

Swenja Surminski, Annegret H. Thieken

Promoting flood risk reduction: the role of insurance in Germany and England

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Swenja Surminski (1), Annegret H. Thieken (2)

(1) Grantham Research Institute on Climate Change and the Environment, London School of Economics, London, UK

(2) Institute of Earth and Environmental Science, University of Potsdam, Potsdam, Germany

Abstract

Improving society's ability to prepare for, respond to and recover from flooding requires integrated, anticipatory flood risk management (FRM). However, most countries still focus their efforts on responding to flooding events if and when they occur rather than addressing their current and future vulnerability to flooding. Flood insurance is one mechanism that could a more ex-ante approach to risk by supporting risk reduction activities. This paper uses an adapted version of Easton's System Theory to investigate the role of insurance for FRM in Germany and England. We introduce an anticipatory FRM framework, which allows to consider flood insurance as part of a broader policy field. We analyse if and how flood insurance can catalyse a change towards a more anticipatory approach to FRM. In particular we consider insurance's role in influencing five key components of an anticipatory FRM: risk knowledge, prevention through better planning, property-level protection measures, structural protection and preparedness (for response). We find that in both countries FRM is still a reactive, event-driven process, while anticipatory FRM remains underdeveloped. However, collaboration between insurers and FRM decision-makers has already been successful, for example in improving risk knowledge and awareness, while in other areas insurance acts as a disincentive for more risk reduction action. In both countries there is evidence that insurance can play a significant role in encouraging anticipatory FRM, but this remains underutilized. Effective collaboration between insurers and government, should not be seen as a cost, but as an investment to secure future insurability through flood resilience.

Key points

The importance of anticipatory flood risk management, with an enhanced focus on risk reduction, is increasing, but remains underdeveloped.

Flood insurance can play a significant role in encouraging anticipatory flood risk management, but this remains underutilized.

Collaboration between insurers and government is not a cost, but an investment to secure insurability through better flood resilience.

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1. Introduction

In many countries around the world flooding is a very costly natural hazard, causing loss of life, destroying or damaging assets, as well as bringing disruption to communities and business processes. The impact of flooding has been increasing in the last few decades and is expected to continue to do so as a result of climate change and socio-economic developments (IPCC, 2012). This is putting pressure on existing governance strategies to cope with floods and to mitigate their impacts. Improving society's ability to prepare for, respond to and recover from these growing risks requires an integrated flood risk management (FRM) approach that addresses risks in an anticipatory way, rather than just responding to flood events. This involves considering future risks alongside current trends in order to achieve a more flood resilient society (e.g. Merz et al., 2014), and engaging with a broad range of stakeholders.

However, the reality still looks different, with a clear imbalance between reactive and anticipatory measures: internationally, just 12% of funds for disaster management are put into risk reduction and prevention prior to a disaster, while 88% go into response during, and repair or reconstruction after an event (Tanner et al., 2015). In times of rising risks and changing risk profiles this is a highly ineffective and costly approach, which is unlikely to lead to long-lasting flood resilience. In response, recent policies have strengthened anticipatory FRM worldwide, see for example Eigenraam et al. (2016) for the Netherlands, or the U.S. Army Corps' efforts combining engineering and other flood risk management approaches (U.S. Army Corps of Engineers, 2015). At the global level, the SFDRR, adopted by the United Nations General Assembly in March 2015, calls for 'a culture of prevention' and enhanced risk reduction. Priority 3 of the SFDRR focuses on 'investing in disaster risk reduction for resilience', proposing that 'public and private investment in disaster risk prevention and reduction through structural and non-structural measures are essential to enhance the economic, social, health and cultural resilience of persons, communities, countries and their assets, as well as the environment' (UNISDR, 2015). Another example from Europe is the Floods Directive, which has established a framework for EU member states to assess and manage flood risks.

While these are promising signs, it still raises the question how such a move towards an anticipatory and risk reduction-oriented approach to FRM can be achieved. The governance literature suggests that a change in the way of handling flood risk is driven by two key aspects: the risk itself, including occurrence of damaging events, changes in risk levels, vulnerability and awareness, which are often driven by events; and societal changes including the role of stakeholders, new ways of collaboration, adjusting political interests, and changing public expectations (Walker et al., 2010).

This resonates with observed governance changes in FRM; as explored by Ran and Nedovic-Budic (2016) or Bubeck et al. (2016): flood events in particular are widely understood as catalysts for change in flood risk governance (e.g. Johnson et al., 2005; Kreibich et al., 2011), creating the necessary public attention and political pressure to act and presenting a window of opportunity for stricter rules and policies. Floods can also be the trigger for strategic adjustments, as seen for example in England with the 'Making Space for Water' strategy developed in the aftermath of the 1998, 2000 and Carlisle floods (DEFRA, 2005; Penning-Rowsell et al., 2014). However, this often remains a reactive approach, focused on the problems that occurred during a flood event rather than anticipating future risks. While growing concerns about climate change and an improved evidence base about future risk trends can lead to a closer alignment of forward looking climate adaptation and FRM, as shown by Wiering et al. (2017), the impact on risk discourse and risk governance

remains somewhat unclear. One FRM mechanism often considered as a possible catalyst for a more strategic, ex-ante approach to flood risk is insurance (Aerts and Botzen, 2011; 2012; Surminski, 2014).

At its core, insurance is a financial instrument, offering the transfer of a risk from one party to another for the payment of a premium. From a socio-economic perspective it offers a more effective way of addressing the costs of disasters than relying on (governmental) post-disaster assistance: if correctly implemented insurance delivers risk spreading over space and time; risk smoothing; faster and more efficient reconstruction; certainty about post-disaster support; and can reduce immediate welfare losses and consumption reductions (see for example Hallegatte, 2011; Brainard, 2008; Von Peter et al., 2012). However, truly catastrophic risks may exceed the capacity of the industry and will always fall back on the state - an important consideration, particularly as rising risk levels might render insurance unviable without strong risk management and adaptation efforts, thus creating more demand for government disaster assistance (Ermoliev et. al. 2000; Botzen et. al. 2010; Jongman et. al. 2014; Jenkins et. al. 2017). Concepts such as risk layering (Mechler, et al., 2014) offer an economic analysis of how different tools, including direct assistance with the construction of resilient infrastructure and more risk protection, can be combined. This also underlines why insurance should not be seen as a stand-alone financial risk transfer, but as a tool that interacts with the overall risk management while also possibly shaping risk governance and influence risk behaviour: at least in theory, insurance can send signals to encourage more risk reduction and prevention, such as flood proofing of buildings and property, retrofitting of houses, local flood protection measures, and building larger scale flood protection schemes (Bräuninger et al., 2011; Aerts and Botzen, 2011; Filatova, 2013; Kunreuther and Michel-Kerjan, 2009; and National Research Council. 2015 as an example for efforts in the US). Efforts have been made to explore this through a system- approach, as outlined by Ermoliev et al. (2000), who explore the role of system approaches models and accompanying decision support systems in achieving a more integrated use of insurance and risk reduction (Ermoliev et al., 2000). This has been enhanced with an emerging body of socio-economic analysis that offers insights on how to combine and utilize different FRM methods and financial instruments, for an overview see Mechler et al. (2016).

However, there is limited evidence in practice of the success of insurance in encouraging risk reduction behaviour at the household level (Thieken et al., 2006; Treby et al., 2006; Crichton, 2008; Botzen et al., 2009; Lamond et al., 2009; McAneney et al., 2013; Surminski et al., 2015). There is also the view that insurance, at least in its current structure, can be detrimental to overall FRM as it can create disincentives for resilience (e.g. moral hazard) and may lead to maladaptation (O'Hare et al., 2015). However, what remains missing is an investigation of how insurance can influence the policy field of FRM. This is the focus of our paper.

We explore the potential for insurance to promote a move towards anticipatory FRM by investigating the cases of England and Germany. In line with the wider risk governance and political science literature, we understand FRM as a public policy field, driven by events, shaped by political decisions, implemented at different scales and requiring input from various stakeholders. In this we follow the theoretical analysis framework developed by Bubeck et al. (2015), who applied the political science concept of Easton's System Theory to explain the differences in FRM approaches across countries. We underlay this with a dynamic FRM cycle model to help identify drivers of flood resilience (section 2). This enables us to assess how FRM and risk reduction efforts are used in both countries (section

3), and to analyse if and how flood insurance can support a more anticipatory approach to FRM (section 4). We conclude with a discussion of our findings and a reflection on existing barriers.

2. Analytical approach and underlying concepts

For an analysis of how a society reacts and adapts to damaging flood events, it is important to first take stock of governance mechanisms in general and how they can promote or hinder change in FRM. In this respect, Walker et al. (2010) recognise that a new, decentralised form of governance has emerged since the 1980s and 1990s, focused on integrating a broader range of actors into decision-making, governance across multiple levels (i.e. local, national and regional), and a greater focus on 'steering' rather than 'coercing' by national governments in order to develop and deliver government policy. These factors are similar to developments in risk governance more specifically, which is defined by Renn (2008) to mean an activity that "...requires consideration of the legal, institutional, social and economic contexts in which a risk is evaluated, and involvement of the actors and stakeholders who represent them. Risk governance looks at the complex web of actors, rules, conventions, processes and mechanisms concerned with how relevant risk information is collected, analysed and communicated, and how management decisions are taken" (Renn, 2008).

In this context, insurance is often considered in the flood risk governance literature as an influencing factor on how a country considers risk ownership and responsibility for action (see for example Walker et al., 2010), with clear differences visible between driving solidarity-based governance approaches with a statutory responsibility on the state to protect its citizen against floods, and more individualistic risk-based concepts (Kaufmann and Wiering, 2017). What remains under-investigated is the question how flood insurance can support a shift to a more anticipatory and risk-reduction focused approach to FRM. The move towards anticipatory FRM is underpinned by a growing understanding of flooding as a multi-faceted phenomenon that requires a broad array of such measures, which extend beyond the domain of engineers, hydrologists and statisticians (Merz et al., 2014). It requires a much broader definition of risk, exploring the hazard alongside vulnerability and exposure, reflecting on future trends and behavioural aspects, and assessing this in an integrated way (Bubeck et al., 2016).

Against this background, the FRM cycle offers a valuable framework for exploring flood insurance as an element of FRM, and its contribution to create a more flood resilient society. The process often starts after a severe event (see e.g. Thieken et al., 2007; Kienzler et al., 2015; DKKV, 2015) with 1) a response (emergency) phase during the event, in which immediate measures are undertaken, with the priority to limit adverse effects and the duration of the impacting event; 2) in the consecutive recovery phase, the affected society starts to repair damage after the event and to regain the same or a similar standard of living as before the damaging event happened; and 3) in the risk reduction phase, measures are planned and implemented that aim at reducing and minimizing risks. Other authors (e.g. Kienholz et al. 2004) stress that the implementation of risk reduction has to be based on risk analysis that includes a systematic analysis of possible hazard and future risk scenarios and a transparent risk assessment, arguing for a fourth phase in the cycle. This points towards a more anticipatory FRM approach, where the process is not triggered by an event, but starts with a systematic risk identification and analysis, which is followed by an assessment and prioritisation of risks as well as decisions on efficient and effective prevention measures and their implementation (Thieken et al., 2014). Monitoring and regularly updated analyses and assessments are further elements (Thieken et al., 2016).

Our analysis uses such a FRM cycle with four phases (figure 1):

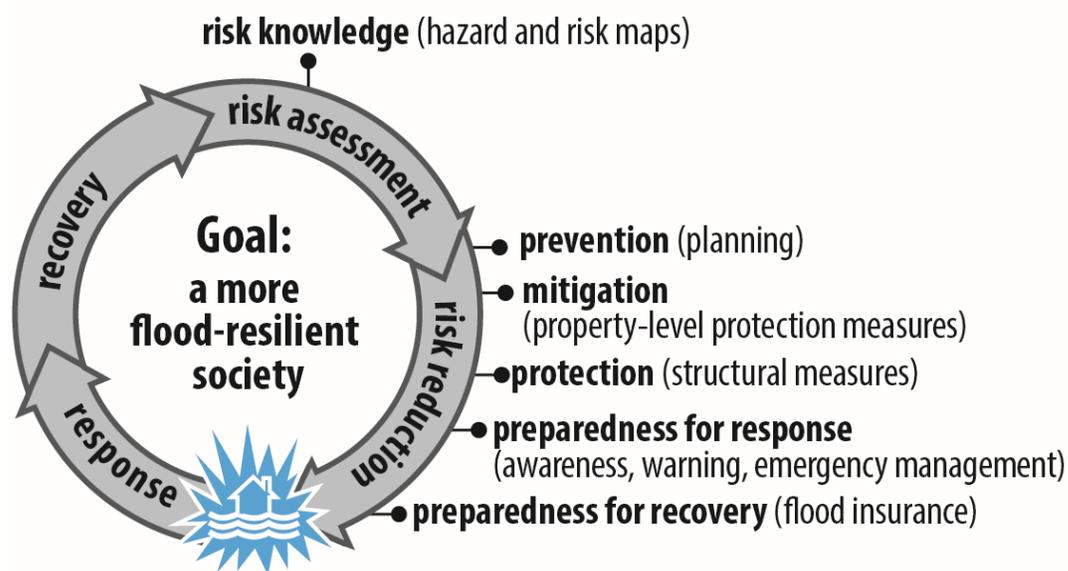


Figure 1: FRM cycle (with risk reduction strategies that are analysed in this paper in brackets)

Depending on the governance issues discussed above, the balance between each of these phases differs between countries (Kaufmann and Wiering, 2017). For our analysis of England and Germany we conduct a stock–take of FRM and consider in particular how flood insurance is used in both countries in section 3, covering the ‘preparedness for recovery’ aspect in the FRM cycle (figure 1). We then investigate in section 4 how flood insurance influences the other key components of flood risk analysis and reduction highlighted in the FRM cycle, as proposed by Hegger et al. (2014):

- *Risk knowledge (models and maps)*: data, information and knowledge sharing to identify areas at risk and to quantify risk (catastrophe modelling); capacity-building through knowledge transfer and educational elements.
- *Prevention (Spatial planning to prevent developments in flood-prone areas)*: incentives or regulations for preventing urban development in flood risk areas; economic incentives to discourage construction in the floodplain; exclusion of new build; retreat of structures from high-risk areas.
- *Mitigation (PLPMs)*: promotion and implementation of resilient reinstatement; explicit incentive structures for risk reduction within flood insurance, such as risk-based pricing or deductibles, where premiums reflect risk such as charging according to local flood risk levels; compulsory risk reduction, such as requiring policy holders to take certain preventive measures as a condition for cover.
- *Protection (Structural measures - hard defences/engineering)*: incentives for public FRM policy; conditions for compulsory risk reduction; promotion of FRM strategies.
- *Preparedness for Response*: risk awareness-raising initiatives, such as the provision of risk-relevant information and knowledge transfer to educate policyholders and the public about preventive and preparatory measures; capacities to warn and alert in case of an event and to stipulate risk-adequate behaviour.

In order to understand how flood insurance can strengthen these elements of risk reduction, we combine the FRM cycle with an adapted version of Easton’s System Theory to create an anticipatory

FRM framework (see figure 2). This allows us to consider FRM as a policy field that can encompass a variety of different tools, instruments and approaches, influenced and driven by actors and events. This is consistent with the broader trends in governance literature and aligns with the system-based view proposed by Ran and Nedovic-Budic (2016). According to Bubeck et al. (2015), this model can also help to explain differences in FRM across countries, as the inputs and their variations, as well as differences in political process, demand and support mechanisms all shape the outputs.

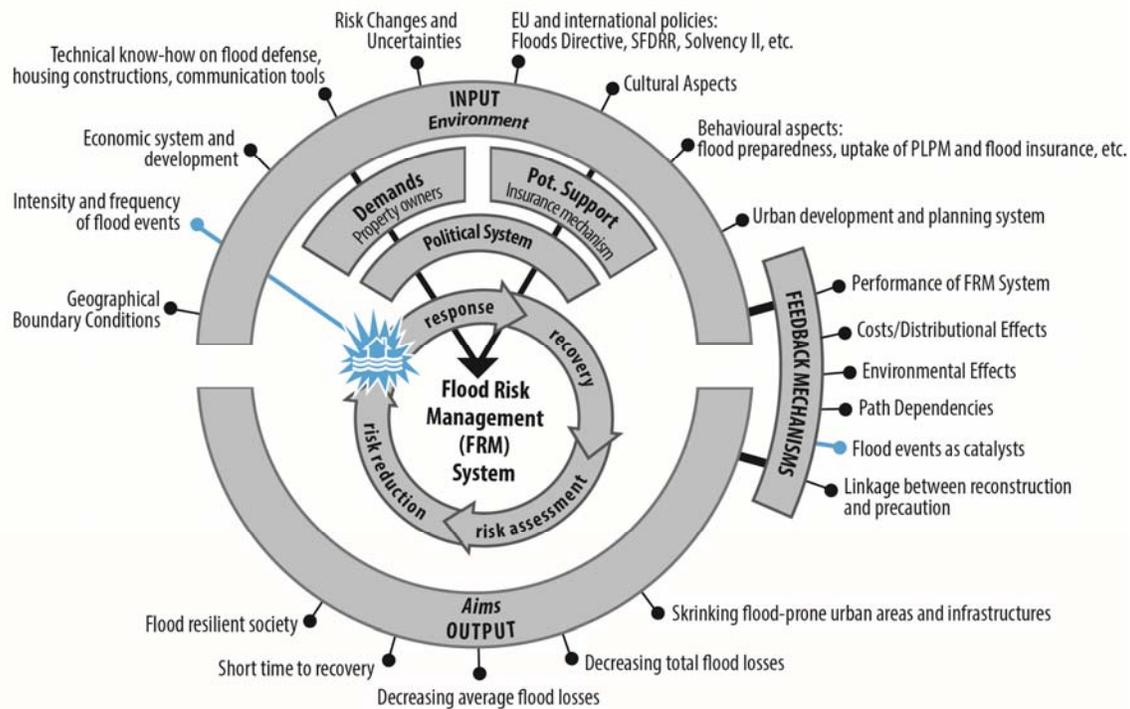


Figure 2: Anticipatory FRM as a policy field with boundary conditions, actors, potential outputs and feedback mechanisms (Source: The authors, based on Bubeck et al., 2015)

At the core of our model is the FRM cycle, which is dependent on a range of inputs and how they are addressed in the political system. We recognize that FRM does have different aims and objectives, which depend on a range of factors, including preferences, traditions, the frequency, intensity and natural variability of flood events, societal objectives and norms (Green et al., 2013). We add to this the ‘demand’ function of property owners, who require protection of their assets.

We use this simplified framework to analyse the role of insurance both as an instrument and as an agent, supporting a more anticipatory and risk–reduction oriented FRM effort beyond its core risk transfer function by influencing public policy as well as individual risk behaviour. In the framework we include insurance mechanisms as a ‘potential supporter’. The term ‘potential’ indicates that insurance may in fact also act as a disincentive to FRM and resilience, as outlined, for example, by O’Hare et al. (2015).

To analyse the influence of flood insurance on the FRM systems in England and Germany we conducted literature searches and expert interviews. For the literature review we considered

relevant peer reviewed papers, using searches through Web of Science and Google Scholar; and relevant non-academic reports and publications, including government and industry publications. During this process flood-related parliamentary inquiries, as outlined by Otto et al. (2016), policy documents and laws as well as publicly accessible flood hazard and risk maps were systematically reviewed to capture developments in FRM for both countries. This then enabled us to develop the historic overview of practices and developments summarized in figures 3 and 4 below. The evidence base was verified and enhanced through extensive stakeholder discussions conducted during the research phase. In Germany, this material was accompanied by five expert interviews with representatives from the (re-)insurance sector and consumer protection. In addition, written surveys among property insurers in Germany as well as among the supreme water authorities of all 16 federal states were conducted. The latter was followed by a stakeholder workshop in June 2014 to derive recommendations on how to improve the FRM system in Germany in the wake of the 2013 flood (see DKKV, 2015). Finally, the role of flood-prone residents has been investigated by computer-aided telephone interviews (CATI) that have been conducted in Germany after severe flood events since 2002 (Thieken et al., 2005; Thieken et al., 2016). In England, the analysis included eight interviews with representatives of the insurance and reinsurance industry, and four interviews with flood insurance experts from the public sector, including the Department for Environment, Food and Rural Affairs (DEFRA) and the Environment Agency, who provided access to survey data and assessments of flood resilience in England. Further investigations took place as part of the ENHANCE analysis of the new Flood Re pool, which included stakeholder workshops in 2014, 2015, and 2016 (Surminski and Eldridge, 2015; Surminski, 2014; Surminski et al., 2015; Jenkins et al., 2017; Crick et al., 2016; Surminski and Hudson, 2017).

3. Recent developments in FRM in both countries

England and Germany share a number of characteristics when it comes to FRM. For both, flooding tends to be the costliest natural hazard in financial terms (for Germany, see Kreibich et al. (2014); for England, see Amos (2016), and in both flood insurance is provided by private insurance companies. Perhaps most importantly, both have amended (or attempted to amend) their approaches to FRM and flood insurance over the last two decades in response to a number of severe and widespread flood events. These efforts are reflected in figure 3 (for England) and figure 4 (for Germany) below, which show the results of our stock-take of FRM developments and offer some insights into key aspects of the FRM policy field (figure 2) for each country and their development over time. Firstly, the figures give an overview of major flooding events (including insured losses where information is available), and show how FRM has developed in England and Germany respectively with regards to flood insurance. In line with the scope of our investigation we list key elements of FRM governance that are either directly or indirectly relevant for the provision of flood insurance. This includes the adoption of legislation, guidelines, strategies or programmes, and changes in the context of risk reduction efforts, for example in risk awareness building or the provision of flood risk data. Major adjustments in the provision of flood insurance are also highlighted in the lower panels; however, only the flood insurance penetration rates of Germany are mapped because penetration rates in England have traditionally been very high (more than 90% and stable (HM Government, 2016).

3.1 England

In England, the roles of the government and the insurance industry have always been clearly delineated; the government is responsible for FRM as a whole and the insurance industry remains the sole provider of flood insurance. This dynamic has continued to date. However, since the early 1960s, the government and the insurance industry have entered into a series of informal agreements in order to ensure flood insurance remains available and affordable (Surminski, 2016). These agreements are reflected in the 'Guidelines, Strategies and Programmes' line of figure 3. The first of these was the 1961 Gentleman's Agreement, which was adopted after serious flooding in the 1950s that revealed that only a small number of homes had flood insurance (Penning-Rowse et al., 2014). Under the Gentleman's Agreement, the insurance industry agreed to make flood insurance available as part of standard home cover. This was replaced by a series of Statement(s) of Principles following major flooding across the country in 2000, which resulted in approximately £1bn damage and flooded 10,000 properties (Environment Agency, 2001) and led to concerns about escalating risk trends. Insurers were lauded for their positive response to the floods, which some commentators have suggested gave the industry the confidence to demand greater investment in flood mitigation by the government (for example, see Penning-Rowse et al., 2014).

The Statement(s) of Principles went through a series of iterations (2002, 2005 and 2008), each with varying commitments by the insurance industry to provide flood insurance coverage and by the government to, in turn, continue investing in flood protection. For example, the 2008 Statement of Principles, which was adopted in the wake of extremely costly flooding in 2007 which caused insured losses of £3.2 billion (Environment Agency, 2010), provided for coverage up to a 1 in 75 annual probability of flooding and excluded properties built after 1 January 2009. The Statement(s) of Principles are generally considered to have been a success in improving flood insurance penetration, which has been estimated to be as high as 95% (HM Government, 2016) and 98% (Flood Re, 2016). This is in large part due to the bundling of flood insurance with building and contents insurance (HM Government, 2016). However, the Statement(s) of Principles were always considered a temporary solution, prompting negotiations to find a replacement in 2010. After years of negotiation it was replaced by the launch of Flood Re, which commenced operation in April 2016 and is intended to be a transitional measure to make way for risk-reflective pricing by 2039. As a reinsurance pool that is owned and operated by the insurance industry, Flood Re gives insurers the option of reinsuring high risk policies at a subsidised price; the logic being that insurers can pass on their own cost savings to policyholders and thus making flood insurance more affordable even for those at high risk (Surminski, 2016). The subsidised price is calculated by reference to the council tax banding of the relevant property; the higher the banding, the more expensive it is to reinsure. The subsidy is collected via a levy (approx. £10.50 per policy) imposed on insurers, which is being passed on to policyholders. 85% of the insurance market have agreed to participate in the pool (Insurance Newlink, 2016) and since inception, Flood Re is estimated to have underwritten 53,000 policies (based on Flood Re information in October 2016). However, it is unclear how Flood Re will achieve the transition to risk-reflective pricing, particularly since it fails to encourage policyholders to reduce their own flooding risk (Surminski, 2016). Questions also remain of its ability to keep flood insurance premiums stable in the future, while underlying flood risk levels rise (Surminski, 2016).

The 'legislation' line in figure 3 highlights a number of measures and policies introduced by the government to improve FRM in England. The Floods Directive, which requires certain steps to be taken to identify, map and manage flood risk areas, was incorporated into English law through the Flood Risk Regulations 2009. This culminated in the release of a series of river basin management plans, promoting risk reduction. Follow ups are supposed to be made every six years to account for

climate change; it is unclear how 'Brexit' will impact this. In 2010, the Flood and Water Management Act was adopted. It granted the Environment Agency strategic overview of FRM and required it to develop a national strategy for flood and coastal risk management in England, which was released in 2011. It also established a series of Lead Local Flood Authorities, which have established a series of local flood risk management strategies (DEFRA, 2017). Not all Lead Local Flood Authorities have finalised their strategies to date (DEFRA, 2017). However, the implementation of the Flood and Water Management Act has since been reviewed and described as a "big step forward in managing flood risk" (DEFRA, 2017).

Significant improvements have also been made in 'risk knowledge' and 'risk awareness & communication' (see figure 3). In particular, concerns with surface water flooding, particularly following the 2007 floods, have culminated in the adoption of new surface water maps (Environment Agency, 2013). Furthermore, following the 2007 floods the Pitt Review called for greater collaboration between the various government departments involved in FRM to improve warning services (Pitt Review, 2008). This led to the development of the Flood Forecasting Centre, which provides a comprehensive, 24/7 forecasting service. The Environment Agency provides flood warnings based on these forecasts (HM Government, 2016). England is also the first country in Europe to provide flood warnings via twitter (HM Government, 2016).

Despite these efforts, major flooding events have still caused significant damage. For example, the 2013/14 winter floods caused insured losses of approximately £1.1bn (ABI, 2014). Flooding in 2015/16 also caused insured losses of approx. £1.3bn (Ward, 2016). In response, the National Flood Resilience Review was commissioned and released in September 2016. It highlighted, amongst other things, the need to protect key local infrastructure more effectively, the need to improve incidence response and the need to continue improving risk communication by the Environment Agency (HM Government, 2016).

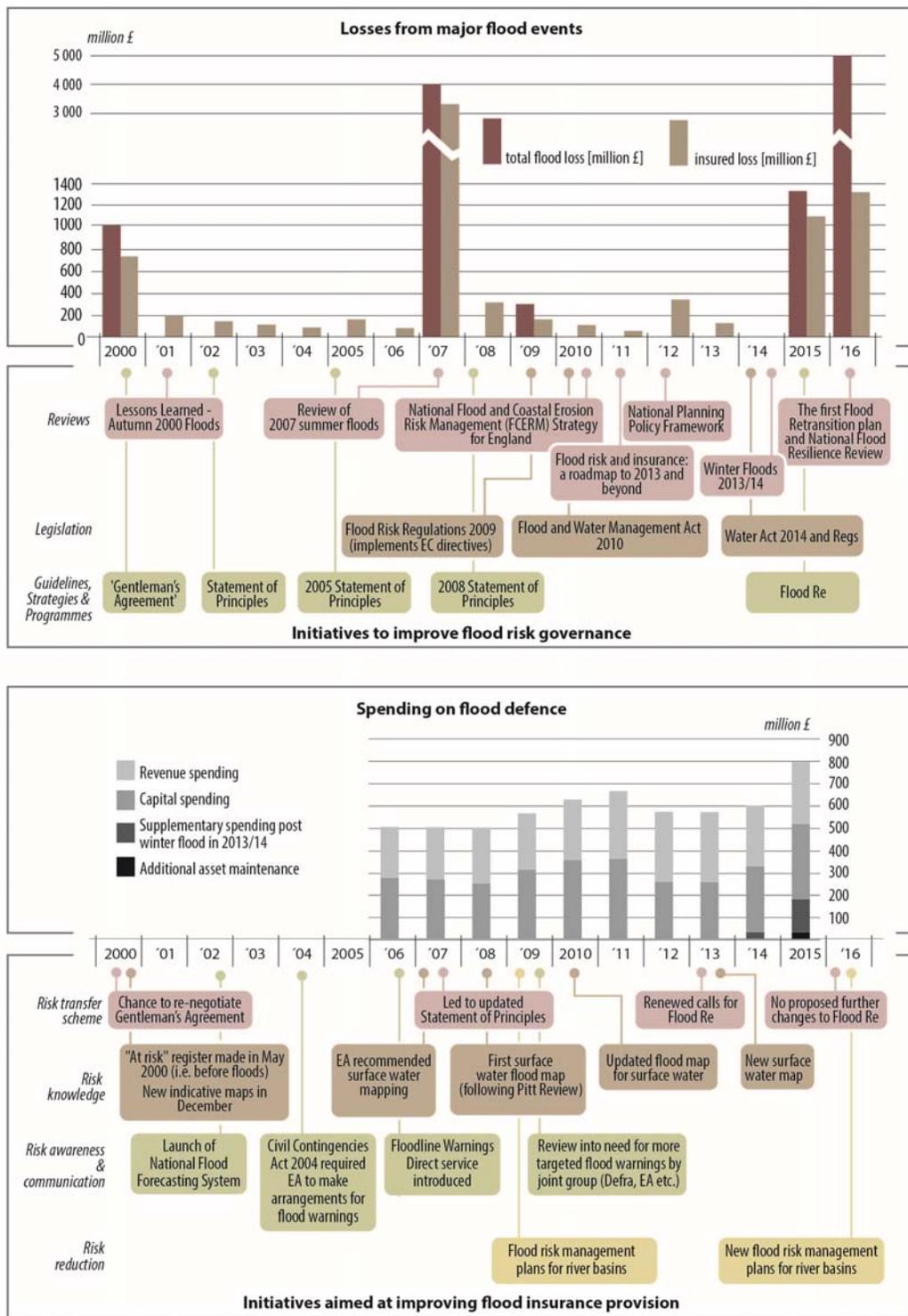


Figure 3: Recent flood impacts and developments of flood policies and flood insurance in England

3.2 Germany

Unlike England, Germany traditionally has very low rates of flood insurance penetration in most parts of the country. This is reflected in figure 4, which notes penetration rates of 19% for residential buildings and 8% for household contents at the time of the 2002 flood. Flood insurance coverage has

been available in all of Germany since 1991 as a supplementary contract to building or contents insurance, which usually only covers losses caused by fire, wind or hail storms, as reflected in the 'Risk transfer scheme' line of figure 4 (e.g. Thieken et al., 2006). This supplementary contract bundles flood risks with natural hazard risks from earthquakes, land subsidence, avalanches or snow build-up. There are, however, two regions in Germany with peculiarities: Baden-Wuerttemberg, a state in the south of Germany, and the territory of the former German Democratic Republic (GDR) in eastern Germany. In Baden-Wuerttemberg, flood loss compensation was included in compulsory building insurance until 1994. Due to EU regulations this monopoly insurance had to be abandoned. Currently, more than 90% of property owners in Baden-Wuerttemberg still have flood insurance coverage (GDV, 2016). In the former GDR, flood losses were covered by household insurance. Up to 45% of residents in eastern Germany still have comparable contracts or have signed the above-mentioned supplement (GDV, 2016).

A number of measures have contributed to increasing flood insurance penetration, which now sits at almost 40% (GDV, 2016). In particular, in 2001 a flood hazard zoning system (ZÜRS) was established by the German Insurance Association (GDV) that at first distinguished three flood probability zones; after the 2002-flood, a fourth zone for areas with low flood probabilities was added (see Falkenhagen (2005) for details). After 2002, the zoning system has increasingly been used to assess the insurability of properties (Thieken et al., 2006; DKKV, 2015). Since official flood hazard maps have become available due to the implementation of the Floods Directive, the insurance-related zoning system has been recently updated, resulting in less areas being recognised as high risk (GDV, 2016).

Similar to England, calls for a compulsory flood insurance scheme have been rejected. In particular, the 2002 flood initiated a political debate about a compulsory flood insurance scheme, which finally failed in 2004, in particular due to the reluctance to provide a government guarantee for outstanding losses (Schwarze & Wagner, 2004). After another major bout of flooding in June 2013, the discussion restarted, but finally resulted in the same conclusion. This is reflected in the 'Risk transfer scheme' line in figure 4. However, a solution similar to Flood Re in England has not been adopted. In June 2017, the conference of the Heads of the Federal States agreed to negotiate a piece of federal legislation that regulates pay-outs of governmental disaster relief aid. Such assistance was provided after the floods of 2002 and 2013 covering up to 80% of the losses (of uninsured properties) and has hence been criticised to counteract efforts that aim at increasing insurance uptake.

The flood insurance situation in Germany has recently been investigated by Seifert et al. (2013), Zahn and Neuss (2011), Keskitalo et al. (2014), and DKKV (2015). Despite the huge amounts of governmental relief aid in 2002 and 2013, insured flood-affected households were better compensated in 2002 as well as in 2013 than uninsured. This includes a higher percentage of compensation in relation to the overall loss at the property level as well as a higher satisfaction with the procedures and services (see DKKV, 2015). Hence, to foster the uptake of flood insurance, the GDV has started risk awareness campaigns jointly with the upper water authorities (per federal state). In 2009, a first campaign was launched in Bavaria, where the 2005 flood caused tremendous damage and calls for a better risk transfer solution. Up to now, such campaigns have been (repeatedly) conducted in several federal states. A positive effect on the uptake of precautionary measures could, however, not be detected so far (Osberghaus & Philippi, 2016). As further measures, the GDV developed the building certificate "Hochwasserpass" together with civil and water engineers that was launched in 2014 and it has published an annual natural hazards report since 2012 (see the 'Risk Reduction' line in figure 4).

In the context of overall FRM, over the past 25 years all big river catchments in Germany have been affected by major floods resulting in severe losses as depicted in the upper part of figure 4. Although the two big floods in the Rhine catchment in 1993 and 1995 already initiated a shift from pure technically oriented flood protection towards a more integrated FRM approach as laid out by LAWA (1995), the legal framework for FRM and particularly for loss prevention was still weak (DKKV, 2003; Petrow et al., 2006). It should be noted that the federal level in Germany only sets general standards for FRM through so-called framework legislation. The federal states (Länder) have the main responsibility for all water issues as well as for civil protection and thus implement the framework legislation and determine actual risk management on the ground (Bubeck et al., 2015). This multi-level governance may result in different management approaches (see examples in DKKV, 2003; Heintz et al., 2012; DKKV, 2015) as well as different levels of flood protection along the main rivers. For example, along the river Rhine safety standards vary between 1/30 years and 1/1000 years (te Linde et al., 2011), although a safety level of 1/100 years is mostly aimed for in Germany (Krieger, 2013; Broekmans et al., 2013). This has been based on the main principle that everybody should have the same level of protection against flood risks (Johnson et al., 2007). In contrast, another principle is dominating in England: FRM should aim at the maximum utility of resources; that is, resources are allocated to those regions that can derive the largest benefit in proportion to the costs (Johnson et al., 2007).

Major flooding in 2002 and 2013 initiated reviews of the FRM system (e.g. for Saxony by von Kirchbach et al., 2002, 2013; for all of Germany by DKKV 2003, 2015). These initiatives are reflected in the 'Reviews' line in figure 4. In particular, the 2002 floods, which caused total damage of €11.6 billion (with insured losses surpassing those suffered in England in 2013/14 and 2015/16), triggered a number of improvements to FRM in Germany. These are reflected – mainly for the federal level – in the 'Legislation' line of figure 4. Immediately after the flooding, the Disaster Relief Act was passed, providing for an unprecedented amount of €7.1 billion for reconstruction. More importantly, a 5-point action programme on how to improve flood risk management was agreed upon and paved the way for amendments in related legislation. These were passed in 2005 as the Omnibus Flood Control Act and changed, among others, the Federal Water Act and the Spatial Planning Act. For example, the preparation of flood management plans per catchment and stricter regulations for built-up areas in flood-prone areas came into effect. In addition, private precautionary action was requested from every person living in a floodplain in accordance with their resources and capabilities. On the European level, the 2002 floods (together with other major floods across Europe) led to the Floods Directive. Accordingly, the Federal Water Act was updated in 2009 and came into effect in 2010. These amendments implied and thus indicated a shift from condition-based governance with precise "if.., then..." rules to performance-based policy regulations that define targets and thus offer a broader scope of implementation (Hartmann and Albrecht, 2014). This offers opportunities to balance conflicting interests (Hartmann and Albrecht 2014), but can also create disputes (Otto et al., 2016). In June 2017, the second Omnibus Flood Control Act was passed, which contains, among other things, regulations for the use of flood-prone areas outside statutory inundation areas, e.g. requirements for flood-adapted building design and flood-secured oil tanks. Floating oil tanks were identified as important damage driver, particularly in areas that had been inundated due to dike breaches (DKKV, 2015).

Although the Floods Directive addresses different flood types (i.e. riverine floods, pluvial flooding and storm surges), the German focus has been on riverine floods and storm surges as risks with national significance. Similarly, England has placed a significant amount of focus on river basins. Pluvial

flooding (also termed surface water flooding or sometimes flash floods) was neglected in Germany. However, due to pluvial floods causing severe damage (approx. €450 million) in the city of Münster in July 2014 as well as insured losses of €1.2 billion in southern Germany in May and June 2016, it is currently being discussed how risks from pluvial floods can be better accommodated in FRM processes and plans.

In contrast to England, Germany does not provide a database on investments in flood protection. Therefore, there is only anecdotal evidence available. For example, the Freestate of Saxony, the most severely hit state in 2002, has planned 1600 measures thereafter (SMUL, 2007). Furthermore, as a joint effort between the Federal Government and all Federal States, a National Flood Protection Programme was agreed upon in 2014 covering around 100 measures with investments of more than €5.4 billion (DKKV, 2015). Furthermore, Germany has invested less into 'Risk awareness & communication' than England, as evidenced in figure 4.

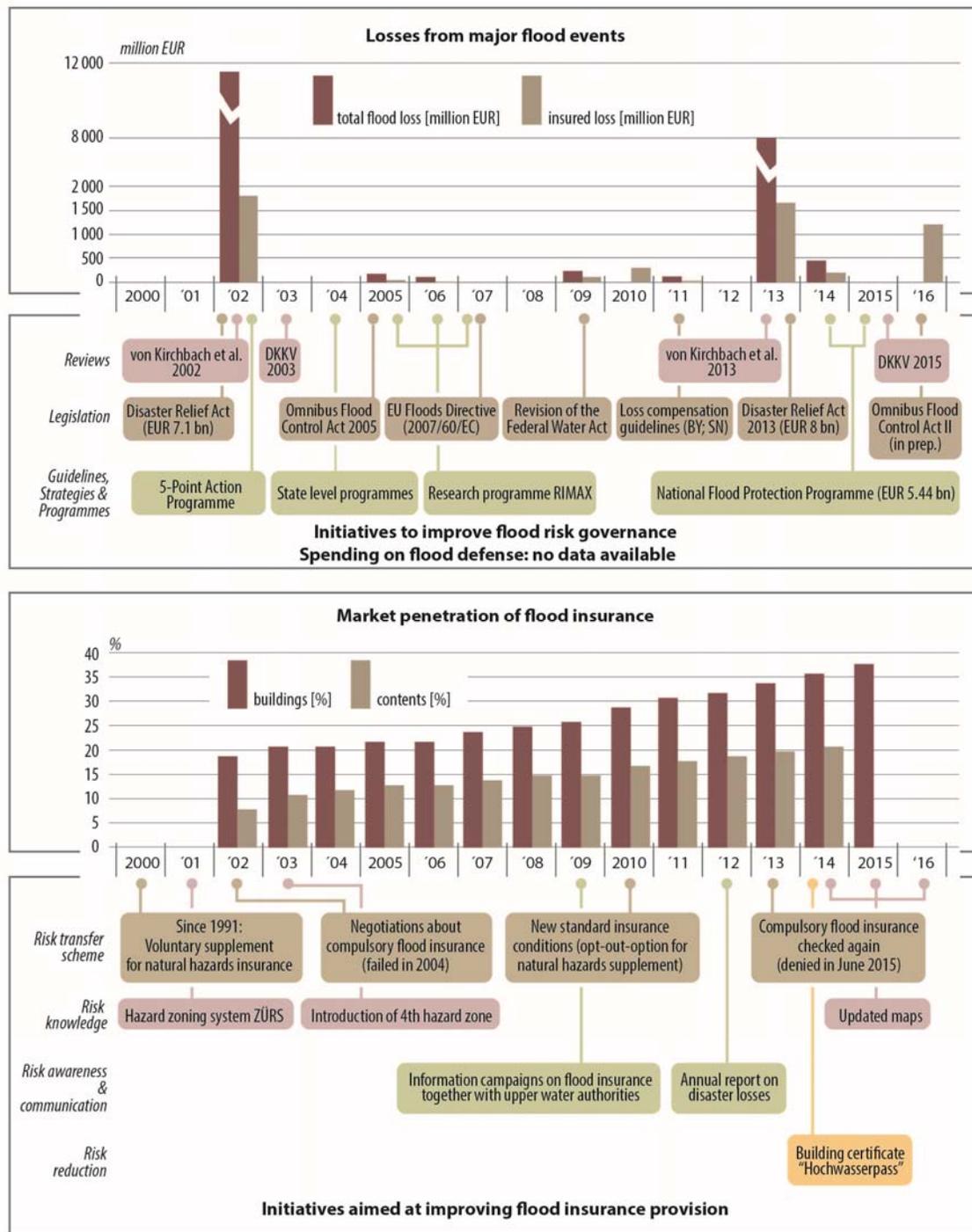


Figure 4: Recent flood impacts and developments of flood policies and flood insurance in Germany.

4 Analysis of how flood insurance contributes to flood risk reduction

Within the FRM policy field (see figure 2), we locate insurance as an input: at its core, flood insurance is an ex-ante financial instrument, which increases preparedness for recovery through the risk transfer function of insurance, thus giving greater certainty over pay-outs in case of losses and ensuring a quick and effective pay-out process. These features create financial resilience, but they do

not automatically lead to a more anticipatory FRM approach or reduction of the underlying physical risk and risk drivers. We therefore consider the wider support role of insurance as a possible driving mechanism that can support and influence the overall FRM system through the different elements of risk analysis and reduction highlighted in our framework (see figure 1).

4.1 Risk knowledge (hazard and risk maps)

Risk knowledge is key for FRM decision making, but the real value in maps and data sets lies in their use. Hazard and risk maps are now available across all of England and Germany (see Environment Agency, 2013 and DKKV, 2015, for overviews). Insurance has played a supportive role in both countries. This is not surprising as insurers have a core interest in reliable hazard maps and risk models. This is reflected by the strong involvement of the insurance sector in mapping and by partnerships with governmental bodies leading to, for example, an exchange of data and information. However, there is limited evidence to suggest that better mapping, and greater reflection of risk, overcomes the 'moral hazard' of insurance; reinforcing the fact that the supportive role insurance can play is conditional.

Generally speaking, the insurance industry utilises a combination of government data (e.g. the flood data collected by the Environment Agency), in-house models and commercial models (e.g. those developed by companies such as RMS and JBA) to price insurance policies. Indeed, some insurance companies have invested heavily in flood risk models to gain a competitive advantage, which has led to the emergence of a modelling industry and a growing understanding of flood risk; although much uncertainty still exists with these models due to the uncertain nature of climate change itself (Committee on Climate Change, 2016), and a lack of information on certain kinds of flood risk (e.g. surface water flooding).

In Germany, the insurance industry (led by GDV) had a countrywide flood hazard zoning system (ZÜRS) already in place in 2001 (see figure 2). However, the maps were based on a coarse DEM and a rough hydraulic modelling approach and did not consider structural flood protection such as dikes. Therefore, the maps were heavily criticized by the water authorities, amongst others. However, the existence of the maps led to a discussion about flood hazard mapping and finally to an improvement of the available maps since local (official) flood hazard zones were incorporated in the system in cooperation with the water authorities (Kron, 2013). Since 2014, the more sophisticated maps created by the public water authorities in accordance with the Floods Directive have been integrated into ZÜRS. According to the GDV, this resulted in a reduction in the share of homes assigned to high-risk areas from 1.5% of all buildings in 2008 to 0.65% of all buildings in 2016 (GDV, 2016). This amounts to a reclassification of 67,000 homes from a high risk zone to lower risk zones. In return, however, 5000 homes from medium risk zones are now assigned to high risk zones (GDV, 2016). This example illustrates that (voluntary) data exchange among different stakeholders in the FRM system is beneficial for the consistency of hazard information and assessment as demanded by Kron (2013).

ZÜRS was mainly developed to assess the insurability of properties. Its usage was fostered after the 2002 flood and is meanwhile as important as other criteria such as the number of damage claims over the preceding 5 or 10 years (DKKV, 2015). Still, in high risk zones that are already affected by 10-year floods, it is difficult for homeowners to get flood insurance coverage.

Similarly, in England, the insurance industry has played a positive role in negotiating with the government for improved flood risk data. This was particularly the case under the Statement(s) of

Principles (ABI, 2005). There have been efforts to improve stakeholder access to flood risk maps, update the National Flood Risk Assessment Data. The Association of British Insurers has also developed a close relationship with the Environment Agency for the express purpose of improving data available to insurers and the general public (Surminski, 2009).

However, there is no formal requirement for the insurance industry to share flood risk information with their customers or the government in England or Germany. This is also due to the fact that flood insurance is typically bundled with building and contents insurance. Furthermore, insurers have expressed concerns about the release of their claims data which they consider to be commercially sensitive, which affects information-sharing between insurers and the government (Surminski and Eldridge, 2015). However, the adoption of Flood Re could significantly improve risk knowledge in England as it will possess a significant data asset of high flood risk homes, including a picture of which of these homes are flooded, the cost of claims and how those costs are made up (Flood Re, 2016). It is unclear how this information will be shared in the future, but Flood Re is considering how it can be utilized to smooth the transition to risk-reflective pricing (Flood Re, 2016). It should allow the government to calibrate measures for managing flood risk in different areas (Oxera, 2015).

Improvements in hazard data and models have led to a number of outputs under the anticipatory FRM framework. For example, improved mapping in England has been used in efforts to steer development away from high risk areas, although floodplain development still continues due to political and economic pressures (HM Government, 2016). By improving awareness and understanding, they have also opened up FRM discourse to the public domain (Alexander et al., 2016).

4.2 Prevention (through spatial planning)

Limiting new developments in flood prone areas unless built in a resilient manner is a key element of the anticipatory FRM framework. However, political will is often limited, as population growth and economic development put pressure on the planning system.

In Germany, accounting for flood risks in spatial planning was weak before the flood of 2002. This changed in 2005 with the introduction of the Flood Control Act. Statutory inundation areas were defined and in general included areas affected by 100-year flooding events and areas that are important for flood retention. In these areas, it is prohibited to erect new buildings or to hinder water flow by fences, bushes etc. The assignment of such areas often leads to disputes with the local population (Otto et al., 2016), but goes hand in hand with the hazard mapping efforts that are necessary to implement the Floods Directive. In 2017, legal instruments to prevent increases in damage potential behind dikes or other structural flood defence have been established in the second Flood Control Act.

England historically had weak spatial planning, with successive governments failing to utilise early flood mapping initiatives in spatial planning decisions (Porter and Demeritt, 2012). Despite the adoption of new measures (e.g. the National Planning Policy Framework), the effectiveness of its current planning system is uncertain. Development on flood plains is still permitted. Furthermore, around 12% of new residential development in England between 2001 and 2014 occurred in floodplains, around 25% of which has been in medium or high flood risk areas (Committee on Climate Change, 2015). In addition, the annual rate of development on the floodplain is higher than for other

areas and the annual rate of development in areas of high flood risk is higher than the average for the floodplain as a whole (Committee on Climate Change, 2015; Crick et al., 2016). However, where the Environment Agency has been aware of a planning decision notice, 97.8% of residential units in those planning decisions were in line with its advice (HM Government, 2016).

In Germany, there is no mechanism by which insurers are asked to assess or approve urban development plans. Kron (2013) proposes that the uninsurability of new homes planned in flood-prone areas should be clearly stated by the insurance industry and communicated to investors who should acknowledge this fact by signature. However, an earlier survey among building insurers revealed a lack of interest in this from insurers, who argued that planning needs to remain the task of governmental bodies (Thieken et al., 2006).

In England, the Department for Communities and Local Government sets planning policy through the National Planning Policy Framework and is responsible for its enforcement (HM Government, 2016). In negotiating the Statement(s) of Principles, the insurance industry was successful in demanding stricter planning regulations. Regardless, the insurance industry has remained relatively hands off; per a report prepared by the Association of British Insurers on government obligations in 2005, it noted that it is the role of the government to “implement[ing] reforms to the land use planning system” (ABI, 2005). However, the exclusion of post-2009 properties both from the Statement of Principles and now from Flood Re can be seen as a disincentive for developments in high flood risk areas. However, up to 10,000 properties are still being built on existing floodplains annually (Flood Re, 2016). This suggests the disincentive has not worked to date. Property developers only have a limited interest in the insurability of new homes due to the high demand for properties. As such, the HM Government (2016) recommends that “[R]isks should not only be passed to homeowners, but those undertaking (and profiting) from development should also retain some responsibility and liability”.

In Germany, if a governmental body decides that a flood-damaged building should be rebuilt elsewhere in order to prevent future flood losses, the model conditions of building insurance provided by the GDV foresees that repair costs equivalent to those in the building’s current location are paid by the insurer (DKKV, 2015). One particular point of conflict are additional costs for a new plot. In the case of Röderau-Süd, an urban area next to the city of Dresden, which was heavily damaged by flooding in 2002 and where 86 homes with 400 inhabitants and 7 enterprises were relocated in the aftermath of the event, the Saxon state provided new plots and the insurers paid for the new homes so that the affected people need not contribute own resources (Müller, 2010). This case is an exceptional example for retreat from floodplains in Germany and was possible because the public administration admitted it had ignored flood risk during the planning procedures. However, due to its high costs of EUR 38 million for the new buildings and EUR 2 million for the demolition of the existing ones, relocation is not seen as a good option in FRM (Müller, 2010).

In conclusion, the role of insurers in demanding stricter planning regulations seems to be underexploited. This limits their ability to provide support to other inputs identified in the anticipatory FRM framework, particularly around housing construction and development. The flow on effects to the insurance industry, in particular the charging of higher premiums for less safe developments, also detracts from its role as a supporter of anticipatory FRM. An interesting form of innovation could be a requirement for property builders to secure flood insurance for their clients for

a period of 10 years or longer, establishing a longer-term interest for developers in this issue. However, pressure for cheap new building stock makes this currently an unlikely political choice.

4.3 Mitigation (Property-Level Protection Measures - PLPMs)

In flood-prone areas, owners of existing homes can implement property-level protection measures (PLPMs) to mitigate losses. Despite their effectiveness (Kreibich et al., 2005), the adoption of PLPMs by homeowners has remained low in both countries, but with some interesting differences. . In Germany, the uptake of PLPMs by property owners has increased after each flood event leading to reduced flood losses and impacts (Grothmann & Reusswig, 2006; Thieken et al. 2007; Kreibich et al., 2011; Bubeck et al., 2012; Kienzler et al. 2015). Overall, areas with high insurance penetration rates (e.g. the river Elbe catchment) tend to have lower uptake of PLPMs: only 13% of residents affected by the 2002-flood used or furnished their home in a flood-adapted manner; this percentage rose to around 35% among flood-affected residents in 2013 (DKKV, 2015). Where penetration rates are lower (e.g. in the Rhine catchment), uptake of PLPMs has been higher: a survey after the 2011-flood revealed that around 65% of the affected residents in the Rhine catchment stated that have used or furnished their home in a flood-adapted manner (Kienzler et al., 2015). However, in a countrywide investigation, Osberghaus & Philippi (2016) found no indication for moral hazard and concluded that flood insurance and PLPMs are commonly seen as complementary safety strategy of homeowners.

In contrast, England has high flood insurance penetration rates and low PLPM uptake despite PLPMs having a high cost-benefit ratio (DEFRA, 2016). Recent analysis has identified a number of possible reasons for this, including property owners (i) lacking awareness of risk, (ii) not accepting risk, (iii) viewing floods as 'one-off events', and (iv) perceiving the authorities as the only party that can pursue flood protection (DEFRA, 2016). Some property owners in England have received support of local and national governments through grant schemes for investments in PLPMs. For example, the Property Resilience Grant Scheme operated by the national government and administered at the district level provided grants of up to £5,000 for the adoption of PLPMs following flooding in late 2015/early 2016 (Priestley, 2016). Between 2007 and 2015, government grants funded the installation of PLPMs in around 3,400 properties (HM Government, 2016). However, unlike in Germany, there has never been a statutory obligation to implement PLPMs.

Generally speaking, the imposition of risk-based insurance premiums is seen as a way of encouraging property owners to adopt PLPMs because it encourages them to reduce their own risk in order to obtain cheaper insurance (e.g. Kousky and Kunreuther, 2014; Hudson et al., 2016). However, this understanding suffers from a number of limitations. Rather, to systematically improve flood risk reduction at the property level, a wide variety of stakeholders must provide support, including developers, builders and the insurance industry, beyond simple economic incentives. German insurers appear to have a better record in this respect. In Germany, deductibles are seen as a common measure to limit moral hazard, keep premiums at an acceptable level and stimulate homeowners to invest in risk reduction, particularly in PLPMs (Kron, 2013). A survey among insurers revealed that there are different options to stipulate deductibles in the insurance contract: in particular, whilst most German insurers consider a fixed sum that is sometimes risk-oriented (i.e. it increases with increasing flood probability according to the zoning system ZÜRS), others determine the deductible as a (fixed) share of the loss or the coverage (Thieken et al., 2006). While a deductible only implicitly stimulates risk reduction (but is still effective (Hudson et al., 2016)), the German

insurance industry has recently endeavoured to explicitly promote PLPMs. Besides risk awareness campaigns (see above), the insurance industry has supported the development of a “flood passport” (i.e. the Hochwasserpäss) for buildings that was developed by the flood competence centre (HKC, see hochwasser-pass.com). This web-based tool offers homeowners a systematic risk assessment with regards to fluvial and pluvial floods which is followed by an on-site consultation with respect to suitable risk reduction measures at the property level. The first rough risk assessment is freely available on the internet; the on-site consultation is charged. The insurance industry has been involved in order to ensure that the certificate can be accepted as proof of flood risk assessment by insurers and banks. The idea is that the presence of the certificate can be used by homeowners in negotiations about a mortgage or flood insurance coverage with banks or insurers, respectively. For example, it could allow homeowners in high-risk zones to purchase insurance if the building is designed and used in a flood-proof manner. Since the tool was launched in 2014, it is too early to evaluate its uptake and use. Some water authorities have considered the use of this tool by flood-prone residents in their FRM plans, which were drafted in accordance with the Floods Directive.

The willingness of insurers to consider PLPMs in the terms and conditions of insurance policies has increased recently as revealed by surveys among German building insurers in 2002/03 and 2012/13 (see DKKV, 2015). 85% of insurers surveyed in 2012/13 informed their clients about possible PLPMs when negotiating or contracting flood insurance. A third of them explicitly asked for PLPMs, while this was not a criterion to assess insurability back in 2002/03 (DKKV, 2015). Furthermore, 86% of building insurers surveyed in 2013 stated that they consider PLPMs by, for example, insuring buildings in high-risk areas, providing a reduced deductible or providing reduced insurance premiums (DKKV, 2015). Back in 2002/03, only 15% of insurers adapted the terms and conditions of their insurance policies due to PLPMs (Thieken et al., 2006). Altogether, there is a tendency among building insurers in Germany to combine flood insurance with flood risk reduction and change insurance conditions that are increasingly more risk-based.

The insurance industry in England appears less supportive of PLPMs, despite recent studies suggest that it is not clear whether the insurance industry values PLPMs or takes steps to incentivise homeowners to adopt PLPMs (DEFRA, 2016). According to a recent survey, over 75% of insurers noted that they did not consider signing up for Environment Agency flood alerts to be an effective means of risk reduction. More concerning is that approximately 40% of insurers did not consider “internal improvements” (e.g. hard flooring and waterproof walls) to be effective (DEFRA, 2016). Insurers also appear to not generally recognise standards for PLPMs (DEFRA, 2016). A significant minority of insurers (almost 30%) also suggested they would not permit a homeowner to adopt PLPMs following a flooding event, even if it were cost-neutral. As such, it can be concluded that insurers have been ineffective in encouraging their policyholders to adopt flood mitigation measures (Lamond et al., 2009). In this respect, the finding by O’Hare et al. (2015) that the ‘no betterment’ principle in loss compensation mechanisms is a major obstacle to the adoption of PLPMs deserves special attention. The linkage of risk reduction during recovery could provide an important feedback mechanism. Furthermore, because flood premiums are bundled with other home insurance costs, insurers usually do not differentiate or disclose to their customers the percentage relating to flood insurance. This affects the ability of policyholders to understand their own personal risk. The Association of British Insurers has recently prepared a policy document on adopting PLPMs, though it is unclear whether its availability is communicated to policyholders (ABI, 2016). The Association of British Insurers (ABI) has also issued guidance to assist developers with building flood resilient properties through practical steps such as raising floor levels of properties (ABI, 2008) and also ran

broader information campaigns such as the 'Floods Destroy, Be Prepared' awareness initiative and information on how to receive flood warnings, flood risk information and risk mitigation. However, the new Flood Re contains no formal program for promoting the adoption of PLPMs (Surminski, 2016).

With regards to the anticipatory FRM framework (see figure 2), the insurance industry's record differs between countries. In Germany, insurers appear much more willing to take into account PLPMs, whilst in England their importance has generally been undervalued. However, insurance coverage tends to be significantly higher in England. It is unclear to what extent this trend can therefore be attributed to the 'moral hazard' of insurance.

4.4 Protection (Structural measures)

The English government has invested considerably in a range of flood and coastal defences (Bennett, 2013). More recently, it has pledged to invest an additional £2.3 billion in flood defences between 2015 and 2021, which will better protect up to 300,000 homes (HM Government, 2016). For example the government is also working with the city of Sheffield to create new kinds of flood defences that can be utilised in the UK's "core cities" (HM Government, 2016) For example, during the winter 2015/16 floods, although 16,000 properties were flooded, 20,000 were protected by existing flood defences (Priestley, 2016). However, more investment is still required, with a 2014 study suggesting that the optimal level of annual investment is £750m to £800m; greater than the amount pledged (Environment Agency, 2014). Furthermore, attempts to encourage local governments and private bodies to contribute more to flood defences have proven relatively ineffective (Bennett, 2013).

In Germany, major flood events have revealed weaknesses in structural measures. For example, while dike breaches only occurred occasionally during the floods of 1997 (Odra) and 1999 (Danube), more than 100 breaches occurred in August 2002 along the rivers Mulde and Elbe in Saxony (and partly in Saxony-Anhalt). By 2011, 468 km of dikes along the river Elbe have been upgraded (IKSE, 2012). Still, some severe breaches occurred during the flood in June 2013, particularly in sections that had not been upgraded, but were in need of technical improvements (Thieken et al., 2016). As such, awareness for the need of enhancing other measures is rising. For example, the national flood protection programme that was launched in October 2014 includes many projects for restoring floodplains or creating retention areas where water can be temporarily stored (flood polders). Past experience reveals, however, that such large projects take years until they are fully implemented.

The role of the insurance industry supporting protection measures differs between both countries. In England, one of the lynchpins of the Statement(s) of Principle entered into between the insurance industry and the government was a commitment by the government to make sufficient investment in flood defences (ABI, 2005). This was agreed to by the government under significant pressure from the insurance industry. The Memorandum of Understanding in relation to Flood Re maintains this approach to some extent, with a 'letter of comfort' from the government providing for long term commitment to expenditure on FRM. In Germany, the presence of uninsurable risks (e.g. coastal flooding in the North) has also encouraged the government to invest heavily in structural measures. As such, the insurance industry has a clear amount of leverage to steer public policy and government spending.

In Germany, the insurance industry, in contrast, is not involved in negotiations about flood defence expenditure, which may be partly due to the devolved nature of the decision-making process across the different Laender. The responsibilities across a river cross-section (used as a waterway) are distributed between several governance levels as shown by DKKV (2003) using the river Elbe at Dresden as an example. Federal agencies are responsible for the navigation of the river Elbe, the monitoring of water quality etc., while the Freestate of Saxony is responsible for the embankments. Flood channels within the city of Dresden are however maintained by the city of Dresden. In other federal states, e.g. Lower Saxony, Bremen or North Rhine-Westphalia, embankments are planned, implemented and maintained by regional dyke associations that are – besides public subsidies – financed by mandatory annual fees on all property owners benefitting from the embankments in a specific region.

Interestingly, insurers in both countries do not appear to value alternatives to structural measures such as nature based flood risk solutions when calculating risk; instead, structural measures are perceived as the “gold standard” (Ball et al., 2013). However, these alternative measures are becoming increasingly recognised as an important means of reducing flood risk (see Poljansek et al. 2017), which suggests that a broader cultural change is required in the insurance industry and society in general to the role that non-structural measures can play in reducing flood risk.

With regards to the anticipatory FRM framework (see figure 2), the insurance industry can leverage their influence to promote government investment in structural measures. However, structural measures will only have an impact on how insurance policies are priced if they are adequately taken into account in risk models. Greater emphasis also needs to be placed on non-structural measures as a means of risk reduction.

4.5 Preparedness for response

Overall, recent developments have significantly improved the awareness and preparedness of flood-affected residents and their knowledge about living in a flood-prone area in both England and Germany. This reduces risk uncertainty and improves flood preparedness, two key inputs to the anticipatory FRM framework (see figure 2).

In England, the Environment Agency operates the flood information service on its website, which allows homeowners to check their 5 day flood risk (ranging from ‘unlikely’ to ‘high risk’) and monitor nearby river/sea levels. Regional differences in flood forecasting were overcome with the establishment of the National Flood Forecasting Service (Alexander et al., 2016). Complicated governance arrangements were overcome with the establishment of the Flood Forecasting Centre, a joint venture between the Met Office and the Environment Agency (Alexander et al., 2016). More recently, the government committed to preparing an integrated flood risk monitoring platform which allows simulations linking meteorology, hydrology and flooding (HM Government, 2016).

In Germany, the meteorological service is a federal authority (Deutscher Wetterdienst – DWD) under the Federal Ministry of Transport and Digital Infrastructure and is - by law - responsible for weather monitoring and forecasting as well as for detecting extreme weather situations in the whole country including the release of appropriate warnings when necessary. Warnings are, however, restricted to meteorological phenomena such as heavy rainfall. Consequently, additional services are in place for flood forecasting and warning. Since all water issues as well as civil protection and emergency management are in the responsibility of the federal states, the organisation of flood forecasting and

warning as well as the organisation of the civil protection differs throughout Germany. Flooding in 2002 revealed major deficiencies in Germany's flood risk warning and communication (DKKV, 2003). For example, warnings came too late or not at all, messages were unclear and alerts were occasionally not propagated due to unclear procedures and outdated contact details (DKKV, 2003). Meanwhile, data and models have been continuously updated, collaboration between DWD, the water authorities and the civil protection has been strengthened and some federal states have reorganized their warning systems (see DKKV, 2015). In addition, flood exhibitions, marks of flood water levels etc. are widespread and keep flood risk awareness on a high level (DKKV, 2015). However, an impact-based flood warning as it exists in England is not available in Germany. Nevertheless, only 7% of affected residents did not receive a warning in the June 2013 floods in contrast to 27% in 2002 (Kreibich et al., 2016). Residents were also better informed about PLPMs (Thieken et al., 2016).

The insurance industry has the potential to support preparedness through information and advise, directly contributing to technical know-how and behaviour as two key inputs in the anticipatory FRM framework (see figure 2). However, evidence for this in England is fairly limited. Even though Flood Re is a quasi-public body accountable to parliament, it does not communicate directly with policyholders nor does it have any formal requirements for the communication of flood risk. This may reflect the priorities that were established under the Statement(s) of Principles, which identified "effectively communicating flood risk" as one of the five performance targets of the government, not the insurance industry (Penning-Rowsell et al., 2014). Interestingly Flood Re is committed to data sharing with the government once it has set up its own flood risk databases Flood Re, 2016). In response, the HM Government (2016) has noted that improvements are needed in how flood risk is communicated. Furthermore, the Environment Agency has announced an awareness campaign in autumn of 2017 (i.e. in anticipation of winter flooding) that is locally delivered to communities at risk of flooding (HM Government, 2016).

While the usability and accessibility of the German flood hazard zoning system ZÜRS (see above) has been limited to professionals from the insurance industry, the GDV launched an additional open-access multi-hazard web portal "Kompass Naturgefahren" for pilot regions in May 2011. By now, hazard zones from the federal states of Lower-Saxony, Saxony, Saxony-Anhalt and Berlin have been integrated. The hazard profile of detailed postal addresses can be searched for and the visualisation is better tailored to the information needs of the general public than the maps that were produced for the Floods Directive and contain a lot of information that is assumed to be too detailed for laypersons (see Meyer et al., 2012). The web portal "Kompass Naturgefahren" can be seen as a prototype for a web-based hazard and risk information platform that was decided to be created for the whole country in October 2014 by the Conference of Ministries of the Environment (UMK), but has not been implemented so far.

While flood hazard maps are an important pre-requisite for risk awareness, they need to be accompanied by information on adequate and risk-reducing options and their costs in order to lead to adapted behaviour of flood-prone residents (see Grothmann & Reusswig, 2006; Bubeck et al., 2012). Kron (2013) suggests that the loss compensation process should be used to better inform homeowners about their risks and mitigation options. Besides, other communication strategies should be intensified such as brochures, videos etc. taking the preventive fire protection as a role model for such activities. However, a clear linkage between repair works and risk reducing measures

has not been established in Germany or England. In fact, the ‘no betterment’ principle in insurance policies might hinder the improvement of resilient homes (O’Hare et al., 2015).

Driven by the discussion about mandatory flood insurance and low uptake of voluntary flood insurance in Germany, the GDV has started risk awareness campaigns together with the water authorities of the federal states. The campaigns mainly inform about the availability, costs and advantages of flood insurance in Germany. The first campaign started in Bavaria in 2009. Meanwhile eight of 16 states have performed such campaigns, some already several times; in two further states campaigns are in preparation. Data from GDV (2016) reveal an increase in flood insurance from 19% in 2002 to 37% in 2015 as a result (see figure 4). However, Osberghaus & Philippi (2016) revealed that changes in preparedness can hardly be attributed to these awareness campaigns.

With regards to the anticipatory FRM framework (see figure 2) and risk awareness, the role of insurance is ambivalent. In some cases, insurance does support awareness campaigns. In other cases, the government has failed to take opportunities available to it to promote awareness; for example, the lack of compulsory communication under Flood Re. In others, the awareness campaign is strongly focused on the uptake of flood insurance rather than flood risk levels or measures to prepare, which is somewhat understandable given Germany’s low penetration rates. This may also explain the limited engagement of insurers in England, where penetration levels are very high. There is clearly more that the insurance industry could therefore be doing to communicate risk (and response measures in particular to homeowners).

5. Concluding discussion

In this paper we explore how flood insurance can support flood risk reduction by investigating the cases of England and Germany. Both countries show many similarities as well as specific differences in the way flood insurance is used and FRM is governed. Interestingly, both offer flood insurance through a private market approach, although with subsidized reinsurance in England. This makes our selection suitable for a comparative investigation as we do not only look at insurance as an instrument, but also as a private sector agent. Nevertheless, the examples outlined in this paper can also serve as illustrations for other countries that consider how best to harness the role of flood insurance. This is particularly timely as across the world FRM is under pressure by rising risk levels and growing budgetary constraints of the public sector. This is triggering reviews of flood insurance systems, such as in the US or in Canada, while several developing countries and international donors discuss the introduction of flood insurance (Surminski, 2014; Surminski et al., 2015). The analysis is framed by the system depicted in figure 2, recognizing that any changes in the FRM will be determined by a range of ‘inputs’ that can become catalysts for change; for example, major flood events, put possibly also insurance.

Our analysis is framed by the system depicted in figure 2, recognizing that any changes in the FRM will be determined by a range of ‘inputs’ that can become catalysts for change; for example, major flood events, put possibly also insurance. The investigations in sections 3 and 4 reveal several new insights for FRM governance:

- In both countries flood events remain the driving forces for FRM efforts, amidst some signs of shift towards more anticipatory FRM.

Events tend to be followed by a review and the adoption of new FRM approaches (particularly legislation and guidelines) in order to mitigate the future impact of flooding. Depending on the kind of flooding suffered and the lessons learnt, changes also tend to be made to risk communication, risk knowledge and risk reduction. Both countries have adopted new legislation to improve FRM in the wake of flood events. For example, England has adopted the Flood and Water Management Act 2010, which required the Environment Agency to establish a national strategy for FRM and has been dubbed “...a big step forward in managing flood risk” (DEFRA, 2017). Similarly, Germany has taken steps to implement the Floods Directive which requires EU member states to take certain steps to identify, map and manage flooding risk, and adopted legislation for improving FRM (the Omnibus Flood Control Act I and II). This indicates a shift towards anticipatory FRM, at least on paper. What impacts this has on risk reduction is hard to tell. Indicators such as spending on flood protection in England, shown in figure 3, are far from transparent and are subject to debate and even dispute (Surminski and Eldridge, 2014). For Germany, an aggregate database on investments in flood protection is not available, also due to the federalist nature of FRM responsibilities, with often decentralized spending across a range of institutions. In Germany, the federal government only sets general standards which can lead to different management approaches between states (for example, see DKKV, 2013; Heintz et al., 2012; DKKV, 2015). Importantly, flood events can also be the source of learning and improvement, driving future resilience based on lessons arising from past events. This can take the form of reviews and public inquiries, such as Pitt and DKVV. An example for a more standardised approach for this is the post-event review capability (PERC) developed by Zurich insurance, which “provides research and independent reviews of large flood events, (...) looking at what has worked well (identifying best practice) and opportunities for further improvements.” (Zurich 2017) These PERCs have been conducted also for Germany and England.

- While there are examples of clear support for anticipatory FRM through insurance, the role that insurance plays beyond risk transfer remains underdeveloped in both countries.

Our investigation builds on the hypothesis that insurance can support anticipative FRM beyond its core risk transfer function through influencing behaviour and capacity building. Table 1 summarizes our findings, showing the role that insurers have on the five different elements of flood risk analysis and reduction in both countries, as per the FRM cycle (figure 2).

Table 1: Role of insurance on FRM in England and Germany based on the analysis in section 4.

Role of insurance on	England	Germany
Risk knowledge (flood hazard and risk maps)	Insurance is engaged in improving risk knowledge, commitment to exchange data with government, also under Flood Re;	Insurance has demanded and driven policy developments in this field, e.g. by the early establishment of a flood hazard zoning system (ZÜRS); current data exchange with water authorities reveal a good partnership.
Prevention / Spatial planning	Insurance has demanded and driven policy developments in this field, e.g. during negotiations in the Statement of Principles and Flood Re’s exclusion of new build	No active role of insurance, except for clear rules around insurance cover in case of relocation of properties. . Potential is underexploited.

	properties. . Potential is underexploited and effectiveness not clear.	
Mitigation (PLPMs)	Some information provision by insurers about PLPMs, but insurance is mostly not supportive due to the no betterment principle, and no provision for this under Flood Re.	Insurance is increasingly supportive by demanding PLPMs in some cases and providing incentives/ better insurance conditions in other cases when PLPMs are in place.
Flood protection	Insurance has demanded and driven policy developments and governmental investments in this field, e.g. during negotiations in the Statement of Principles and Flood Re. This has led to protection of flood defence spending during budget cuts, but no long-term commitment by government.	Insurance tends to demand policy developments and governmental investments in this field, but there are no formal agreements except for the exclusion of storm surge losses from insurance, which reinforce the importance of coastal protection.
Flood preparedness (warning and risk communication)	No active role of insurance in warning, but engagement in awareness raising and information provision, for example through ABI or individually by insurance companies.	Insurance demands policy developments and governmental investments in this field, e.g. by supporting the development of prototypes (Kompass Naturgefahren; Hochwasserpass); good partnerships in risk awareness campaigns

These findings underline that the insurance industry can be a catalyst for change towards more anticipatory FRM. Our analysis highlights that insurance is playing a supportive role with regard to an improved risk knowledge basis, awareness raising and, to a limited extent, supporting the uptake of PLPMs. As the case of England shows there is a clear supportive role for more public investments in protection – which was in fact a condition under the Statement(s) of Principles and has helped to protect the flood budget in times of overall fiscal austerity. The Flood Re arrangement is far less clear on this, which could indicate a backwards trend in terms of the risk reduction focus of the insurance industry. In England insurers have also supported a strengthened spatial planning approach, through official agreements such as the Statement of Principles. The effectiveness of this, particularly with regards to spatial planning, remains unclear as planning rules have recently been eased due to pressure to build more homes. In Germany the cooperation between the insurance industry and governmental bodies seems to be much more informal, but has developed in many arenas over the past 15 years. A particular constraint for insurers is the fact that FRM is to a large extent a State-matter, and governed differently across Germany's 16 Bundeslaender. Still, insurers influence many elements of FRM beyond risk transfer and uptake of PLPMs (see Table 1).

- There are barriers that limit the role of insurance, which need to be addressed.

Our study also shows that the broader risk reduction role of flood insurance does not occur automatically and requires long-term efforts, in collaboration with government and others. Our discussions with stakeholders in both countries have highlighted a range of barriers for insurance to support risk reduction, such as:

- Risk Knowledge (maps): Insurers' concerns about confidentiality of their claims data, licencing questions regarding public flood data when used for commercial purposes, communicating probabilities and flood risk information to individuals, reaching those most vulnerable; large group of data-owners; cost of collating and streamlining data
- Prevention (planning): Incentive for new build faces limited interest by property developers, administrative burden for insurers, and often clashes with political pressure to build more homes.
- Mitigation (PLPMs): Information about and incentives for risk reduction measures at property level is often facing unclear cost-benefits, behavioural barriers, hassle factor, size of premium not big enough to trigger investment, difficulty in tracking/data implementation of PLPM, affordability challenge, one year contract length, resilient repairs might take longer than standard repairs.
- Protection (structural measures): Incentives for public policy and public investment in protection is difficult due to a lack of transparency about how much is spent publicly on flood defences, how are they maintained over time, how effective are the measures.
- Preparedness for response: missing tailor-made communication and information material; missing links between hazard information and mitigation options.

These points offer some insights on the constraints and challenges that insurers and governments are facing in this area. Some of these points are well-known (see for example Surminski and Eldridge, 2015; Surminski and Hudson, 2016), particularly the apparent trade-off between affordability of insurance cover and use of the risk-signalling function of insurance through risk based pricing, which heavily influenced the design of Flood Re in England, and meant that Flood Re does not apply any risk-signalling (Jenkins et al., 2017). Furthermore, evidence from England shows that insurers do not automatically operate efficiently as agents of risk reduction (Surminski, 2017; Lamond et. al .2009). Indeed, it can be difficult for insurers to know how to quantify the benefits of a risk reduction measure, particularly where they are adopted proactively (i.e. prior to a natural disaster rather than afterwards). As such, although flood insurance may provide an incentive for risk reduction, it is an incentive some struggle to take advantage of (Surminski and Hudson 2016).

- Both countries show that collaboration between private insurance and those who make decisions relevant for FRM is important for anticipatory FRM and securing future insurability.

The barriers highlighted above underline why collaboration between industry and government is so important when responding to the challenges of flood risk. Particularly in the context of rising risks due to climate change, there is a growing recognition that anticipatory FRM with a strong focus on risk reduction and resilience is the only viable way to ensure future insurability of these risks (Jenkins et al., 2017; Surminski and Hudson, 2016; see also Ermoliev et. al. 2000 for an earlier investigation of this).

In both countries there are many examples for collaboration (see table 1), and the industry as well as policy makers deserve credit for this approach, which is far less developed in other countries (Surminski 2015). However, this collaboration is lacking in structure and formality and there is little

stream-lining of efforts. For example, in England the move from the Statement of Principles to Flood Re can be seen as a step back from a FRM –focused partnership (Surminski and Eldridge 2014).

Our analysis shows that this broader role of flood insurance is far from exhausted and that there is the possibility to enhance this further through better collaboration between industry and government. As a first step, it is recommend to schedule regular meetings between government and insurance to establish partnerships in the various fields of FRM shown in Fig. 1. This could help to streamline efforts, to clarify who pays for what, to jointly test innovative approaches, particularly with regards to linking recovery and repair work to risk reduction, and to agree on an upscaling of successful solutions.

It is encouraging to see the industry calling out for better collaboration between government and insurers, suggesting to form partnerships in support of anticipatory FRM (see for example Golnaraghi et al., 2016). However, it is often far from clear what this collaboration would entail, and there is also a risk that this becomes a ‘talking shop’, admiring the problem rather than focusing on real improvements. The need for clear action is increasingly recognized by insurance companies, such as the Zurich Flood Resilience Research partnership, investigating ways to increase flood resilience (Zurich 2016). It is important to recognize that such collaborations also come at a cost – it requires time and resources by both, industry and government. However, in times of rising risks due to climate change, this should be seen as an investment (that pays off in future) rather than a cost.

Despite many examples in both countries it is far from clear whether the insurance industry will continue with its efforts and how much influence this will have within the FRM field, particularly in the face of other pressures such as political priorities or demands for cheap housing. The real test will come with the next significant flood in either Germany or England - both in terms of effectiveness of current FRM efforts, and willingness of insurers and government to pursue flood resilience in earnest.

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REFERENCES

Aerts, J.C.J.H. and W.J.W. Botzen (2011): Flood-resilient waterfront development in New York City: Bridging flood insurance, building codes and flood zoning, *Ann. N. Y. Acad. Sci.*, 1227, 1–82.

Aerts, J.C.J.H. and W.J.W. Botzen (2012): Brief communication “Hurricane Irene: a wake-up call for New York City?” – *Nat. Hazards Earth Syst. Sci.*, 12, 1837-1840.

Alexander, M., S. Priest, A.P. Micou, S. Tapsell, C. Green, D. Parker and S. Homewood. 2016. “Analysing and evaluating flood risk governance in England – Enhancing societal resilience through comprehensive and aligned flood risk governance arrangements”. STAR-FLOOD.

Amos, J. 18 April 2016. Economic losses from natural disasters counted. BBC News.

Arthur, C. 27 February 2014. “Environment Agency poised to open flood data to public”. The Guardian.

Association of British Insurers, 2005. “ABI Statement of Principles on the provision of flood insurance”. Association of British Insurers: London.

Association of British Insurers. 2008. “Insurance in the UK: The Benefits of Pricing Risk”. *Association of British Insurers*.

Association of British Insurers. 2009. “Guidance on Insurance Issues for New Developments”.

Association of British Insurers. Available at:

<https://www.abi.org.uk/~media/Files/Documents/Publications/Public/Migrated/Flooding/Climate%20adaption%20guidance%20on%20insurance%20issues%20for%20new%20developments.ashx>

[accessed 15 January 2017]

Association of British Insurers. 2016. “Home insurance premiums remain stable despite winter floods”. *Association of British Insurers*. Available at: <https://www.abi.org.uk/News/News-releases/2016/08/ABI-Q2-Property-premium-insurance-tracker> [accessed 10 October 2016]

Ball, T., A. Werritty and A. Geddes. 2013. “Insurance and sustainability in flood-risk management: the UK in a transitional state”. Volume 45 No. 3 Area.

Bennett, O. 2013. “Flood defence spending in England”. House of Commons Library.

Botzen, W. J. W., J. C. J. H. Aerts and J. C. J. M. van den Bergh. 2009. “Dependence on flood risk perceptions on socioeconomic and objective risk factors”. Volume 45 Issue 10 Water Resources Research.

Botzen WJW, van den Bergh JCJM, Bouwer LM (2010) Climate change and increased risk for the insurance sector: a global perspective and an assessment for the Netherlands. *Nat Hazards* 52(3):577–598

Brainard, L. (2008) What is the role of insurance in economic development? Zurich Government and Industry Affairs, Thought Leadership Series (No. 2). Available at

https://www.draudimas.com/allpics/What_is_the_role_of_economic_development.pdf

Bräuninger, M., S. Butzengeiger-Geyer, A. Dlugolecki, S. Hochrainer, M. Köhler, J. Linnerooth-Bayer, R. Mechler, A. Michaelowa, and S. Schulze. 2011. Application of economic instruments for adaptation to climate change Final report [online]. Perspectives GmbH. Available at:

http://ec.europa.eu/clima/policies/adaptation/what/docs/economic_instruments_en.pdf [accessed 17 December 2013].

Brown, P. 7 October 2004. "New flood maps pinpoint risk areas". The Guardian.

Bubeck, P., H. Kreibich, E.C. Penning-Rowsell, W.J.W. Botzen, H. de Moel and F. Klijn (2015): Explaining differences in flood management approaches in Europe and in the USA – a comparative analysis. *Journal of Flood Risk Management*, online first 28 April 2015, DOI: 10.1111/jfr3.12151.

Bubeck, P., J.C.J.H. Aerts, H. de Moel and H. Kreibich (2016): Preface: Flood-risk analysis and integrated management. – *Nat. Hazards Earth Syst. Sci.*, 16, 1005–1010.

Bubeck, P., W.J.W. Botzen, H. Kreibich, J.C.J.H. Aerts (2012): Long-term development and effectiveness of private flood mitigation measures: an analysis for the German part of the river Rhine. – *Nat. Hazards Earth Syst. Sci.* 12: 3507-3518.

CEA. 2007. *Reducing the Social and Economic Impact of Climate Change and Natural Catastrophes Insurance Solutions and Public-Private Partnerships*, Brussels, Belgium.

CEA. 2009. *Tackling Climate Change: The Vital Contribution of Insurers* [online]. Brussels: CEA. Available at: <https://www.scor.com/en/sgrc/pac/environment-climate-change/item/1371-cea-tackling-climate-change-the-vital-contribution-of-insurers.html> (accessed 30 March 2017).

Committee on Climate Change. 2015. "Progress in preparing for climate change". Report to Parliament.

Committee on Climate Change. 2016. "UK Climate Change Risk Assessment 2017". Available at: <https://www.theccc.org.uk/wp-content/uploads/2016/07/UK-CCRA-2017-Synthesis-Report-Committee-on-Climate-Change.pdf>.

Crichton, C. 2008. "Towards a comparison of public and private insurance responses to flooding risks". Volume 24 Issue 4 *International Journal of Water Resources Development*.

Crick, F. Jenkins, K. and Surminski, S. 2016: Strengthening insurance partnerships in the face of climate change insights from an agent-based model of flood insurance in the UK, Grantham Research Institute On Climate Change and the Environment Working Paper, No. 241, London, in journal review. Available at <http://www.lse.ac.uk/GranthamInstitute/wpcontent/uploads/2016/06/Working-Paper-241-Crick-et-al.pdf>

Department for Environment, Food and Rural Affairs. 2005. "Making space for water – Taking forward a new government strategy for flood and coastal erosion risk management in England". DEFRA. Available at: <http://coastaladaptationresources.org/PDF-files/1329-Making-space-for-water.pdf> [accessed 15 January 2017]

Department for Environment, Food and Rural Affairs. 2016. "The Property Flood Resilience Action Plan". DEFRA. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/551615/flood-resilience-bonfield-action-plan-2016.pdf [accessed 10 October 2016]

Department for Environment, Food and Rural Affairs. 2017. "Post-legislative Scrutiny of the Flood and Water Management Act 2010". Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/585493/flood-water-management-post-legislative-scrutiny.pdf [accessed 28 February 2017]

DKKV – Deutsches Komitee Katastrophenvorsorge (Ed.). 2003. Lessons Learned – Hochwasservorsorge in Deutschland – Lernen aus der Katastrophe 2002 im Elbegebiet. Schriftenreihe des DKKV 29, Bonn (in German).

DKKV (2013) Das Hochwasser im Juni 2013. Schriftenreihe des DKKV 53, Deutsches Komitee für Katastrophenvorsorge e. V. (DKKV)

DKKV – Deutsches Komitee Katastrophenvorsorge (Ed.). 2015. Das Hochwasser im Juni 2013 – Bewährungsprobe für das Hochwasserrisikomanagement in Deutschland. Schriftenreihe des DKKV 53, Bonn (in German).

Environment Agency. 2010. “Flood and Coastal Risk Management Risk Mapping Strategy 2010–2015”. Environment Agency.

Environment Agency. 2013. “What is the updated Flood Map for Surface Water?”. Environment Agency.

Environment Agency. 2014a. “Flood and coastal erosion risk management: Long-term investment scenarios (LTIS) 2014”. Environment Agency.

Ermoliev, Y.M., Ermolieva, T.Y., MacDonald, G.J., Norkin, V.I., Amendola, A., 2000. A system approach to management of catastrophic risks. Eur. J. Oper. Res. 122, 452–460

European Commission. 2007. “Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks”.

Falkenhagen, B. (2005): ZÜRS Das Zonierungssystem der deutschen Versicherungswirtschaft zur Einschätzung der Überschwemmungsgefährdung. In: Kleeberg, H.-B. (Ed.): Hochwassergefahrenkarten. Forum für Hydrologie und Wasserbewirtschaftung No. 08/05, p. 85-91 (in German).

Filatova, T. 2013. “Market-Based Instruments for Flood Risk Management: A Review of Theory, Practice and Perspectives for Climate Adaptation Policy”. Volume 37 Environmental Science & Policy.

Flood Re. 2016. “The first Flood Re transition plan”. Flood Re.

GDV (2016): Naturgefahrenreport 2016. Berlin.

Golnaraghi, M., S. Surminski and K.-U. Schanz. 2016. “An Integrated Approach to Managing Extreme Events and Climate Risk – Towards a Concerted Public-Private Approach”. Geneva Association. Available at: https://www.genevaassociation.org/media/952146/20160908_ecoben20_final.pdf [accessed 10 January 2017]

Green, C., C. Dieperink, K. Ek, D. Hegger, M. Pettersson, S. Priest and S. Tapsell. 2013. “Flood Risk Management in Europe: the flood problem and interventions”. STAR-FLOOD.

Grothmann, T. & Reusswig, F. (2006) People at risk of flooding: Why some residents take precautionary action while others do not. Natural Hazards 38(1-2), 101-120.

Hallegatte, S., 2011. ‘How economic growth and rational decisions can make disaster losses grow faster than wealth’, World Bank Policy Research Working Paper No. 5617, World Bank, Washington, DC.

Hegger, D. L. T., P. P. J. Driessen, C. Dieperink, M. Wiering, G. T. Raadgever, H. F. M. W. Van Rijswijk. 2014. Assessing stability and dynamics in flood risk governance: an empirically illustrated research approach. *Water Resources Management* 28:4127-4142. <http://dx.doi.org/10.1007/s11269-014-0732-x>.

Heintz, M.D., Hagemeyer-Klose, M. & Wagner, K. (2012): Towards a Risk Governance Culture in Flood Policy—Findings from the Implementation of the “Floods Directive” in Germany. - *Water* 4(4): 135–156.

HM Government. 2016. “National Flood Resilience Review”. HM Government.

Hudson, P., W.J.W. Botzen, L. Feyen, J.C.J.H. Aerts (2016): Incentivising flood risk adaptation through risk based insurance premiums: Trade-offs between affordability and risk reduction. – *Ecological Economics*, 125: 1-13.

IKSE, 2012. Abschlussbericht über die Erfüllung des „Aktionsplans Hochwasserschutz Elbe“2003–2011. Magdeburg, Internationale Kommission zum Schutz der Elbe (IKSE). Available at: http://www.ikse-mkol.org/fileadmin/media/user_upload/D/06_Publikationen/02_Hochwasserschutz/2012_IKSE_Abschlussbericht_AP%20HWS_2003-2011.pdf [accessed 30 March 2017]

Intergovernmental Panel on Climate Change (“IPCC”). 2012. “Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation”. Special Report of the Intergovernmental Panel on Climate Change.

Jenkins, K., Surminski, S., Crick, F., Hall, J. 2017: Assessing surface water flood risk and management strategies under future climate change: insights from an Agent-Based Model, *Science of the Total Environment*, in press.

Johnson, CL, Tunstall, SM, Penning-Rowsell, EC (2005): Floods as catalysts for policy change: Historical lessons from England and Wales. – *International Journal of Water Resources Development* 21(4): 561-575.

Jongman B, Hochrainer-Stigler S, Feyen L, Aerts JCJH, Mechler R, Wouter Botzen WJ, Bouwer LM, Pflug G, Rojas R, Ward PJ (2014) Increasing stress on disaster-risk finance due to large flood. *Nat Clim Change* 4:264–268

Kaufmann, M. and M. Wiering. 2017. Discursive junctions in flood risk governance – A comparative understanding in six European countries. Volume 196 *Journal of Environmental Management*.

Kienholz, H., Krummenacher, B., Kipfer, A., and Perret, S. (2004): Aspects of Integral Risk Management in Practice – Considerations with Respect to Mountain Hazards in Switzerland. *Österreichische Wasser- und Abfallwirtschaft*, 56, 43–50 .

Kienzler, S., Pech, I., Kreibich, H., Müller, M., and A.H. Thielen. 2015. After the extreme flood in 2002: changes in preparedness, response and recovery of flood-affected residents in Germany between 2005 and 2011. *Nat. Hazards Earth Syst. Sci.* 15:505-526.

Kousky, C. and H. Kunreuther. 2014. “Addressing Affordability in the National Flood Insurance Program”. Volume 1 No. 1 *Journal of Extreme Events*.

Kreibich, H., A.H. Thieken, Th. Petrow, M. Müller, B. Merz (2005): Flood loss reduction of private households due to building retrofitting – Lessons learned from the Elbe floods in August 2002. – *Nat. Hazards Earth Syst. Sci.* 5: 117-126.

Kreibich, H., P. Bubeck, M. Kunz, H. Mahlke, S. Parolai, B. Khazai, J. Daniell, T. Lakes and K. Schröter. 2014. A review of multiple natural hazards and risks in Germany. *Natural Hazard* 74: 2279-2304.

Kreibich, H., I. Pech, K. Schröter, M. Müller and A. H. Thieken. 2016. New insights into flood warning and emergency response from the perspective of affected parties, *Nat. Hazards Earth Syst. Sci. Discuss.*, doi:10.5194/nhess-2016-133, in review.

Kreibich, H., I. Seifert, A.H. Thieken, E. Lindquist, K. Wagner, B. Merz (2011): Recent changes in flood preparedness of private households and businesses in Germany. – *Regional Environmental Change* 11(1): 59-71.

Kron, W. (2013): Versicherung von Hochwasserschäden. In: Patt, H., R. Jüpner (Eds.): *Hochwasserhandbuch*. Springer: Berlin, 2nd edition, chapter 10, p. 553-606 (in German).

Kunreuther, H. and E. Michel-Kerjan. 2009. “Managing catastrophes through insurance: challenges and opportunities for reducing future risks”. Working Paper 2009-11-30. The Wharton School, University of Pennsylvania, Philadelphia.

Lamond, J., D. Proverbs and F. Hammond. 2009. “Flooding and Property Values”. In Brown, S. (Ed.). 2009. *Findings in Built and Rural Environments (FIBRE)*. Royal Institute of Chartered Surveyors, London.

Linnerooth-Bayer J. and Hochrainer-Stigler 2015, *S. Climatic Change*, 133, 85-100 (2015).

McAneney, J., R. Crompton, D. McAneney, R. Musulin, G. Walker and R. Pielke Jr. 2013. “Market-based mechanisms for climate change adaptation”. Macquarie University, Aon Benfield Analytics Asia Pacific and University of Colorado, Boulder.

Mechler, R., Pulido-Velazquez, M., Koehler, M., Jenkins, K., Surminski, S., and Williges, K.: Economic Instruments, in ENHANCE (2016). *Novel Multi-Sector Partnerships in Disaster Risk Management. Results of the ENHANCE project*. Jeroen Aerts and Jaroslav Mysiak (eds). EU FP7 project ENHANCE.

Mechler, R., Bouwer, L. M., Linnerooth-Bayer, J., Hochrainer-Stigler, S., Aerts, J. C. J. H., Surminski, S. and Williges, K., 2014. Managing unnatural disaster risk from climate extremes. *Nature Climate Change*, 4, pp. 235–237

Merz, B., J. Aerts, K. Arnbjerg-Nielsen, M. Baldi, A. Becker, A. Bichet, G. Blöschl, L. M. Bouwer, A. Brauer, F. Cioffi, J. M. Delgado, M. Gocht, F. Guzzetti, S. Harrigan, K. Hirschboeck, C. Kilsby, W. Kron, H.-H. Kwon, U. Lall, R. Merz, K. Nissen, P. Salvatti, T. Swierczynski, U. Ulbrich, A. Viglione, P. J. Ward, M. Weiler, B. Wilhelm, M. Nied (2014): Floods and climate: emerging perspectives for flood risk assessment and management. – *Nat. Hazards Earth Syst. Sci.*, 14, 1921-1942.

Meyer V., C. Kuhlicke, J. Luther, S. Fuchs, S. Priest, W. Dorner, K. Serrhini, J. Pardoe, S. McCarthy, J. Seidel, G. Palka, H. Unnerstall, C. Viavattene, and S. Scheuer. 2012. Recommendations for the user-specific enhancement of flood maps. *Nat. Hazards Earth Syst. Sci.* 12:1701-1716.

Müller, U. 2010. Hochwasserrisikomanagement: Theorie und Praxis. Vieweg+Teubner, Wiesbaden, 372 pp. (in German).

National Research Council. 2015. *Tying Flood Insurance to Flood Risk for Low-Lying Structures in the Floodplain*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/21720>.

O'Hare, P., White, I. and Connelly, A. (2015): Insurance as maladaptation: Resilience and the 'business as usual' paradox. *Environment and Planning C: Government and Policy*. ISSN 0263-774X

Oliver, R. 22 July 2016. "Better data risk making some people uninsurable: Individual pricing". *Financial Times*.

Osberghaus, D., A. Philippi (2016): Private Hochwasservorsorge und Elementarschadenversicherung: Moral Hazard, der Effekt von Informationskampagnen, und eine Versicherungsillusion. *ZVersWiss* 105: 289-306, DOI: 10.1007/s12297-016-0341-2

Otto, A., A. Hornberg, A.H. Thieken (2016): Local controversies of flood risk reduction measures in Germany. An explorative overview and recent insights. – *Journal of Flood Risk Management*, online first 17 FEB 2016, DOI: 10.1111/jfr3.12227.

Oxera. 2015. "Why does it always rain on me? A proposed framework for flood insurance". Available at: <http://www.oxera.com/Latest-Thinking/Agenda/2015/Why-does-it-always-rain-on-me-A-proposed-framework.aspx> [accessed 10 October 2016]

Penning-Rowsell, E. C., S. Priest and C. Johnson. 2014. "The evolution of UK flood insurance: incremental change over six decades". *International Journal of Water Resources Development*, vol. 30(4). 694-713.

Poljanšek, K., Marin Ferrer, M., De Groeve, T., Clark, I., (Eds.), 2017. *Science for disaster risk management 2017: knowing better and losing less*. EUR 28034 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-60678-6, doi:10.2788/688605, JRC102482

Porter, J. and D. Demeritt. 2012. "Flood-Risk Management, Mapping, and Planning: The Institutional Politics of Decision Support in England". Vol. 44, Iss. 10, *Environment and Planning A*.

Priestley, S. 2016. "Winter floods 2015-16". House of Commons Library.

Raadgever, T., M. Steenstra, J. Steenbergen, M. van Herten, D. Hegger, M. Bakker and C. Dieperink. 2014. "Towards improving the implementation of integrated flood risk management". *Policy Brief Issue No. 1*.

Ran, J. and Z. Nedovic-Budic. 2016. "Integrated spatial planning and flood risk management: A new conceptual framework for the spatially integrated policy infrastructure". Volume 57 *Computers, Environment and Urban Systems*.

Renn, O. 2008. *Risk Governance: Coping with uncertainty in a complex world*. London, Earthscan.

Schwarze, R., Wagner, G.G. (2004). In the aftermath of Dresden: New directions in German flood insurance. *Geneva Papers on Risk and Insurance—Issues and Practise*, 29(2), 154–168.

Surminski, S. 2009. "How Can the Insurance Industry Promote Climate Change Adaptation? A Case Study from the UK". Chartered Insurance Institute.

Surminski, S. 2014. "The role of insurance in reducing direct risk: the case of flood insurance". Volume 7 Issue 3-4 International Review of Environmental and Resource Economics.

Surminski, S. 2016. "Fit for purpose and fit for the future? An evaluation of the UK's new flood reinsurance pool". Working Paper prepared for RFF/Wharton workshop: Improving Disaster Financing: Evaluating Policy Interventions in Disaster Insurance Markets, Washington/US - 29-30Nov 2016.

Surminski, S. and J. Eldridge. 2015. "Flood insurance in England: an assessment of the current and newly proposed insurance scheme in the context of rising flood risk". Journal of Flood Risk Management.

Surminski, S. and P. Hudson. 2017. "Investigating the risk reduction potential of disaster insurance across Europe". The Geneva Papers on Risk and Insurance - Issues and Practice.

Surminski, S., J. Aerts, W. Botzen, P. Hudson, J. Mysiak and C. Pérez-Blanco. 2015. "Reflections on the current debate on how to link flood insurance and disaster risk reduction in the European Union". Natural Hazards, vol. 79(3): 1451–1479.

Surminski, S., Bouwer, L., and Linnerooth-Bayer, J., 2016. How insurance can support climate resilience. Nature Climate Change April 2016

Tanner, T., D. Lewis, D. Wrathall, R. Bronen, N. Cradock-Henry, S. Huq and M.A. Rahman. 2015. "Livelihood Resilience in the Face of Climate Change". Nature Climate Change 5(1).

Thieken, A. H., M. Müller, H. Kreibich and B. Merz. 2005. "Flood damage and influencing factors: New insights from the August 2002 flood in Germany". Water Resources Research 41: doi: 10.1029/2005WR004177. issn: 0043-1397.

Thieken, A.H., Petrow, Th., Kreibich, H. & Merz, B. (2006) Insurability and mitigation of flood losses in private households in Germany. Risk Analysis 26(2), 383-395.

Thieken, A. H., H. Kreibich, M. Müller, and B. Merz. 2007. Coping with floods: preparedness, response and recovery of flood-affected residents in Germany in 2002. Hydrological Sci J 52(5):1016-1037.

Thieken, A.H., S. Mariani, S. Longfield, W. Vanneuville (2014): Preface: Flood resilient communities – Managing the consequences of flooding. – Nat. Hazards Earth Syst. Sci. 14: 33-39, doi: 10.5194/nhess-14-33-2014.

Thieken, A.H., S. Kienzler, H. Kreibich, C. Kuhlicke, M. Kunz, B. Mühr, M. Müller, A. Otto, T. Petrow, S. Pisi, K. Schröter (2016): Review of the flood risk management system in Germany after the major flood in 2013. – Ecology & Society 21(2): 51, DOI: <http://dx.doi.org/10.5751/ES-08547-210251>.

Treby, E., M. Clark and S. Priest. 2006. "Confronting flood risk: Implications for insurance and risk transfer". Volume 81 Issue 4 Journal of Environmental Management.

United Nations Office for Disaster Risk Reduction. 2015. "Sendai Framework for Disaster Risk Reduction". Available online at: <http://www.unisdr.org/we/coordinate/sendai-framework> [accessed 15 January 2017]

U.S. Army Corps of Engineers (2015): North Atlantic Coast Comprehensive Study Final Report: Resilient Adaptation to Increasing Risk;
http://www.nad.usace.army.mil/Portals/40/docs/NACCS/NACCS_main_report.pdf

von Kirchbach, H.-P., S. Franke, H. Biele, L. Minnich, M. Epple, F. Schäfer, F. Unnasch and M. Schuster. (2002). "Bericht der Unabhängigen Kommission der Sächsischen Staatsregierung Flutkatastrophe 2002.". Available at: <http://www.schlaudi.de/hw/Kirchbachbericht.pdf> [accessed 30 March 2017]

von Kirchbach, H.-P., T. Popp, J. Schröder (2013): Bericht der Sächsischen Staatsregierung zur Untersuchung der Flutkatastrophe 2013. Sächsische Staatskanzlei, Dresden.

Von Peter, G., S. von Dahlen and S. Saxena (2012) Unmitigated disasters? New evidence on the macroeconomic cost of natural catastrophes, BIS Working Paper No. 394, Basel: Bank for International Settlements. Available at: www.bis.org/publ/work394.pdf

Walker, G., R. Whittle, W. Medd and N. Watson. 2010. Risk governance and natural hazards, CapHaz-Net WP2 Report, Lancaster Environment Centre, Lancaster University, Lancaster.

Wiering, M., M. Kaufmann, H. Mees, T. Schellenberger, W. Ganzevoort, D.L.T. Hegger, C. Larrue and P. Matczak. 2017. Varieties of flood risk governance in Europe: How do countries respond to driving forces and what explains institutional change? Volume 44 Global Environmental Change.

Zurich Financial Services. 2017. Learning from past flood events, available at <https://www.zurich.com/en/corporate-responsibility/flood-resilience/learning-from-post-flood-events>Zurich