

Swenja Surminski and Paul Hudson **Investigating the risk reduction potential of disaster insurance across Europe**

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Investigating the risk reduction potential of disaster insurance across Europe

Abstract

The notion that insurance can play a significant role in risk reduction has gained attention in the wake of rising natural disaster losses. However, little is known about if and how insurance promotes efforts to lower risk. Direct linkages between risk reduction and insurance appear lacking and are usually not considered when designing insurance schemes. We seek to establish how the risk reduction linkages of insurance can be assessed and enhanced, by revisiting existing metrics used to determine the viability of disaster insurance schemes and proposing additional indicators for risk reduction. We then consider four methodologies that assess insurance's risk reduction potential, and apply those to several European case-studies. Through engagement with case-study stakeholders we explore how these methodologies can assist in strengthening the risk reduction implication of insurance. We find that the four methods help to better understand driving forces behind design, development and operation of insurance schemes. Our conclusions show that risk reduction can reduce the pressure placed on the current (or potential) insurance mechanisms, while also highlighting existing barriers.

Keywords

Insurance; Natural Hazards; Risk Reduction; Adaptation; Partnerships

1 Insurance and risk reduction

Insurance is a widely used risk financing instrument that seeks to promote the sharing and transfer of risks and losses including those from natural disasters such as floods and storms (Bräuninger et al., 2011; Chambwera et al., 2014). It is purchased by those at risk before an event, offering financial compensation in the case of a loss event. Insurance is either

provided publicly, privately, or through a public-private partnership; it can be subsidized or mandated, and guided either by the principle of solidarity or by the market (Schwarze et al., 2011; Paudel et al., 2012).

Insurance is based on the concept of spreading the losses incurred by the few over a large group. However, a common concern is adverse risk selection, which may obstruct the functioning of insurance markets if insurance is predominantly taken up by those with a high risk (Akerlof, 1970; Rothschild and Stiglitz, 1976). Beyond this direct financial purpose, insurance can also alter risk behaviour through different incentive mechanisms such as risk based pricing, deductibles, no-claims bonuses or the provision of hazard information leading to risk reduction. In this context risk reduction refers to different types of action that lower the occurrence probabilities of an event or reduce its impacts. The behaviour stimulated can be positive as policyholders protect themselves, leading to risk reduction (advantageous selection). However, policyholders' behaviour can also increase risk through moral hazard (Ehrlich and Becker, 1972), a well-known concern (e.g. Osberghaus, 2015; Petrolia et al. 2015; Hudson et al., 2016a).

This concept of risk reduction has recently gained growing attention in the wake of rising losses from natural disasters, amidst concerns about the future viability of insurance (e.g., Bouwer et al., 2007). In 2013 the European Commission published the Green Paper on the insurance of natural and man-made disasters (EC, 2013), which reflects on accommodating increasing risk through new and existing insurance schemes. The consultation document frames insurance in two ways: the question of availability and affordability of insurance policies, and the potential to use insurance as a lever for prevention and disaster damage reduction. The EC specifically asked how risk transfer can reduce disaster risk today and into the future (EC, 2013; Surminski, 2014)). Although no official EC response has been published since the launch of the consultation there appears to

be wide agreement that European harmonization of insurance operations is likely to be ineffective economically and politically (Surminski et al., 2015a). However, the consultation responses also allude to the need for more efforts in linking the risk transfer and risk reduction roles of insurance in order to address the changing risk profiles that could make insurance nonviable in the future.

Socio-economic developments and climate change are understood to be driving the loss potential, raising several questions regarding the role of insurance. Most research in this area has explored the impact of these factors on risk trends and patterns and what implications this may have for the continued provision of natural disaster insurance (e.g. Mills, 2009; Botzen et al., 2010; IPCC, 2014). A recent example is an investigation of the warming of the oceans and the implications that may result for the (re)insurance industry (The Geneva Association, 2013) or the rapid increase in losses due to an increasing number of people and assets being located in flood prone areas (e.g. Rojas et al., 2013). Risks and uncertainties arise directly from the physical impacts of climatic changes such as extreme weather events or slow-onset developments, such as sea-level rise, or the greater cluster of socio-economic development in risky areas, but also indirectly from the political responses to these challenges. These disaster risk trends are likely to pose a significant challenge for financial compensation mechanisms; unless more risk reducing measures such as flood defences or stricter building codes (e.g. Kreibich et al., 2005; Aerts et al., 2013) are implemented.

Our analysis seeks to determine how the risk reduction linkages of insurance can be assessed and enhanced. As a first step, we revisit existing metrics used to determine the viability of disaster insurance schemes and propose additional indicators for risk reduction. Traditionally efforts to evaluate disaster insurance are focused on affordability, commercial availability and financial solvency. We add to this the feature of ‘risk reduction’ as an

indicator of the impacts that insurance can have on the underlying risk levels. We then consider four methodologies (a mix of quantitative and qualitative) applied in previous studies, that allow an assessment of the risk reduction elements of insurance, and test them for several European hazard case studies: Flood insurance in England; Wild Fire Insurance in Portugal; Flood and Drought risk in the Po river basin, Italy; Flood risk in the unprotected areas of the Port of Rotterdam; Flood and Earthquake risks in Romania; Multi-hazard risk across the European Union via the European Union Solidarity Fund. While very different in scope and history our examples share one common feature: they can all be considered as multi-sector partnerships, bringing together insurance, policy makers and other stakeholders in order to pursue new approaches to disaster insurance. Through engagement with stakeholders we explore if and how the four methodologies can assist the partnerships in strengthening the risk reduction implication of insurance. Once the hypothetical application of the four methods to the case studies has been completed, we draw lessons across methods and cases.

2 Towards a new insurance evaluation methodology: a review of the underlying metrics

Three metrics are commonly used to assess feasibility of new insurance and to evaluate effectiveness of existing insurance schemes: commercial viability for schemes with private sector involvement; financial sustainability; and affordability (Surminski, 2014). *Table 1* provides a summary of metrics and definitions commonly applied in the recent literature. Traditionally the focus has been on classical supply and demand questions. On the demand side this includes willingness to pay given the customers' budgetary constraints and their risk profiles. Supply issues deal mainly with the behaviour of (re)insurers for those

schemes that involve the private sector. Insurance providers must choose the degree of coverage and prices at which insurance is offered given the risk faced by the policyholder, the costs of providing insurance, how competitive the insurance market is, the company's risk appetite in covering new risks or meeting solvency requirements as well as the general regulatory environment. Additionally, primary insurers must decide on the amount of reinsurance to be purchased as primary insurers may be hesitant to insure certain natural disasters because of the consequences of low-probability/high-impact events unless some of this risk can be transferred to reinsurers. Taken together the interaction of the above decision variables determines if an (re)insurer will provide an insurance policy and at what price. Interacting with these economic effects are governmental efforts within the insurance market. It is nearly impossible to discuss any insurance market without considering governmental policies. For example, in many markets, the government is the sole reinsurer while in others it determines market rules, subsidises premium or sets prices (Paudel et al., 2012). Analysing these components depends on data availability, data usage and the underlying assumptions, which can place the same or similar information in a different context leading to different outcomes. For instance, a common method of assessing affordability is to check if the premium does not exceed a set amount of income. Employing different assumptions on this threshold can produce noticeable differences if the threshold is taken as 5% of income (Kousky and Kunreuther, 2013) or residual income (Hudson et al., 2016b). Similar, analysing the future behaviour of insurers faces data limitations as the risk models that are commonly used by insurers for rate setting (Grossi and Kunreuther, 2005) are sensitive business information that are not freely accessible. Therefore, such studies must be based on assumptions on how (re)insurers believe future risk will develop and how (re)insurers will behave.

While the concepts of ‘commercial viability; financial sustainability; and affordability’ form the traditional basis of designing and assessing disaster insurance, we notice a lack of consideration of a fourth: the ‘risk reduction’ element of insurance. There is ample evidence that insurance, or risk transfer in general, can boost resilience to natural hazards more (effectively) than ex-post disaster aid (Ranger et al., 2011). Moreover, risk pricing may encourage the reduction of exposure and lead to lower damage costs (Kunreuther, 1996; DiDi Falco et al., 2014). Yet on the other hand poorly designed insurance products and ill-structured insurance markets can drive economic inefficiency and mal-adaptation to future risks (Michel-Kerjan, 2010; Surminski, 2013).

From the existing economic methodologies for assessing the impacts of disasters (Kliesen and Mill, 1994; Cavallo and Noy, 2010; Hallegatte and Przyzluski, 2010) we can derive some metrics focused on how to reduce the ex-post impact of disasters, as outlined below in *Table 2*. However, the interactions between risk reduction and the other three concepts, particularly the question of trade-offs between them, are still under-researched. Hudson et al. (2016b) conducted an analysis for France and Germany investigating the potential trade-off between offering households risk reduction incentives and the affordability of risk based insurance premiums. Hudson et al. (2016b) concludes that while many households would find risk based insurance premiums unaffordable, strengthening the link between insurance premiums and policyholder risk reduction could have substantial impacts on the aggregate risk profile within a country

The rising risk trends are likely to pose a significant challenge for insurance (Jongman et al., 2014), unless more risk reducing measures are applied, such as flood defences, stricter building codes and/or land use (zoning) policies. Successful and efficient prevention is expected to play a significant role for affordability and availability of loss compensation mechanisms (Kunreuther, 1996), but it is far from clear how these two

approaches interact, and where the scope for future reform is. Overall there is a very limited understanding of how risk reduction measures reduce the stress on the system as a whole influencing financial sustainability, commercial viability and affordability. A key question that arises is how risk reduction, such as investment in flood protection infrastructure, could reduce the stress on the insurance system. Ranger and Surminski (2013) identify positive and negative scenarios for insurance resulting from differences in policy responses to climate change, regulatory levels, company strategy, risk awareness and willingness-to-pay (Ranger and Surminski, 2013). One aspect that is widely agreed is the need for increased collaboration between stakeholders, including insurers and governments. To overcome some of the barriers associated with achieving adaptive responses and risk reduction, insurance partnerships with the public sector are advocated to harness skills and expertise in supporting insurance approaches (see for example KPMG, 2015). While disaster risk management has traditionally involved the activities of multiple actors across different sectors, the last couple of decades have seen a shift towards a greater diversity of actors being involved and the development of stronger and more formal collaborations and partnerships (e.g. Walker et al, 2010). These multi sector partnerships (MSPs) are increasingly seen as critical as natural hazards have a multi-lateral impact and as such require multi-lateral governance (UNISDR, 2011). The Hyogo Framework for Action, the UN's set of principles for disaster risk reduction, identified MSPs as critical and called for 'vigorous pursuit of MSPs' (UNISDR, 2011), an approach that is now pursued by the new Sendai Framework for disaster risk Disaster Risk Reduction 2015-2030.

However, despite the growing calls for partnerships in disaster risk management, there has been little research examining how effectively they can help reduce the risk from disasters and there remains a lack of clarity around the roles of public, private and civil society actors, and how they can act together (Crick et al. 2016)).

This is also evident in the context of insurance: amending existing insurance mechanisms or developing new tools requires political will and stakeholder buy-in at different levels and over varying time-scales, as well as collaboration across different sectors (Surminski et al., 2015a) with varying aims and priorities. This presents challenges for enhancing collaboration; and it underlines the importance of developing better methods and metrics to assess the risk reduction implications of insurance.

3 Investigation of risk reduction implications of insurance – four different methodologies

In this section we explore a selection of four quantitative and qualitative approaches that could further our understanding of the risk reduction potential of disaster insurance. The methods have been built with two questions in mind: how to assess existing insurance offerings and how to design new schemes? In the absence of one single measure to analyse insurance and risk reduction we consider a wider range of criteria and methods for our cases being investigated (*Table 3*). This allows us to decompose the high-level metrics into various sub-metrics, which a single method or criteria may not capture.

3.1 Stress testing

Insurance companies have legal requirements to hold capital reserves that limit the company's insolvency probability to a specific degree. The calculation of these capital reserves requires risk models that reliably estimate the risk portfolio held by the insurance company or industry as a whole. Stress testing assesses how suitable or viable capital reserves currently are and how reserves must evolve to maintain solvency. The core method of stress testing is estimation of the total reserves required in a given period to meet the solvency constraint. The methodology developed for stress testing is an aggregated

probabilistic flood damage model, as presented in Jongman et al. (2014). Jongman et al. (2014) integrates the interdependencies in flood occurrence probabilities across river basins. Occurrence probability interdependencies can lead to large impacts that models assuming independent occurrence probabilities may miss. This feature allows for reliable information on correlated loss probabilities, which is crucial for developing robust insurance schemes and public adaptation funds (Mills, 2005). Jongman et al. (2014) present an example of how this approach can be used: they provide estimates that by 2050 the European Solidarity Fund's probability of reaching its financial limit will be 80% larger compared to 2013 (following the fund's previous design); that the total insurance capital reserves are to double over the same time; and it highlights the benefits of investing in flood risk reduction infrastructure. Moreover, such a probabilistic approach takes into account supranational effects that are important concerns (Jongman et al. 2014).

3.2 Estimation of effectiveness of household-level flood risk mitigation measures

The role of household-level measures in risk reduction strategies depends on their effectiveness, which can be assessed through statistical analysis of survey data. We present two methods aimed at estimating a similar outcome and as such both can be used to check the consistency of the final estimate. This has the advantage of reducing bias in previously used evaluation methods. Hudson et al. (2014) and Poussin et al. (2015) evaluate the effectiveness of risk reduction measures and explore how these interventions could lower premiums, potentially making insurance more affordable. Both investigations present methods that provide novel but logical extensions of the traditional methods used in some strands of natural hazards literature. Hudson et al. (2014) use propensity score matching, while Poussin et al. (2015) use regression models. These two methodological approaches

show the need to control for systematic differences between households. Failing to do so adequately can substantially overestimate the risk reduction measures' effectiveness. The refined effectiveness estimates of several mitigation interventions show that these measures are still very cost effective methods for reducing flood damage. Overall, these methods can evaluate both risk reduction measures and strategies across natural disaster types. Hudson et al. (2014) and Poussin et al. (2015) find that household mitigation measures are a potentially useful element of risk management strategies.

3.3 Analysis through a Risk Reduction Framework

While there is broad agreement in the literature about the theoretical potential for insurance to reduce flood risk as long as it is beneficial for both the insured and the insurer, it is less clear how this could happen in practice. We find different categories with regards to the possible practical applications. The most commonly cited aspect is an improved understanding of risks due to the use of catastrophe models and increased data sharing from insurers, which in turn can help to evaluate the cost-effectiveness of potential risk reduction measures in areas of data scarcity or to refine insurance premiums to offer the most accurate incentives for risk reduction (Surminski et al., 2015a). Crichton (2008) goes beyond catastrophe modelling and suggests five additional ways of how the provision of insurance could lead to flood risk reduction:

- Assistance with identifying areas at risk;
- Economic incentives to discourage construction in the floodplain;
- Collection of data on the costs of flood damage to feed into benefit cost appraisals for flood management schemes;
- Promotion of resilient reinstatement techniques after a flood loss;
- Promotion of temporary defence solutions.

Paudel et al. (2012) argues along similar lines to Crichton (2008) and differentiates between ‘1) risk assessment and mapping; (2) public policies and regulations that are integrated in the insurance system; and (3) (financial) incentives that the insurer provides to policyholders to invest in mitigation’. Surminski and Oramas-Dorta 2013 investigate this for a range of case studies in developing countries and distinguish between

- risk awareness-raising initiatives, such as the provision of risk-relevant information and knowledge transfer to educate policy-holders and the public about preventive measures;
- capacity-building through knowledge transfer and educational elements;
- explicit incentive structures for risk reduction, such as risk-based pricing, where premiums reflect risk such as charging according to local flood risk levels; and
- compulsory risk reduction, such as requiring policy holders to take certain preventive measures as a condition for cover.

Building on from the above categorizations the Risk Reduction Framework is an analytical framework that compares and assesses insurance schemes against seven criteria. The criteria were selected because of their relevance for risk reduction:

- Awareness and knowledge sharing;
- Promotion of risk management and preventative measures;
- Promotion of resilient reinstatement;
- Incentives to invest in risk reduction;
- Incentives for public risk management policy;
- Incentives for preventing development in high risk areas;
- Conditions for compulsory risk reduction within insurance policy.

3.4 Investigation of design principles of insurance

At the heart of our fourth method are the different stakeholder motivations and expectations for insurance schemes. Identifying and establishing if and how those are reflected in any new scheme that may eventual become operational offers insights on the

negotiations and priorities that surround disaster insurance. An investigation of the underlying design principles of insurance considers the aims and objectives stated by different stakeholders during the development and design of an insurance scheme, and asks if and how those have been met by the solution that was eventually implemented. Different stakeholders can have varying constellations, motivations, and problem definitions at play when considering introduction or reform of insurance schemes. On the one hand there is the aim of reducing current public expenditure for disaster losses, while at the same time there are political considerations such as the need to maintain a visible 'helping hand' function after a disaster. This is particularly relevant in the run-up to elections, as an elected official may deliberately not choose to increase spending and hence raise taxes while they are in office, particularly when no clear benefits are visible during this time. As outlined in Surminski et al. (2015b), the investigation of design principles allows insights into potential trade-offs between certain aims, such as affordability, availability, and risk reduction, particularly when considering the political realities that drive the reform or development of new insurance schemes. This has been shown in the context of the flood insurance scheme in England. At the outset government and industry identified a set of principles, outlining a common vision for flood insurance shared by industry and government (Defra2011 p.5):

1. Insurance cover for flooding should be widely available
2. Flood insurance premiums and excesses should reflect the risk of flood damage to the property insured, taking into account any resistance or resilience measures.
3. The provision of flood insurance should be equitable.
4. The model should not distort competition between insurance firms.
5. Any new model should be practical and deliverable.

6. Any new model should encourage the take up of flood insurance, especially by low income households.
7. Where economically viable, affordable and technically possible, investment in flood risk management activity, including resilience and other measures to reduce flood risk, should be encouraged. This includes, but is not limited to, direct government investment.
8. Any new model should be sustainable in the long run, affordable to the public purse and offer value for money to the taxpayer.

Unsurprisingly, achieving all of these aims is extremely difficult. The proposed scheme, Flood Re, takes principles 1, 3 and 8 at its core and aims to ‘ensure the availability and affordability of flood insurance, without placing unsustainable costs on wider policyholders and the taxpayer’ (Defra 2013a). However, the ‘value for money’ aspect of this is highly debatable as the scheme does not meet the minimum government standard for cost-benefits (Defra, 2013a p.30; Defra, 2013b). The lack of risk reduction is clear in the official proposal other than in the Memorandum of Understanding which sets out the government’s commitment to flood risk management and joint efforts to improve flood risk data (Surminski and Eldridge, 2014).

4 Findings from the case studies

The insurance case studies used to investigate the suitability of the different methodologies are presented in *Table 4*. They have been selected for two main reasons: First, they cover a range of risk profiles. The hazards range from flooding to droughts and wildfires; each case study is located in a different country placing it within a different socio-

political context; different objectives and concerns for how future risk profiles should evolve. Secondly, the case studies share at least one thing in common: they all embrace the concept of multi-sectoral partnership in order to lower the underlying risks through better collaboration, thus fulfilling one of the key pre-conditions for more effective disaster risk reduction (Surminski 2014).

Figure 1 presents an overview of all the insurance-focused case studies indicating their position on the scale of their insurance application, from no insurance to established insurance. The case studies have been drawn from the ENHANCE project¹. The EUSF case stands out from the others as it investigates how non-insurance compensation mechanisms could be reformed to support risk reduction, and considers what impacts this could have on insurance schemes². After an initial testing and application we presented the four methods (Section 3) to the multi-sectoral stakeholder(s) involved in a set of insurance case studies, with the aim of exploring if and how the method could be applied to specific contexts. Overall the discussions with the stakeholders indicated that data availability and access to stakeholder information were the key determinants of whether a tool could be successfully applied or not.

4.1 Case Study: Port of Rotterdam infrastructure (flood)

The Port of Rotterdam case focuses on assessing risk levels and establishing collaboration between different stakeholders to manage or reduce flood risk, with insurance being one possible response measure. The stakeholders have expressed an interest in expanding to a mixture of measures that both prevent floods from occurring and limiting their impacts when they occur. For this the four methods differ in their suitability:

¹ ENHANCE is an EU FP-7 project investigating how MSPs can be used to increase societal resilience to natural disasters. More information on the ENHANCE website can be found at: <http://enhanceproject.eu/>.

² The case studies are currently ongoing and as such detailed examples and summaries of the final objectives of stakeholders is not available.

- Stress testing: The solvency mentality of the tool combined with a probabilistic model allows for the evaluation of high-impact low-probability events that are a key interest to these stakeholders. While in this case there is no insurance scheme currently in place, the stress testing methodology could be used to investigate the capital requirements of any proposed scheme, such as the Rotterdam based 'co-op' style insurance fund currently being discussed. The required funds can create a financial logic for investing in risk reduction measures. Additionally, the use of such a probabilistic model could provide a suitable way of evaluating the effectiveness of risk reduction measures.
- Estimation of effectiveness of policyholder-level mitigation measures: Rotterdam has not suffered major flood events in the past years due to the high level of protection around the area. Therefore, this tool is not applicable due to data scarcity (as outcome data is missing).
- Analysis through a Risk Reduction Framework: This method is not applicable, as a proper insurance design phase has not started. However, the framework criteria could inform discussion about possible design of any new scheme. Currently the high cost of insurance is considered a key barrier - here the risk reduction framework could be applied to point towards risk reduction measures as a way to make insurance affordable.
- Investigation of the design principles of insurance: As insurance has not been formally explored one would need to organize a structured discussion/workshop between stakeholders to discuss different aims of any insurance scheme. Similar to the Risk Reduction Framework this could prove beneficial for the design, should stakeholders agree to proceed.

4.2 Case study: Romania (multi-risk)

According to Law 260/2008, homeowners in Romania have to purchase home insurance (PAD), and if they do not, they can be fined (by the local authorities). However, many do not purchase insurance because there are clauses within Law 260/2008 that allow homeowners to remain uninsured if they meet certain socio-economic conditions. The coverage ratio of the housing sector in Romania, obtained by reporting the number of compulsory and voluntary insurance contracts to the total number of dwellings was 37.65%. There is a large potential market (8.5 million housing), but the standards of living below the EU average influence available income for insurance purposes (even though premiums range from 10-20 EUR). The compulsory home insurance provides cover in case of three natural phenomena: floods, landslides and earthquakes. According to this law, all natural persons and legal entities are required to insure against natural disasters all the homes in the rural or urban environment. The Romanian government is also a common recipient of EUSF funds after a disaster event. The stakeholders wish to promote a high insurance coverage in a way that reduces risks. A possible cause of action is to use the EUSF funds after a disaster event as a nudging tool so that defences and protection infrastructure is 'built back better', moving the structures to a more resilient level than it currently is.

- Stress testing: This method is applicable. By employing the probabilistic model approach the flood risk between the various river catchment areas of Romania could be correlated, which could allow for a more accurate estimation of the total flood risk. Moreover, the model could be further extended to combine all the hazards covered by the current insurance into a pan-hazard model for Romania. A pan-hazard risk model could offer a better perspective on the total pressure that natural hazards place on compensation mechanisms in Romania. A further possible outcome from the application of this methodology to the Romanian case study would be that sharing the expected

damage across the potential policyholders would provide an indication of how the mandatory premiums could be adjusted upwards so that the insurance scheme is more robust.

- Estimation of effectiveness of policyholder-level mitigation measures: The employment of household mitigation measures under the existing scheme could help to reduce flood damage, lessening pressure on insurers or other compensation mechanisms. An application to Romanian risk data appears feasible. This would help to judge the potential of a set of risk reduction measures for reducing the size of flood losses. Additionally, the evaluation methodology could be applied to risk reduction measures commonly employed in Romania.
- Analysis through a Risk Reduction Framework: The Romanian disaster risk financing framework, in its current form, is rather ex-post oriented. Risk reduction and risk financing is not well linked and the case study aims to address this issue. Here the framework could provide input by illustrating this gap.
- Investigation of the design principles of insurance: The Law 260/2008 provides the basis for the insurance scheme. An assessment of this in terms of risk reduction references is feasible. The law has created a link between the homeowners, the insurance companies/PAD and the local and central authorities - analysing what the different aims and expectations were/are and how this is reflected in the design would offer some insights for the planned adjustments.

4.3 Case study: European Union Solidarity Fund (multi-risk)

The European Union Solidarity Fund (EUSF), in its current form, is the main post-disaster instrument of the EU providing financial aid to governments after major (natural) disasters. Considering the EUSF as an EU-wide disaster pool, the case study investigates

how its current structure can be reformed to better promote risk reduction and solidarity, such as supporting regional insurance pools.

- Stress testing: The stress testing methodology can be applied directly to the EUSF in order to investigate the EUSF's insolvency probabilities under various risk reduction investment scenarios. See Jongman et al. (2014) for more information on this application. Moreover, the probabilistic method provides a mechanism for estimating the benefits from investing in structural protection measures.
- Estimation of effectiveness of policyholder-level mitigation measures: This methodological approach is not relevant to this case study. This is because the measures that would be applied to reduce the risk to the EUSF would be, most likely, large scale engineering projects seeking to reduce the occurrence probability of various natural hazards, rather than household-level measures.
- Analysis through a Risk Reduction Framework: This could be applied to the current EUSF roles. Information about the different public bodies and other stakeholders and their roles is available, data on operation and performance too. The framework might also be useful when comparing existing to newly proposed structures.
- Investigation of the design principles of insurance: For the EUSF the main design principles include solidarity, robustness and promotion of risk reduction. There is literature available to trace back any considerations of risk reduction in the design phase of EUSF, including different stakeholder preferences. This could then be applied to the current discussion about reorienting the EUSF.

4.4 Case Study: Po River basin (flood and drought)

The case study explores controlled flooding on agricultural (low value use) land in order to avoid larger losses in the urban (high value use) areas; and the reform of drought insurance towards an innovative policy mix in which a mutual insurance scheme facilitates

temporary water entitlement exchange. The main impetus of the stakeholders is to find or improve tools that use insurance for risk reduction. Investigating the potential role of a new or modified MSP is useful as the lack of inter-sectoral coordination along the watershed is often mentioned as one of the main failures of water management along the Po watershed (Bozzola and Swanson, 2014). For flooding, there exists no or only a marginal coverage for flood insurance of private properties in the case study area. Based on insurance data for 1980-2013, the share of insured losses out of total losses is around 5 per cent.

- Stress testing: The probabilistic model approach in this case uses drainage basins and capacity of drainage network as the basic units of observation. In addition, the probabilistic model is combined with identification of the areas along the rural-urban divide where deliberate flooding upstream causes lower damage than the uncontrolled floods downstream. An additional benefit is that by developing an entire probabilistic model for the sample area, risk managers have more risk information at their hands, particularly with regards to the damage distribution; this in turn could allow for solvency requirements to be calculated for varying insurance penetration rates in order to judge the possible degrees of pressure that could be placed on an insurance company or sector operating in this region.
- Estimation of effectiveness of policyholder-level mitigation measures: The measures that the case study seeks to investigate are novel measures and are not in common usage across the region, therefore, a backwards looking evaluation method is not suitable.
- Analysis through a Risk Reduction Framework: This could complement the current analysis of three instruments (flood protection tax, land easement, and flood insurance) by comparing those against each other for the seven criteria in the framework. The data and material gathered for the current analysis should enable this additional investigation.

- Investigation of the design principles of insurance: This is a particularly interesting case – as the insurance is specifically designed to cover the deliberate costs arising from a risk-reduction scheme (temporary flooding of land). Understanding the different aims and principles guiding the stakeholders would be very informative. The driving principle is a fair compensation of the incurred losses. Additional principles could be highlighted such as NAI (no adverse impact on downstream areas, or even more stringent form of constant water discharge).

For droughts a state-subsidized insurance for agriculture (and insurable risks) exists since 1970 and is being now transformed so as to exploit the opportunities of the new rural development program (and the new risk management schemes included therein):

- Stress testing: The development of a new insurance scheme involves an understanding of its solvency needs. The stress testing methodology was developed specifically to investigate the solvency capital required for a fund.
- Estimation of effectiveness of policyholder-level mitigation measures: The measures that the case study seeks to investigate are novel measures and are not in common usage across the region, therefore, a backwards looking evaluation method is not apropos. However, dependent on the distribution of farmed crops it may be possible to use crop type as a type of mitigation measure in reducing output losses due to droughts. Using this methodology to judge monetary outcomes for this mitigation measures might not be suitable because a drought is hard to judge in terms of its length and its extent and combined with other possible general equilibrium effects.
- Analysis through a Risk Reduction Framework: A comparison of the existing and the newly proposed scheme could be conducted, similar to the England flood case. For the

risk reduction focus one could add the ‘water entitlement exchange’ as a key aspect to consider.

- Investigation of the design principles of insurance: The ongoing efforts to design a new insurance scheme provide an opportunity to reflect on aims and principles – possibly through literature or stakeholder engagement. It appears that risk reduction is a key driving factor – exploring this and comparing this to the other guiding principles would provide further insights.

4.5 Case Study: Portugal (wildfire)

Forest insurance is mandatory in Portugal according to article 20 of the Lei de Bases Florestal (Law 33/96) which explicitly demands all publicly funded forest areas to be covered by appropriate insurance. However, the law has not been applied and insurance products are scarce. State initiatives to kick-start forest insurance dates from at least 1999, when a group composed of the National Forest Authority, IFADAP, the Portuguese Insurance Institute and Portuguese Insurance Association worked to expand knowledge on possible schemes and costs. The stakeholders wish to know and to understand the relative merits of different possible schemes at improving insurance uptake and promoting policyholders to employ more measures to protect themselves.

- Stress testing: The stress testing framework could be used to develop a probabilistic model for the total outcome for the wider region under investigation. A probabilistic model based on the amount of land burnt can be used as a tool to determine the severity of the problem faced by the potential policyholders. This could assist with mobilising support for developing and strengthening a multi-sector partnership as there is a better degree of understanding. A model developed on monetary damage outcomes can estimate the total capital required for a proposed insurance partnership to be solvent. In

doing so an estimate of the expected risk-based premiums, deductibles and capital stocks can provide indications regarding the potential affordability of the partnership.

- Estimation of effectiveness of policyholder-level mitigation measures: The information offered by the case study means that estimating the effectiveness of the risk reduction measures in monetary terms might be difficult while estimating the effectiveness in terms of total hectares of avoid burnt land might be a better option.
- Analysis through a Risk Reduction Framework: An assessment of the existing and proposed schemes seems feasible and would provide a very useful analysis of the wildfire insurance study. There are currently four insurance products available. A key question is the pricing and potential subsidy of premiums for landowners, as premiums may be subsidized to appear to be affordable to potential policyholders. Another aspect currently considered is the inclusion of Forest Intervention Zones (ZIF) which aggregates several landowners from small properties, as an eligible entity to have forest fire insurance. Data for the current scheme is available (see below) – a reflection on risk reduction for existing and newly proposed options could offer new insights on the issue of moral hazard, a key challenge for all fire insurance schemes.
- Investigation of the design principles of insurance: This methodology appears very useful for this case study and would elicit a study of the different design principles that have guided this long-running exercise - such as current use of public funds to restore forest potential (e.g. after fire events); the need to bundle coverage of restoration costs and revenue loss into a single scheme; the need to spread mutualized risk by covering areas in the south (lower risk) as well as in the north (higher risk); prioritization of areas included in Forest Intervention Zones and Landowners' Associations, as well as those certified, or in the process of certification, according to sustainable forest management schemes; profitability of insurance companies; creation of a new legal framework for

forest insurance. Points 1, 3 and 8 from the UK flood insurance example appear relevant for this example.

4.6 Case Study: Flood insurance in England (flood)

This case study assesses risk reduction within the current and future flood insurance systems in England. The change to a new system carries some of the previous elements over, including the agreement between government, to provide risk management, and insurers to underwrite flood insurance. However, the proposed new Flood Re scheme does not contain specific risk reduction features.

- Stress testing: The stress testing framework can lead to the development of a probabilistic flood damage model for the households that would be covered by the Flood Re scheme. Once the model has been developed the insolvency probability of Flood Re can be investigated, to judge if its current funding arrangement is suitable. Additionally, the Stress testing framework can investigate how the introduction of Flood Re may affect the overall solvency of the flood insurance industry.
- Estimation of effectiveness of policyholder-level mitigation measures: The methodology can be directly applied to flood risk models for England in altering depth damage curves. Conducting a survey would provide the opportunity to investigate the effectiveness of the particular mix of mitigation measures employed by English households and compare this to findings in other countries.
- Analysis through a Risk Reduction Framework: Analysis of the two insurance systems against the seven risk reduction framework criteria shows that there are very little risk reduction features within the new system, Flood Re.
- Investigation of the design principles of insurance: In developing Flood Re the driving principles have been affordability and availability of flood insurance for households,

while risk reduction has not been captured in the design of the scheme. There are some measures, such as information sharing, that may lead to greater flood risk awareness. However, it remains unclear how this will play out in practice. Although the detailed plans are not yet in place of exactly how the scheme will operate over its life of 25 years the current discourse is focused on the operation of the scheme rather than designing the scheme towards reducing risk over time.

5 Discussion of findings

Disaster losses are highly volatile, and the most common causes of financial problems in these schemes are a lack of risk assessments and insufficient funds, often due to inadequate premium levels. This in turn clashes with the requirement of affordability of insurance cover, which often results in subsidisation to make insurance more economical for those at higher risk (Surminski and Eldridge 2015). Rising disaster losses are already putting pressure on all those involved in the provision of disaster insurance and in extreme cases could lead to private insurers withdrawing from certain regions or hazards, with systems facing insolvency or requiring a greater public sector involvement (Prudential Regulation Authority, 2015) unless risk levels are reduced.

Linking risk reduction and insurance for disaster losses is deemed possible in theory. However, a successful linkage can be difficult to achieve in practice due to barriers that may arise from the conflicting priorities of stakeholders or informational limitations, for example. In this paper we show several methods of how one can assess the risk reduction implications of insurance in cases where insurance already exists or where the creation of insurance instruments is under consideration. The availability of and access to data can be a limiting

factor in assessing those linkages, particularly in cases where insurance does not have a long history or where there are strongly normative concepts.

5.1 Implications in the context of the insurance case studies

The initial application of the four different methods to the case studies has revealed some interesting findings: the stress testing approach suggests that the annual ceiling of the pre-reform EUSF is 80% more likely to be exceeded in 2050. The increased probability of reaching the funding ceiling shows that without strengthening or promoting risk reduction, insurance and other compensatory tools such as the EUSF are bound to become less financially viable and sustainable. There is scope for using similar probabilistic models and solvency approaches when developing or reforming MSPs to improve risk reduction. While the tool is not connected to risk reduction directly it can provide a probabilistic risk assessment, which can help to overcome informational barriers inhibiting the development of (new) MSPs. The probabilistic models provide tangible values for stakeholders, which helps to reduce ambiguity, one of the known problems of insurance MSPs (Kunreuther, 2015). The analysis of the EU Solidarity fund (Jongman et al., 2014) shows that socio-economic development and climate change can substantially increase pressure on risk transfer or financing mechanisms, unless more risk reducing measures are applied, such as flood defences, stricter building codes and/or land use (zoning) policies. Improved risk assessment and data sharing amongst stakeholders are essential for developing those forward-looking solutions in an integrated way. National, local and household level DRR activities could be used as a mechanism for reducing the pressure placed on risk transfer schemes. In other words, risk reduction efforts are essential in maintaining the insurability of these risks, especially in the context of flooding and other extreme weather events. Effective adaptation may actually become a condition for granting insurance cover in the future (Surminski et al., 2015b).

The assessment of the effectiveness of household level risk reduction measures show that these offer cost effective household risk reduction. However, the two methods are data intense, which can limit their applicability. Additionally, there may be concerns that the results of these methods are case specific with limited applicability to other areas. However, the findings could be applied at least to some case study elements: the monetary savings or savings as a percentage of household value can be used to alter state-damage curves used in flood damage models, for example, to model and compare various risk reduction strategies. The methods employed in Hudson et al. (2014) and Poussin et al. (2015), while focused on flooding, could also be applied to other disasters. The methods appear particularly relevant for project assessment, in order to investigate success. If and how they could be applied further across all case studies remains to be seen, due to the early stages of some of the cases.

The consideration of design principles highlights that there appears to be trade-offs between affordability, availability and risk reduction, particularly when considering the political realities that drive the reform or development of new insurance schemes. Investigating the designing principles behind an insurance scheme is highly applicable to all the case studies. Such an analysis can point the stakeholders to the important elements to be emphasised or to detecting areas that can be improved upon. For instance the England or Rotterdam cases indicate that a concern for the affordability and availability of insurance is a possible barrier to risk reduction linkages. On the other hand in the Romanian, EUSF, Po river basin and Portugal cases a discussion of the design principles could help to focus attention on the stakeholders' often contrasting aims and objectives, supporting their efforts in reaching an acceptable compromise. This could be facilitated through a workshop to bring the stakeholders together to share their perceptions, aims and objectives. An example of such a workshop is detailed in Surminski et al. (2015a).

The risk reduction framework investigation reveals that direct linkages between risk reduction and insurance are lacking in most insurance schemes. This raises the question of how innovation and stakeholder collaboration could overcome this limitation. For this a combination with some of the other tools appears relevant. For example, the risk reduction framework and consideration of design principles when taken together can provide an indication of where the current inhibiting barriers lie, and support the development of innovative solutions to address those. The two other methods can support this by providing information regarding the potential needs and benefits of achieving such a risk reduction link, for example in the context of household level risk reduction measures, or through the investigation of future solvency needs.

These initial findings are based on particular cases and the transferability of any of these results remains to be seen. Nevertheless they offer some relevant points in response to our underlying questions about linkages between insurance and risk reduction.

5.2 Implications of findings beyond the insurance cases

By bringing together qualitative and quantitative approaches with the case-study evidence from across Europe we can make observations that appear relevant beyond these selected examples, as highlighted by the recent discourse on the EU Green Paper on Disaster Insurance (Surminski et al., 2015a). This informs our discussion about the applicability of the selected methods:

- **Applicability:** the applicability depends to some extent on the development stage of insurance in the particular case investigated. In those examples where insurance has already been available for some time, such as the England insurance case, all four methodologies are applicable. In those cases where insurance is considered as a potential

option, such as the Rotterdam case, determining which methods could be applied at this initial stage is more complex. All of our case studies exemplify that different stakeholders have different problem definitions, which guide their assumptions and perceptions with regards to possible solutions. Offering any of the four methods can facilitate further discussion and support the collaboration efforts. This is evident in the case of Rotterdam, where the MSP was only created because of new risk data and modelling results (Nicoli et al. 2015). The Portuguese case study indicates that a reflection on underlying design principles could be very useful in providing critical reflections on the ongoing insurance deliberations.

- **Data intensity:** The stress testing and estimation of effectiveness of household level flood risk mitigation measures are data intense, and therefore have limited ‘off the shelf’ applicability. However we note a high relevance for stakeholders wishing to evaluate the success of their suggested or implemented reforms. The other two methods are also sensitive to data intensity, but of a different sort: understanding the underlying aims and objectives of an insurance mechanism will require detailed consultation with the stakeholders involved in the process and will involve an assessments of stakeholders’ preferences and their assumptions around the operational aspects of an insurance mechanism.
- **Diversity of methods:** The modelling results of Jongman et al. (2014) show that socio-economic development and climate change can substantially increase pressure on the provision of insurance. However, the results of Hudson et al. (2014) and Poussin et al. (2015) show that household level flood risk mitigation activities could be used as a mechanism for reducing this increasing pressure on insurance. Relying on a single metric or method will not produce a complete picture of the current or future situation.

Employing a variety of tools can create a more complete picture or indicate possible solutions.

- **Role of MSPs:** All of our case studies embrace the concept of multi-sectoral partnership, however it remains difficult to understand the current barriers, perceived or otherwise, that are inhibiting innovation towards more risk reduction. For example, it may be that the level of risk is inhibiting the partnership or that the stakeholders do not have a suitable platform upon which to engage. Stakeholder engagement can also create a common understanding of the variables and objectives, where otherwise differences appear to be unsolvable. This is apparent in the case of the design principles. In most cases this has not been properly documented and would require further stakeholder discussions. While collaboration across sectors and stakeholders appears ever more important when responding to growing disaster risks, our findings also show that these MSPs may not succeed due to a narrow view of insurance. One reason for this impasse may be that the stakeholders are trying to achieve too many different objectives with a single instrument, in this case insurance. Rather, stakeholders may have to see insurance as an instrument that interacts with other instruments and objectives, and consider synergies, trade-offs and broader implications before applying it. For this the application of any of the four methods can facilitate discourse and support innovation within the MSPs.

6 Conclusion

Until today efforts to reform disaster insurance mechanisms in Europe have been predominantly focused on dealing with the financial losses, without considering the implications for managing and reducing the underlying risks (Surminski et al., 2015a). The four methods described in the paper help understand the driving forces behind design, development and operation of insurance, and they show that risk reduction can reduce the

pressure placed on the current (or potential) insurance mechanisms. However, our case studies also indicate that in order to integrate insurance and risk reduction efforts several barriers will have to be overcome. Stakeholder engagement and multi-sectoral collaboration is understood across our case studies to be basic success criteria, but we note that with this come further challenges: there appear to be key data limitations, most notably around local risk assessments, which would be important for pricing and differentiating premiums. The costs and benefits of risk reduction measures that can be implemented by policyholders are often unclear and there is limited information about the performance of such measures under different conditions. In addition there is only very little investigation into how effective insurance incentives for risk reduction are. A range of barriers exist for insurance companies to proactively stimulate policyholders to limit risks.

. An insurance market that allows premiums to reflect risk may provide a strong incentive for risk reduction, but be unaffordable to consumers. Therefore it is important to avoid the situation where methods for reducing the pressure on the insurance system though risk reduction incentives are seen as a trade-off with affordability and availability. Considering these aspects as mutually reinforcing appears to offer a more sensible approach. One could argue that risk reduction efforts are essential in maintaining the insurability of these risks, especially in the context of flooding, and that effective adaptation may actually become a condition for granting insurance future cover (Surminski, 2014). An example are household risk reducing measures leading to lower insurance premiums, in turn making insurance more affordable. Progress in this area will depend on a mix of increased evidence and understanding of underlying risk, better collaboration between stakeholders and openness about limitations and costs. The issue spans many dimensions and in some cases conflicting priorities, which makes innovation and reform challenging for political decision makers and private companies. The continued movement towards the development and

promotion of MSPs may help to address this issue as the stakeholders engage more strongly with one another at different levels. This is an area where closer collaboration between academia, industry and government is needed to proceed (Surminski et al., 2015a).

Our findings are relevant for discussions on the potential of insurance schemes to incentivise risk management and climate adaptation in the EU and beyond. There is a clear current momentum at international level to use insurance to incentivise risk prevention and adaptation, as highlighted by the increased efforts to design new insurance schemes in developing countries through the new G7 ‘InsuResilience’ initiative, and underpinned by the UNFCCC’s Paris Agreement (see Surminski et al. 2016). The engagement of multi-sectoral partners and the clarification of their roles and responsibilities will determine if and how those new schemes can support climate resilience. This is an opportunity, and the lessons from across Europe provide important insights that can help to harness disaster insurance for risk reduction and climate adaptation.

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Table 1: Variables and associated metrics of insurance

Term	Definition	Metrics used
Affordability	Cost effectiveness of an insurance product from the perspective of the consumer	<ul style="list-style-type: none"> • Average Premium Paid / Average Coverage Amount (Michel-Kerjan and Kousky, 2010; Michel-Kerjan, 2010) • Premium paid/expected insured losses; Premium spent/income (Blumbey et al., 2007; Stone, 2010) • Price elasticity of insurance (Tooth, 2007)
Commercial Viability/ Availability	Demand of an insurance product to the particular market segment the product is designed for and the potential risk-adjusted profit and the matching supply of insurance cover.	<ul style="list-style-type: none"> • (Administrative Cost + Indemnity Payments)/ Premium Payments (Hazell, 1992) • Opportunity cost of money held in reserves (Bardsley et al., 1984) • Number of Insureds/Number of Eligible Persons (Swiss Re, 2013) • Potential revenues = (number of insured + number of potentially insured) x average premium, including returns from investing accumulated premium in equity markets • Public financial backing
Financial Sustainability/ Solvency	<p>Short Term - Operating income is sufficient to cover operating costs, including salaries and wages, supplies, loan losses, and other administrative costs.</p> <p>Long Term – Operating income and capital is sufficient to cover costs of funds and other forms of subsidies received when they are valued at market rates (Definition from Meyer, 2002)</p>	<ul style="list-style-type: none"> • (Administrative Cost + Indemnity Payments)/ Premium Payments (Hazell, 1992) • Administrative Cost + Indemnity Payments/ Non-Subsidized Premium Payments (Mahul and Stutley, 2010) • Solvency Ratios

Table 2: Examples of economic methodologies used to assess the impacts of disasters

Term	Metrics used
<p>Risk Reduction = Measures to lessen disaster impacts</p> <ul style="list-style-type: none"> • Direct Impacts – those resulting from building; lifeline; and infrastructure damage. • Indirect Impacts – those that follow from physical damages (Kliesen and Mill, 1994) 	<ul style="list-style-type: none"> • Change in individual wealth, physical and other assets from disaster events (Kliessen and Mill, 1994) • Monetary value of indirect and direct impacts (Kliessen and Mill, 1994) • Percentage of total losses insured (Kliessen and Mill, 1994) • Number of people killed or otherwise affected (Cavallo and Noy, 2010) • Number of risk reduction measures installed in households • Number of households moving out of high risk areas

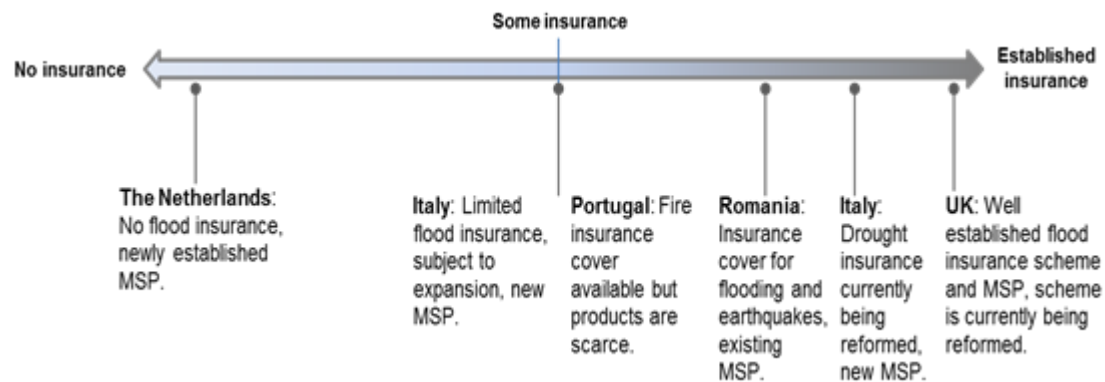
Table 3: Overview and associated detail of the four methods to assess risk reduction

Methodology	Stress testing	Estimation of effectiveness of household-level mitigation measures	Analysis through a Risk Reduction Framework	Investigation of the design principles of insurance
Name				
Aim	<ul style="list-style-type: none"> Develop a probabilistic model of losses. Investigate the required solvency capital. Investigate the pressure on the EUSF. 	To investigate the effectiveness of policyholder level risk reduction measures.	Compares and assesses seven key aspects of risk reduction: <ul style="list-style-type: none"> Awareness and knowledge; the benefits of flood risk management and preventative measures;- financial incentives to invest in mitigation; promotion of resilient reinstatement; incentives for public flood risk management policy; conditions for compulsory risk reduction; incentives present; for preventing development in flood risk areas. 	To design an insurance system in a way to meet the needs of stakeholders, without compromising the potential for risk reduction elements and a long term focus.
Approach (quant./qual.)	Quantitative	Quantitative	Qualitative	Qualitative and quantitative
Data needs	<ul style="list-style-type: none"> Flood damage Model projections Protection standards Insurance penetration rates 	<ul style="list-style-type: none"> Risk characteristics Measures undertaken Cost of measures undertaken Detailed questionnaire on the (past) flood events and measures employment 	<ul style="list-style-type: none"> Information on the operation of the scheme Involved stakeholders Financial detail Evidence of risk reduction elements 	<ul style="list-style-type: none"> Information on the Operation of the scheme Key principles of the scheme Financial detail
Evidence base (which countries and which cases)	EU wide (EUSF)	Germany (Hudson et al., 2014) France (Poussin et al., 2015)	Flood insurance schemes in England and low/medium income countries (see Surminski and Oramas- Dorta, 2013; Surminski and Eldridge, 2014)	Flood Re
Key Findings	Annual ceiling is likely to be Exceeded 80% by 2050. While, the private capital reserve of insurers is estimated to double by 2050.	A more refined estimate is made using risk characteristics between individuals who have, or have not, implemented mitigation measures. Hudson et al. (2014) and Poussin et al. (2015) find substantial finds overestimates of mitigation measures' effectiveness using the methodologies of previous studies but demonstrate that that these measures are still very cost effective.	Evidence of risk reduction in flood insurance schemes is lacking. Flood insurance is practically non-existent in least developed countries. In developing countries many schemes are at an early stage and have yet to be tested against large events and also may lack comprehensive risk data – posing challenges to effective delivery and design but risk reduction elements (direct and indirect) are present in 33.3% of the schemes assessed.	Flood Re is designed based on affordability and availability principles for those at highest risk, yet little formal evidence is in place for effective risk reduction over the life of the scheme.

Table 4: Summary of case studies, including risk reduction measures and novel approaches

Name/ Country	Port of Rotterdam infrastructure: flood risk	Romania	Europe	Po River basin	Portuguese wildfire insurance	Flood insurance in England
Hazard Type	Flood risk in unembanked (or outer dike) areas	Flood and Earthquake	Natural hazards	Flood and drought	Fire	Flood
Key stakeholders involved in the development/delivery	Province of South-Holland; the municipality of Rotterdam ;the Port of Rotterdam Authority; businesses, the citizens, the environmental protection agency of local and regional authorities; three water boards, the Ministry of Infrastructure and the Environment.	Government, local public authority, the private industry (e.g. insurance) and homeowners.	EU policy-making bodies including DG Regional and Urban Policy and DG Internal Market and Services, primary insurance companies, reinsurers (with a special attention to Europe Re), national governments.	River basin authority, land reclamation and irrigation boards, civil protection agencies. The drought case sees involvement of all major users through the drought steering committee.	Union of Farmers Associations for the development of Chameca Portuguese Association of Insurers Forest and Nature Conservation Institute	Private insurers cover all aspects of insurance provision, UK Government determine and deliver flood risk management.
Description of insurance instrument (existing and/or planned)	Flood insurance is currently uncommon and not obligatory. For some areas it is not yet available and unlikely to be realized without a indication of the expected consequences.	Voluntary and Compulsory home insurance (PAD). A compulsory insurance system (Law 260/2008) for residential properties with homeowners subject to fines for non- purchase.	The EUSF, in its current form, is the main post-disaster instrument of the EU. It provides financial aid to MS/candidate countries in case of major (natural) disasters.	There is no or only a marginal coverage for flood insurance due to state compensation (For drought a state-subsidized insurance for agriculture (and insurable risks) has been in operation since 1970).	Forest insurance is mandatory under law- yet this is not enforced and insurance products are scarce.	The previous agreement between insurers and government has been replaced by Flood Re, a pooled approach for the highest risk households, delivered and run by private insurers.
Consideration of risk reduction	Insurance does not reduce societal risk. Insurance aims to spread risk (both spatially as well as in time). With insurance the costs of floods are divided between public and private bodies.	The Romanian Disaster risk financing framework, in its current form, is rather ex-post. Risk reduction and risk financing is currently not well linked.	As an ex post financing instrument, the EUSF may discourage Member States to invest in risk reduction.	Yes, indirectly in both cases. For flood insurance the incurred costs are a result of controlled floods whose primary aim is reducing flood risk. In the drought case, the insurance should enable a shift of the available (remaining) water resources from low to high value water uses.	Yes – In an indirect way, the landowners only can have these kind of insurances if they promote an active management of the forested areas.	The government commits to flood risk management investment, mapping and planning policy. Risk reflecting pricing is implemented over 25 years, There are no formal plans for risk reduction in the scheme other than data sharing between the government and insurers.
What is novel about the case?	Quantifying flood risk (with a focus on low probability, high impact events) has not been conducted for the Port of Rotterdam .	Re-orienting established insurance schemes as not only post- disaster instrument, but also as a pre-disaster instrument.	Reorienting the EUSF as not only a post-disaster instrument, but also a pre-disaster instrument.	In both cases a new mix of instruments and policies is being applied to reduce risk.	The integration of public funds into a scheme supporting risk transfer and reduction more equitably.	UK flood insurance is unique in that there is no government involvement in its provision. Flood Re is focused on affordability and availability for those at high risk.

Figure 1: an overview of the insurance spectrum of the ENHANCE case studies



Source: Authors

¹ Financial sustainability will also be driven by the investment income of insurers. However, in this paper we focus on the underwriting operations of the industry.