrian Ministry of Finance, 2012). The remainder is borne by local government budgets.

We develop a two-staged model framework to study the development of flood risk to public infrastructure and to assess the burden it implies on public budgets. At the first stage, a risk model assesses and projects the flood risk to public infrastructure in Austria. At the second stage, an insurance model is applied to analyze three different compensation arrangements for covering the projected increase in flood damage. In essence, we compare an informal insurance system with more formalized systems. Austria's disaster fund is considered informal as differing shares of losses will be compensated in different years. In a formal insurance policy, clear rules determine compensation. Two main benefits of insurance are studied: the potentially increased financial certainty and the potential for additional flood risk adaptation. The compensation mechanisms are evaluated by a multi-criteria analysis that assesses the future monetary burden in conjunction with the volatility of payments under each arrangement, while also accounting for a range of different adaptation priorities.

The advantage of the two-staged model framework is its transferability to other countries and hazard classes. The flood risk model could easily employ inundation maps from other regions. Given that the relationship between the magnitude of the hazard and the damage it causes (as illustrated by the stage damage curves) can be established, provided that hazard maps and exposure data are available, the risk model can be applied to other hazard types. The advantage of the insurance model in that regard is its direct application of the estimates and spatial resolution of the risk model. Thus, it allows for the comparison of different compensation arrangements irrespective of hazard types, spatial scales, and geographic location.

The results indicate that a combination of risk transfer to private insurance companies, incentivizing cost efficient damage mitigation measures at the building level and collaboration between the public and the private sector represent an improvement over current practices. This is because governments gain more financial certainty, in addition to potentially lower flood losses due to the incentivized risk reduction. These two features reduce the overall pressure placed on public budgets in terms of reduced monetary burden and increased certainty of financial arrangements. While the pure monetary burden grows under insurance-based systems, the benefit of insurance is that the financial uncertainty caused by flood losses decreases since losses can be budgeted for in advance. Therefore, these results offer further support to the growing momentum toward increasing multi-sectorial partnerships in flood risk management (European Commission, 2017; Flood Re, 2018; Golnaraghi et al., 2017; Hochrainer-Stigler and Lorant, 2018; Insurance Europe, 2018; Surminski et al., 2015a, 2015b; The Geneva Association, 2018).

2. Methods: Flood Risk and Insurance Model

2.1. Flood Risk Model

The monetary loss L caused by a given flood is a function of inundation depth H, the value of elements that can be damaged E, and their susceptibility to being damaged V (Crichton, 2008). Flood risk, or the expected annual damage (*EAD*) is the probability-weighted sum of losses from all possible flood events.

$$L = f(H, E, V) \tag{1}$$

Flood hazard information is obtained from the GLOFRIS model cascade (Ward et al., 2017) at a resolution of approximately $1 \times 1\ \text{km}^2$. The current flood hazard is modeled by using meteorological data from the EU-WATCH project (Weedon et al., 2011). For the projections until 2080, meteorological fields from the ISIMIP data are applied to the GLOFRIS model (Frieler et al., 2016). These meteorological data are derived from five different global climate models[1] (GCMs), which are run for one representative concentration pathway (RCP 8.5). The GLORFIS model focuses on riverine floods rather than pluvial flooding, burst water mains, etc. The model has been successfully validated in a range of contexts (Ward et al., 2017, 2013; Winsemius et al., 2013).

For the current climate and future projections, flood inundation maps for the following return periods are used: 1/2; 1/5; 1/10; 1/25; 1/50; 1/100; 1/250; 1/500; 1/1000. Flood protection, such as dikes and increased retention basins, lowers risk by preventing certain floods from occurring. Flood protection measures are included in the model by excluding damage from flood events with return periods that are higher than or equal to the protection standard of the measure, which means that the damage for that flood event is set equal to 0. As an illustration, if flood protection measures for up to 30-year events are assumed, then only events that happen less frequently than 1 in 30 years cause damage. Currently 88% of the areas that exhibit significant risk of

[1] The GCMs are: GFDL-ESM2M, HadGEM2-ES, IPSL-CM5A-LR, MIROC-ESM-CHEM, Nor-ESM1-M.