282746
IMPACT2C
Quantifying projected impacts under 2°C warming

Instrument	Large-scale Integrating Project
Thematic Priority	FP7-ENV.2011.1.1.6-1

D9.2: Recommendation of reform steps for the financial risk transfer mechanism

Due date of deliverable:	**M46**
Actual submission date	**July 2015**
Start date of the project	01.10.2011
Duration	48 months
Organisation name of lead contractor for this deliverable	**JR**

Revision: ***Draft***

Project co-funded by the European Commission within the Seventh Framework Programme		
Dissemination Level		
PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Authors

Franz Prettenthaler (JR), Hansjörg Albrecher (UNIL), Peiman Asadi (UNIL), Judith Köberl (JR)

Content

1 Introduction

Based on the analyses and results of Deliverable 9.1 – particularly with respect to the values at risk in EU-27 from flooding – and on collected qualitative data about the national (flood) risk transfer systems in place, the deliverable at hand presents some suggestions on institutional (and regulatory) reform for the financial risk transfer mechanisms in place to increase adaptive capacity in the EU-27. The deliverable is structured as follows: Chapter 2 starts with some general remarks on flood risk and its insurability by listing the key challenges related to flood insurance and presenting strategies (in place) to handle these challenges. Chapter 3 gives an overview of the national (flood) risk transfer mechanisms in Europe by providing a snapshot of the diversity of mechanisms currently in place and presenting selected examples in more detail. Chapter 4 deals with the heart of the present deliverable, i.e. a thought experiment on reforming the risk transfer system by the establishment of Joint Risk Pooling Initiatives (JRPs). Impressions from discussions with stakeholders in chapter 5 conclude the deliverable.

2 Flood risk & insurability: Some general remarks

Floods rank amongst the most wide-reaching and commonly occurring natural hazards in Europe. In the International Disaster Database EM-DAT (Guha-Sapir et al. 2015), flood events account for 36 % of the damages recorded from natural disasters in Europe, followed by storm events (27 %) and earthquakes (21 %). Losses from floods show an increasing trend, which is mostly attributable to socio-economic factors, including population growth, economic development and construction activities in vulnerable areas. However, also climate change is expected to intensify the impacts of flooding (IPCC 2014). Hence, while representing a major issue already today, managing the risk of flooding is expected to become an even more important topic in the future.

Efficient flood risk management requires a combination of risk reduction, risk retention and risk transfer. In the present deliverable, we mainly focus on the latter. Risk transfer, which is defined as shifting the burden of disaster loss to another party (for instance by means of insurance), represents an important instrument in order to manage the risk resulting from natural perils such as floods and can help mitigating or minimizing disaster losses. A well implemented plan how to spread economic risks from extreme events within society and/or transfer them from the victims to the financial markets is a fundamental adaptation measure that crucially decides on how impacts from climate change will finally disturb a society. Although risk transfer does not prevent damages from climate change, it represents an effective mechanism to manage the hardship related to climate risks, especially of those climate risks which cannot be prevented (cost-effectively) by means of risk mitigation measures. Moreover, adequately designed, risk transfer mechanisms even have the potential to generate incentives for individuals as well as the collective to actively engage in risk reduction.

With respect to flood events (and natural catastrophes in general) a broad range of alternative national risk transfer systems can be found in EU member states. These may vary considerably regarding their organizational structure and design elements (see section 3 for more details). However, what most of these systems have in common is some sort of state intervention. The public sector's role may take quite different forms, ranging from enhancing people's awareness over providing a legal framework for private insurance companies to the public provision of insurance or ex-post aid for victims. One reason for the – partly far-reaching – role of the public sector within a nation's flood risk transfer system can be found in the special characteristics of flood risk, which make the provision of a sustainable working insurance system somewhat of a challenge.

2.1 Key challenges in flood insurance

The sustainable provision of a working insurance system, that is able to transfer, share and reduce risk, requires particular conditions to be fulfilled (see e.g. Kunreuther and Freeman 1996; Kunreuther 2008; Prettenthaler and Albrecher 2009). Preconditions for the insurability of an event usually include the existence of a huge number of similar insurance entities, the determinability, measurability and randomness of the resulting damages – including that the occurrence and severity of the damage is beyond the control of the insured – as well as the calculability of the damage probability. Moreover, damages experienced by the insured entities should occur independently from one another, i.e. they should not hold any catastrophic damage potential. Lastly, premiums are to remain affordable.

Floods – like most other types of natural perils – show various characteristics that make the sustainable provision of a working insurance system at affordable price challenging. One challenge relates to the creation of a risk collective of sufficient size (see e.g. Prettenthaler and Albrecher 2009). Floods tend to occur at the same place over and over again. If insuring against floods is voluntary, coverage tends to be demanded mainly in those areas that show an excessive damage probability. The overrepresentation of "bad risks" in the collective that demands insurance especially becomes a problem, if insurance companies have difficulties in screening clients (i.e. in case of information asymmetries e.g. due to lacking hazard maps) and/or are not able or allowed to charge risk-based premiums. This situation, where an individual's demand for insurance is positively correlated with its risk of loss and the insurer is unable to account for this additional risk in the price of insurance – also known as "adverse selection" problem – causes a vicious circle of increasing premiums and decreasing insurance demand of less endangered potential assureds. Hence, adverse selection leads to a small risk collective and can threaten the economic viability of an insurance system.

Besides adverse selection, there is a second consequence that may arise from information asymmetries between insurance companies and policy-holders and reduce insurance demand: the problem of "moral hazard" (see e.g. Prettenthaler and Albrecher 2009; Surminski 2013). It may occur after taking out an insurance policy and refers to a change in the assured's behaviour that causes the probability of loss to be higher than considered when setting up the contract. Examples for changes in the assured's behaviour include reduced efforts of avoiding damages or of keeping them at a minimum. The problem of moral hazard – which is not exclusively related to flood risk but rather represents a key challenge for any insurance product – leads to a costly cycle of losses and hence makes it difficult to provide sustainable insurance.

The demand for insurance coverage may also be negatively affected by a lack of risk awareness – if e.g. information on the exposure is not sufficiently available – or by the so called "charity hazard". The latter refers to the tendency of an individual to forego purchasing insurance or taking other precautions provided that governmental assistance or aid from other sources can be anticipated in the event of a disaster (see e.g. Lewis and Nickerson 1989; Browne and Hoyt 2000; Prettenthaler and Albrecher 2009).

Besides difficulties in creating a sufficiently large risk collective, there are further factors making the provision of flood insurance at an affordable price challenging: It is, for example, difficult to estimate uncertain low-frequency high-impact risks and, hence, the respective insurance premiums (see e.g. Paudel 2012; Surminski 2013). Surminski (2013, p.260) mentions in this context that *"[f]lood is often regarded as the most technically challenging type of insurance due to a lack of accurate assessment of exposure, difficulty in estimating the probability of occurrence of an event and potential losses faced*". Another challenge regarding the coverage of flood risk results from the possibility of a catastrophic damage. As natural hazards typically affect large connected areas, the resulting damages are correlated. Hence, large amounts of capital have to be available all at once in order to prevent insolvency on the one hand and to be able to guarantee coverage of the insured damages even in case of damage peaks on the other hand.

Before presenting strategies (in place) that aim at handling the mentioned challenges related to the insurability of flood risk, Table 1 finally gives a summarizing overview of the conditions required for the sustainable provision of a working insurance scheme and the special characteristics and challenges of flood risk.

Table 1: Summarizing overview of key challenges in flood insurance

Conditions for a working insurance scheme	Characteristics/challenges related to flood risk
■ Huge number of similar insurance entities (sufficiently large risk collective) ■ Determinability, measurability and randomness of resulting damages ■ Calculability of damage probability ■ Independent damages (no catastrophic damage potential) ■ Affordable premiums	■ Tend to occur at the same place over and over again (adverse selection) ■ Asymmetric information (if e.g. hazard maps do not exist) ■ Difficulties due to low frequency events ■ Potential for catastrophic loss events (correlated risks) ■ Moral Hazards (hidden action) increases premiums

2.2 Strategies (in place) to handle problems

There are different ways and strategies of dealing with challenges related to the provision of flood insurance. What follows is a description of common strategies (in place) to handle the challenges mentioned in section 2.1, without any claim to completeness. A summarizing overview is given in Table 2.

Strategies to handle "Small risk collective / adverse selection"

Since a risk collective of sufficient size is necessary in order to ensure the provision of insurance coverage, additional actions are required in case that contracting insurance is voluntary. One possible option is to bundle flood insurance with other kinds of (preferably) uncorrelated perils, such as fire or earthquakes. This enlarges the number of potential assureds being at risk of one of the perils in the bundle, which increases the demand and hence extends the risk collective. Simultaneously, it reduces the problem of adverse selection by avoiding that insurance is only purchased by individuals facing high flood risk (see e.g. Prettenthaler and Albrecher 2009; Botzen 2013).

Further measures aiming at the enlargement of the risk collective include information campaigns about the exposure and risk-based premiums. The latter again counteracts the problem of adverse selection. However, if the premiums reflect the full risk of the assured, insurance could become unattainable for individuals in highly exposed areas. Hence, although able to solve the problem of adverse selection, premium differentiation may be politically infeasible when premium differences between low and high-risk areas become too large (Botzen 2013). Thus, alongside with the enlargement of the risk collective the question about the extent of solidarity, i.e. the cross-subsidization between assureds in different risk classes, arises. With a solidarity contribution of less exposed assureds the premium for highly exposed assureds can be lowered, which makes coverage possible for a bigger part of society.

In case the measures of the insurance industry are not sufficient for developing and maintaining a working insurance solution, some sort of state-introduced compulsion is often suggested. Especially if areas and objects highly at risk are intended to be included in the shared risk community, such interventions seem somehow unavoidable. Obligatory coverage extensions and compulsory insurance solve the problems of adverse selection and insufficient demand. However, compulsory insurance elements are often unpopular and thus politically difficult to implement.

Strategies to handle "Moral hazard"

Since moral hazard arises from an information asymmetry between insurer and insured, monitoring the insured is one option to reduce the problem (see e.g. Botzen 2013). Due to its high costs, perfect monitoring is however an unattractive strategy in practice. Other measures include the introduction of deductibles, co-insurance or upper limits on coverage. All three tools have in common that the insured has to bear parts of the damage on its own, which provides incentives for the policyholder to undertake loss-reducing measures, at least in theory. However, in practice "[…] *the effectiveness* [of these tools] *in reducing moral hazards in relation to residential natural catastrophe risks remains unclear*" according to Surminski (2013, p.267).

Another tool that is said to help preventing moral hazard and stimulating risk reduction behaviour is risk-based pricing, as insurance premiums are assumed to send risk price signals (Surminski and Crick 2013). However, as already mentioned above in the context of risk-based premiums and adverse selection, maintaining affordability represents one of the challenges when using risk-based premiums.

Strategies to handle "Correlated risks"

Due to the catastrophic damage potential, the insurance of flood risk requires large amounts of capital to be available all at once. Precautions such as the introduction of various limits, the development of insurance pools, reinsurance or the involvement of the international capital markets aim at limiting the damage burden for the single insurance company and at ensuring the required capacities.

Table 2: Overview on the strategies (in place) to handle challenges related to flood insurance

Small risk collective / adverse selection	Moral hazard	Correlated risks
▪ Bundling ▪ Information campaigns ▪ Risk-based premiums ▪ Compulsory elements (often unpopular)	▪ Monitoring (costly) ▪ Deductibles, co-insurance, upper coverage (effectiveness however unclear) ▪ Risk-based premiums	▪ Introduction of limits ▪ Insurance pools ▪ Reinsurance ▪ International capital markets (ART)

If not insurable by private market (alone)	
State intervention:	
▪ Establish framework for private insurance companies (e.g. compulsory elements) ▪ Reinsurer ▪ Insurer of last resort ▪ Ex-post ad-hoc aid or compensation funds (moral hazard problem)	▪ Subsidize insurance premiums ▪ Low-interest loans to victims of flood events ▪ Manage the insurance scheme ▪ Purely underwrite the insurance scheme (governmental monopoly insurance institution)

State intervention

Despite the described possibilities of coping with the mentioned challenges, it might be difficult or even impossible for the private insurance sector to efficiently provide comprehensive insurance coverage for the whole population on its own. Small risk collectives, a lack of risk awareness among the population, adverse selection and moral hazard as well as the risk of loss accumulation contribute to the facts, (i) that insurance penetration related to flood risk is often very low, (ii) that coverage is strongly limited in many cases or only available at high costs and (iii) that only a small part of the losses resulting from a catastrophic event is covered by insurance. Due to these difficulties as well as the political dimension of ex-post disaster relief, the adequate role of the state in a nation's risk transfer system is frequently discussed. As will be illustrated in further detail in section 3, different countries have developed different systems, ranging from a rather passive role of the state to the establishment of the adequate framework for the insurance industry to compulsory insurance, governmental monopoly insurance institutions or ex-post disaster relief. Systems with state involvement are commonly set up as Public-Private Partnerships (PPP) between the state and private insurance companies, where roles and responsibilities of the involved parties may vary considerably depending on the concrete design of the system.

In case insurance against floods (or natural disasters in general) is decided to be handled by private insurance companies, an important role of the state within a clearly defined public-private partnership could be the establishment of the necessary framework. This includes

- the public provision of information about the exposure as well as the possibilities for prevention and individual financial precaution,

- the provision of nation-wide hazard maps[1], risk-minimizing spatial planning and building regulations,
- sufficient investments in prevention measures,
- and efficient disaster management.

One important feature of a public-private partnership, in which the private insurance industry takes on the task of compensating damaged individuals, is the discharge of the state. Thus, the government can focus on other challenges related to the catastrophic event and concentrate its financial resources on the reconstruction of damaged infrastructure.

If an active role of the state in compensating private damages is taken into consideration, acting as an insurer of last resort is principally preferred to governmental ad-hoc aid or compensation funds, since the latter is related to negative incentive effects. With governmental ad-hoc aid or compensation funds, individuals are unlikely to reduce the risk of their behaviour. In other words, the problem of moral hazard arises. Only with ex ante strategies preventive behaviour can be rewarded, e.g. in the form of premium reductions or smaller deductibles.

As already mentioned in the context of the strategies available for handling the problem of small risk collectives, the state may introduce some sort of compulsion, e.g. obligatory coverage extensions or compulsory insurance. Compulsory elements are able to solve the problems of adverse selection and insufficient demand, while it limits the need for governmental aid programs and the related charity hazard (Prettenthaler and Albrecher 2009; Paudel 2012). At the same time the advantages of an insurance solution come into effect for maximum parts of the society. However, as mentioned above, compulsory insurance elements are often unpopular and thus politically difficult to implement.

3 National risk transfer mechanisms in Europe

Considering the national flood risk transfer mechanisms currently in place in the EU member states, a broad range of alternative systems can be found, which evolved in the light of diverse historical and cultural backgrounds. These systems may vary considerably regarding their organizational structure and design elements, including:

- available insurance options,
- the public sector’s role,
- the existence of compulsory elements,
- the coverage conditions,
- the existence of deductibles,

[1] In case of lacking nation-wide hazard maps, risk assessment may not be possible or only at high costs. If there is no possibility of assessing the risk adequately, insurance companies will hesitate to offer comprehensive coverage. Thus, by reducing asymmetric information, hazard maps contribute to a higher availability of insurance coverage. In addition, they also form a precondition for regulative interventions from the state in spatial planning and building regulations.

- the implemented risk assessment approach,
- the applied premium structure,
- the form of reinsurance coverage,
- and the existence of incentives for risk mitigation.

Section 3.1 gives some impression of Europe's diversity regarding the design of the risk transfer mechanisms currently in place, whereas sections 3.2 to 3.5 provide short descriptions of four selected and partly highly diverse national risk transfer systems. For more comprehensive overviews on the different mechanisms currently in place or details on selected countries see e.g. CEA (2011), IBC (2015), Jongman et al. (2014), Keskitalo et al. (2014), Maccaferri et al. (2012), Paudel (2012), Prettenthaler and Albrecher (2009), Seifert et al. (2013), Surminski (2013), Surminski et al. (2014), Schwarze and Wagner (2009) or Schwarze et al. (2012).

3.1 Some impressions of Europe's diverse flood risk transfer mechanism designs

As mentioned above, Europe shows a broad variety of national flood risk transfer systems currently in place. This starts with the different roles and responsibilities of the public and private sector and ends with the design of insurance policies. Some countries (e.g. Germany, Italy, United Kingdom, and – just recently – Finland) show (purely) market-based systems, sometimes systematically coupled with state-funded ad-hoc relief. Others (e.g. Spain and France) exhibit public or quasi-public monopoly insurance provision. A third group of countries (e.g. Austria, Denmark, Belgium, and Norway) manage flood risk transfer either mainly via tax-financed public disaster funds or by means of a combination between public disaster fund and private insurance provision. Table 3 provides some kind of graphical illustration of Europe's diverse designs with respect to national flood risk transfer mechanisms by comparing the current systems of the EU-27 according to some selected characteristics. These characteristics include, whether …

- … flood risk is bundled with other risks
- … premiums are risk dependent
- … there are some limits or deductibles related to the coverage of flood damages
- … the system exhibits compulsory elements
- … there is any kind of financial governmental intervention
- … governmental ad-hoc aid has been granted in the past
- … there is some kind of state guarantee
- … there is an explicit public-private-partnership

Table 3: A snapshot of Europe’s diversity regarding the characteristics of their national risk transfer mechanisms in place for flood events (Sources: CEA 2011; IBC 2015; Maccaferri et al. 2012; Paudel 2012; Prettenthaler and Albrecher 2009; Rytkönen et al. 2014; Surminski et al. 2014; UNISDR-EC-OECD 2014)

	Bundled	Risk-based premiums	Limits / deductibles	Compulsory elements	Financial GVT-intervention	GVT ad-hoc aid (in the past)	State guarantee	Public-Private-Partnership
BE	Y	Y	Y	(Y)[a]	Y	N	Y	Y
BG	(Y/N)[b]	N	(Y/N)[b]	N	Y	Y	-	-
CZ	Y	Y	Y	N	Y	Y	N	N
DK	Y	N	Y	N	Y	N	Y	-
DE	(Y)[c]	Y	Y	N	Y	(Y)[d]	N	N
EE	-	-	-	N	-	-	N	N
IE	Y	Y	-	(N)[e]	N	N	N	N
GR	Y	Y	Y	N	-	-	-	-
ES	Y	N	Y	(Y)[f]	Y	N	Y	Y
FR	Y	N	Y	(Y)[f]	Y	N	Y	Y
IT	(Y/N)[b]	Y	-	N	Y	Y	N	N
CY	-	-	-	N	-	-	N	N
LV	-	-	-	-	-	-	-	-
LT	-	-	-	-	-	-	-	-
LU	N	-	-	N	-	-	N	N
HU	-	-	-	N	-	N	Y	N
MT	-	-	-	-	-	-	-	-
NL[g]	Y	Y	Y	N	Y	Y	Y	N
AT	(Y)[h]	N	Y	N	Y	Y	N	(Y)
PL	-	N	-	N	Y	Y	N	-
PT	Y	-	Y	N	-	-	N	N
RO	Y	Y	Y	Y	Y	Y	Y	Y
SI	Y	-	-	N	-	-	N	N
SK	Y	-	Y	-	-	-	-	-
FI[i]	Y	N	-	N	(Y)[j]	Y	-	Y
SE	-	N	N	(N)[e]	-	-	N	N
UK[k]	Y	Y	Y	(N)[e]	N	N	N	Y

a) Natural disasters (incl. floods) mandatorily covered in the fire insurance contract; Fire insurance compulsory since 2010.
b) Depends on the insurance company.
c) Flood coverage is an optional add-on to standard homeowner’s insurance (usually bundled with other natural hazards).
d) Governmental ad-hoc compensations in the past, but now low-interest-rate loans to victims of natural disasters.
e) Optional, but most mortgages require home owners to have building/flood insurance.
f) Compulsory extension of various property and casualty insurance contracts
g) Flood coverage is hardly available; Since 2012 offered for homeowners (but not for tenants) by Lloyd’s coverholder Neerlandse in a bundle with earthquake and terrorism risks.
h) (Very limited) flood coverage either automatically included in standard homeowner’s insurance or available as an optional add-on (sometimes bundled with other natural disasters).
i) With 1.1.2014, state compensation system for flood damages expired and coverage of damages was shifted to private insurance companies.
j) The state's role in compensating flood damages did not end completely in 2014. Agricultural damages caused by waterway floods and flood damages to private roads are still covered by state funds.
k) Presented information refers to the current system. With April 2016, the state-backed “Flood Re” scheme, that guarantees affordable insurance for households in flood-prone areas, is planned to be put into service.

In most of the member states, for which information is available, the coverage of flood risk is somehow bundled with other perils, such as fire or natural hazards including earthquakes, landslides, avalanches, etc. The usage of risk-based vs. risk-independent premiums is, however, more or less balanced. In Finland, where the system changed from state compensation to a new private-insurance-based system in 2014, flood insurance is now provided in a package with home insurance, with – for the time being – no increase to insurance premiums. Hence, premiums are currently risk-independent. However, it is expected that after a few years of experience, premiums will be recalculated, eventually reflecting the risk level then (UNISDR-EC-OECD 2014).

The overwhelming majority of systems, for which information is available, make use of deductibles or include some compensation limit. Flood risk transfer systems with compulsory elements are, by contrast, rather the exception than the rule. In most countries, insuring against flood risk is voluntary, although taking up insurance may represent a requirement to receive mortgage and loan (Ireland, Sweden, United Kingdom). However, there are a few countries with compulsory elements in their flood risk transfer system, including Belgium, France, Spain and Romania. In Romania, insurance against natural disasters (including floods) is compulsory for every public and private dwelling (Prettenthaler and Albrecher 2009; Maccaferri 2012). In Belgium, floods are mandatorily covered in the fire insurance contract, where fire insurance has been compulsory since 2010 (Paudel 2012). In Spain and France, flood coverage represents a compulsory extension of various property and casualty insurance contracts (Prettenthaler and Albrecher 2009; Maccaferri 2012).

Most national systems show some form of financial governmental intervention. This may include the (monopolistic) provision of insurance, the provision of reinsurance, the implementation of a compensation fund, the granting of ad-hoc relief, the provision of state guarantee, etc. Moreover, some countries exhibit an explicit public-private-partnership with roles and responsibilities clearly defined between the public and private sector. For example, in the current system of the United Kingdom the agreement on the distribution of tasks between the Association of British Insurers (ABI) and the government is set out in the Statement of Principles (SoP) (Surminski and Eldrige 2014). While the agreement declares the private sector to provide flood insurance coverage, it specifies the government's responsibility to include flood management and the provision of flood risk information.[2]

Besides this rough overview on some characteristics of the member state's flood risk transfer mechanisms, the following subsections provide further details on four – partly very distinct – national systems: Spain and France provide two examples for state-managed insurance schemes, whereas a completely private market solution of flood insurance provision is illustrated by the example of Germany. Finally, with Austria some sort of dual system is presented that consists of a tax-financed public catastrophe fund supplemented by offerings of the private insurance market.

3.2 Example Spain

In Spain, offering coverage against "extraordinary events" – including both, natural and man-made disasters – is the responsibility of the "Consorcio de Compensación de Seguros" (CCS), which is a public monopoly insurer. Being part of the catastrophe coverage, flood risk is automatically (i.e. compulsorily) covered when underwriting particular property and casualty insurances, including personal accident policies, life policies

[2] The current approach in the United Kingdom is planned to be replaced by the new state-backed "Flood Re" scheme in April 2016.

and property damage policies (Vetters 2006; Maccaferri et al. 2012). Premiums are set by the CCS, but do not differentiate between flood risk zones. However, for capital close to rivers an additional premium is charged (Vetters 2006). Compared to other systems, premiums are rather low, which also holds true for deductibles (Paudel 2012). Thus, overall the Spanish scheme is characterized by high solidarity. Whereas premiums are collected by the private insurance companies on behalf of the CCS[3] for a commission of 5 %, claims are settled by the CCS itself (Vetters 2006; Paudel 2012). Instead of having a market-funded reinsurance cover, the CCS is backed by an unlimited state guarantee. So far, it however has not been necessary for the CCS to draw on this unlimited state guarantee, as its own reserves– cumulatively endowed with its annual profits– have sufficed to cover the losses (Maccaferri et al. 2012). Due to the compulsory nature of the catastrophe coverage, the density of flood insurance is high and the problem of adverse selection low. However, financial incentives that encourage the implementation of risk mitigation measures, such as risk-based premiums, are more or less missing in the Spanish system (Paudel 2012).

To sum up, the Spanish (flood) risk transfer system is characterized by:

- a quasi-monopolistic public insurance provider
- compulsory insurance (subsidiary)
- the bundling of natural (and man-made) hazards
- unlimited state guarantee
- a high (flood) insurance penetration rate due to the compulsory elements
- comparably low premiums and high solidarity
- risk-independent premiums
- hardly any financial incentives for risk mitigation measures

3.3 Example France

The French system is, in many aspects, similar to the Spanish model. Flood risk is covered by the state-managed CatNat (Catastrophes Naturelles) system, which is based on the principles of solidarity and collective risk-sharing (Paudel 2012). Coverage against floods – and other "exceptional" natural catastrophes, including landslides, earthquakes, drought, and volcanic eruptions – is available as a compulsory extension of various property and casualty insurance contracts. In France property owners and tenants, whether it is a private person or a company, are obliged to obtain liability insurance. In combination with the compulsory extension this results in an obligation to insure against "exceptional" natural hazards, including floods (Prettenthaler and Albrecher 2009). However, coverage for new buildings in risk zones after the publication of risk prevention plans is exempted from the mandatory extension (Vetters 2006).

In communities with a Natural Risks Prevention Plan (PPR) deductibles are a fixed percentage of direct property damage in communities, whereas in communities without a PPR deductibles depend on the number of

[3] Although private insurance companies can formally provide competitive insurance coverage against natural hazards, this competition is practically insignificant, as they have to hand on the additional premiums to the CCS (Schwarze and Wagner 2009).

hazard-specific past official natural disaster declarations (Prettenthaler and Albrecher 2009). Premiums are set by the government at a flat rate, irrespective of individual risk exposures. Private insurers receive the additional premiums paid by their customers due to the mandatory extension of property insurance to "exceptional" natural hazards and settle the claims. However, the compensation of damages due to floods and other "exceptional" natural hazards requires an official natural disaster declaration (Prettenthaler and Albrecher 2009; Paudel 2012). Insurance companies may purchase reinsurance either from the private insurance market or the public reinsurer Caisse Central de Réassurance (CCR). The latter is supported by an unlimited state's guarantee, which, together with the relatively low reinsurance price, provides an incentive to mainly reinsure bad risks with the CCR, but good risks with the private reinsurance market. Hence, the public reinsurer faces the problem of adverse selection due to the lacking obligation of using CCR for reinsurance (Vetters 2006; Paudel 2012).

Due to the compulsory nature of the CatNat scheme, market penetration of flood insurance is high with a rate of about 90 % (Maccaferri 2012; Paudel 2012), whereas the problem of adverse selection is low. Deductibles that depend on the number of hazard-specific past official natural disaster declarations in case of missing Natural Risks Prevention Plans apply some pressure on communities to prepare such plans. This promotes risk reduction and loss prevention. Nonetheless, incentives that encourage collective risk prevention could be further enhanced. Moreover, the introduction of risk-based premiums or premium reductions in case of risk prevention measures could contribute to a reduction of moral hazard and promote individual risk mitigation (Vetters 2006).

To sum up, the French state-managed CatNat insurance scheme is characterized by:

- (regulated) private insurance carriers
- a mandatory extension of property insurance to include floods and other "exceptional" natural hazards
- a risk-independent premium surcharge (in %)
- the requirement of a governmental decision ("state of emergency") for compensation
- an (optional) unlimited government reinsurance by CCR
- a sliding scale for deductibles in communities without risk prevention plans
- no extension of coverage for new buildings in risk zones after the publication of risk prevention plans
- a high (flood) insurance penetration rate (i.e. about 90 %)
- hardly any financial incentives for risk mitigation measures at individual level.

3.4 Example Germany

Germany provides an example for a purely market-based flood insurance system with no governmental backing. Flood insurance is provided by private insurance companies. Usually it as part of a bundle of several natural disasters – so called elemental perils – that is offered as an optional extension to standard homeowner's policies (Vetters 2006; IBC 2015). Hence, the purchase of flood coverage is optional. Insurance premiums for extended flood coverage are actuarially sound and based on the nationwide zoning system ZÜRS that was developed by the German Insurance Association (Paudel 2012; IBC 2015). ZÜRS is also used by the insurers to determine insurability in principle. Premiums as well as deductibles may vary from insurer to insurer. Due to the fully private nature of the insurance system, reinsurance is obtained from the international private market.

The government's main responsibility is to provide flood protection. In the past, it also provided ad hoc ex-post compensation after some major flood events, including the flood of 2002 (Paudel 2012). However, instead of paying subsidies it now provides victims with loans at low interest rates to bridge the time until claims are settled by the insurers (Maccaferri et al. 2012).

Compared to systems with compulsory elements, the penetration rate of natural disaster coverage (including flood risk) is rather low. The German Insurance Association estimates it at 30 % (IBC 2015). Depending on the risk zone, premiums for flood insurance can be high. In some areas of extremely high risk, coverage against elemental damage is either not available at all or only under unaffordable conditions (Vetters 2006). However, risk-based premiums somehow limit adverse selection and moral hazard (Vetters 2006) and may provide incentives to the insured to mitigate flood risks (Paudel 2012).

To sum up, the purely market-based mechanism in Germany is characterized by:

- private insurance carriers
- optional purchase of flood coverage – usually within a bundle of natural perils – as extension to home insurance
- risk-based premiums
- no (or unaffordable) coverage in areas with extremely high risk exposure
- no state guarantee
- governmental ex-post compensations in the past, but now loans at low-interest-rates to victims of natural catastrophes
- a low (flood) insurance penetration rate (i.e. about 30%).

3.5 Example Austria

Austria exhibits some sort of dual system, consisting of a tax-financed catastrophe fund and supplementary offerings of the private insurance market.

Flood coverage is optional and usually offered by private insurers in exchange for an additional – typically risk-independent – premium to household insurance (Prettenthaler and Albrecher 2009). Very limited coverage is sometimes automatically and obligatorily included in standard homeowner's policies. Enhanced coverage of damages from flooding is often offered in a bundle together with damages from earthquakes, landslides, avalanches and backwater. However, such extended coverage is usually quite expensive. In areas of extremely high risk, coverage against floods is either not available at all or only under unaffordable conditions. Full coverage of flood damages is not offered at all. Overall, private flood insurance system suffers from adverse selection, which causes flood coverage to be expensive and penetration rates to be low. According to Maccaferri et al. (2012) flood insurance penetration only amounts to 18 %. Incentives to insure against the risk of flooding may also be undermined by the ex-post compensation payments of the Austrian catastrophe fund (charity hazard).

The tax-financed Austrian Catastrophe Fund is intended to (i) finance public protection and prevention measures and (ii) to compensate damages due to natural disasters, including floods. Private property damage due to natural disasters is usually compensated by the "*Bundesländer*" for up to 20-50 % of the loss suffered[4]. 60 % of the compensation expenses of the "*Bundesländer*" are reimbursable by the Catastrophe Fund. Although financed ex ante via taxes, the compensation payments of the Catastrophe Fund partly do have some sort of ex-post and ad-hoc character. If common compensation payments cannot be met by the resources of the fund, as was e.g. the case after the extreme floods in 2002 and 2005, the Catastrophe Fund is raised by resources from the public budget (Prettenthaler and Albrecher 2009).

Overall, the public compensation system brings some disadvantages. Behavioural effects, i.e. incentives for risk-reducing behaviour, are largely missing due to the ex-post character. The predictability of public compensation payments is likely to cause some charity hazard and hence to somewhat contribute to the low insurance penetration. Moreover, major-loss events bear risks for the national budget (Prettenthaler and Albrecher 2009).

To sum up, Austria's dual (flood) risk transfer system is characterized by:

- a public compensation fund that …

  … is tax-financed

  … reimburses the "*Bundesländer*" up to 60 % of their compensation payments

  … does not provide incentives for risk-reducing behavior

  … may reduce the willingness to buy flood insurance

- a private insurance market that …

  … only offers (very) limited flood coverage

  … shows a very low flood insurance penetration rate (i.e. 18 %)

  … charges risk-independent premiums

  … faces the problem of a small risk collective and adverse selection

3.6 Conclusions

After this short description of four rather diverse national risk transfer options and the overview of the entire diversity once all of European member state's mechanisms are looked at (as in section 3.1), it should have become clear that any harmonization project, i.e. an endeavor that seeks to prescribe one solution for all European member states to the various problems (even if they might be very similar in every member state) seems to be a very demanding task. Already discussions within nations on reforming the national

[4] In case of hardship, compensation may be higher than 50 % of the loss suffered.

systems usually take very long as the examples of Romania, the United Kingdom, Austria, Germany or the Netherlands show (see e.g. Prettenthaler and Albrecher 2009; Surminski 2013; Surminski et al. 2014).

This is why the reform option that we would like to put forward in this deliverable is of a completely different nature. It does not concentrate on the European Union as a potential player to harmonize national legal frameworks by superimposing a directive that then is supposed to be implemented into national law. We would rather like to propose a completely different perspective to the problem: Suppose the European Union would be a sovereign state and act economically rationally as this state, taking into account which problems can be solved on the national level at lower cost than on the EU level or vice versa. Certainly solving the partial problems to get enough flood risk insurance coverage for all citizens of Europe is a problem. For this problem, the EU level could provide a public insurance scheme (also by means of a Public Private Partnership of course) at much lower cost than every Member State on its own. This is so because flood risk is not necessarily correlated across member states. But a strong correlation of flood damages within a nation is often the problem, why the typical mechanism of insurance (pooling a large number of uncorrelated risks) does not work. So since the EU has many different regions, with weakly or even negatively correlated flood risks, this is the economically best level, where this risk should be insured, at least in theory. In the following section we propose a concrete procedure to better exploit the diversification potential even if not all member states agree on pooling their respective flood risk with all the members.

4 Joint Risk Pooling Initiatives (JRPIs) – A thought experiment

In Deliverable 9.1, extreme value theory (EVT) was used to define a model for the distribution of flood damages to residential buildings for 20 individual EU member states as well as their aggregate. Based on these modelled distributions, estimates of the Value at Risk (VaR) at the 99.5 % level, which represent the capital requirements for insurance companies prescribed by the Solvency II Directive of the European Commission, were derived.[5] Table 4 summarizes the results, which were already presented in Deliverable 9.1. The last column shows the 99.5 % Value at Risk, i.e. the flood risk capital requirements[6], for the 20 individual EU member states considered as well as the aggregate ("Europe"). The sum of the VaRs of the individual countries represents the overall capital amount that would be needed at the 99.5 % safety level in case each country dealt with flood risks stand-alone. With 155,483 M€ it is almost four times as large as the VaR calculated on the basis of the aggregated loss data of all 20 member states, which incorporates the dependence structure between the individual countries. In other words, pooling the flood risk across these 20 EU member states reduces the capital requirements to 41,080 M€. Hence, there is quite a strong diversification benefit arising from pooling the flood risk across countries. Based on this observation, the implementation of a flood damage pool or a joint reinsurance either at EU level, or – if no agreement at EU level could be achieved – between subsets of EU countries, seems a reform option worthwhile to consider. Hence, the rest of the deliverable at hand will deal with the thought experiment of "Joint Risk Pooling Initiatives" (JRPIs) and cover the following research questions:

[5] We gratefully acknowledge Munich Re for providing data from their loss database NatCatSERVICES (Munich Re (2014))

[6] The VaR figures reported to the regulator will typically substantially differ from the stand-alone VaR figures as reported in Table 4, since flood risk is often pooled with other risks and further factors, such as the assets of the company, loss reserves, etc. will have to be considered.

1. What would the annual (theoretical) premium volume be if each country dealt with flood risks stand-alone or if the risk was pooled at EU level?
2. If no agreement could be achieved at EU level, what would meaningful "Joint Risk Pooling Initiatives" (JRPIs) between subsets of EU member states look like, i.e. which groupings of EU countries would be most beneficial in terms of flood risk reduction?

Table 4: Best model, largest observed insurance loss (in % of the building value and absolute value), fitted upper bound T, total building value 2013 and 99.5 % VaR (in % of the building value and absolute value) for 20 EU member states and their aggregate ("Europe")

Country	Distr.	Largest Obs.		T (TP)	BV 2013	VaR (99.5%)	
		[% of BV]	[Mio. €]	[% of BV]	[Mio. €]	[% of BV]	[Mio. €]
Austria	TP	0.455	3,970	5.167	914,593	2.530	23,139
Belgium	TP	0.027	211	0.086	792,452	0.074	586
Bulgaria	TP	0.514	773	2.464	141,053	1.983	2,797
Croatia	LN	0.079	158	Inf	197,198	0.122	241
Cyprus	TP	0.017	6	0.098	40,062	0.076	30
Czech Republic	TP	1.300	4,080	3.644	323,412	3.181	10,288
France	LN	0.030	1,660	Inf	6,001,039	0.051	3,078
Germany	TP	0.167	14,900	0.286	8,704,763	0.260	22,632
Greece	TP	0.042	208	0.279	511,834	0.189	967
Hungary	LN	0.223	673	Inf	291,411	2.231	6,501
Ireland	LN	0.145	410	Inf	286,464	0.322	922
Italy	TP	0.391	12,203	0.621	3,366,374	0.570	19,188
Netherlands	LN	0.077	1,250	Inf	1,768,730	0.892	15,774
Poland	TP	0.483	5,160	2.186	1,065,883	1.794	19,122
Portugal	TP	0.210	1,090	4.012	513,923	2.084	10,710
Romania	TP	0.594	1,690	0.985	266,283	0.927	2,468
Slovakia	WB	0.280	490	Inf	175,723	0.439	771
Spain	TP	0.209	3,670	0.343	2,161,979	0.314	6,798
Sweden	TP	0.003	32	0.009	1,175,719	0.007	82
United Kingdom	TP	0.137	60,000	0.224	4,583,064	0.205	9,395
Sum							**155,483**
Europe	TP	0.093	29,842	0.131	33,281,959	0.124	**41,080**

4.1 Actuarial premium calculations: "Stand-alone" vs. "Joint Risk Pooling"

We start by determining annual actuarial premiums. A premium is a monetary quantity that is paid up-front to the insurer for paying the loss, if it occurs, according to the contract specifications. Such premiums can be calculated in different ways. Often they are determined on the basis of a *premium principle*, which is a rule to transform the risk (or its distributional properties) into a number. Examples for common actuarial premium principles include the expected value principle (EVP), the standard deviation principle (SDP) and the risk-adjusted principle (RAP).

Expected value principle (EVP)

$$\Pi_X = (1+\theta)E(X)$$

Standard deviation principle (SDP)

$$\Pi_X = E(X) + \alpha\sqrt{Var(X)}$$

Risk-adjusted principle (RAP)

$$\Pi_X = \int_0^{\infty} \left(1 - F_X(x)\right)^{1/\rho} dx$$

Each of those principles adds a safety margin to the expected loss *E(X)*. In the first case, this margin is proportional to the expected loss itself, whereas for the SDP it is expressed in terms of standard deviation of the loss size. Here θ and α are fixed constants. The higher their values the higher is the premium. In actuarial practice, the values are often chosen based on experience in that respective line of business (note that for risks of flood type there is often not sufficiently much reliable claim history available to rely on risk measures beyond the first or first two moments of X, so that such principles are not uncommon and we use them here for comparative purposes). In the RAP, the coefficient $\rho \geq 1$ is called the risk aversion index, a bigger value of ρ means more risk aversion and hence a higher premium.

Table 5 and Table 6 illustrate the results of the premium calculations along with the building values and the moments of the fitted distributions. Column 5 of each table shows the premiums (in % of the building value) resulting from applying the EVP for a relative safety loading of 15 % (Table 5) and 30 % (Table 6), respectively. Column 6, on the other hand, gives the level required for the loading factor α such that the standard deviation principle results in the same premium as the expected value principle with a relative safety loading of 15 % (Table 5) and 30 % (Table 6), respectively. Analogously, column 7 reflects the level required for the risk index ρ such that the RAP results in the same premium as the EVP with a relative safety loading of 15 % (Table 5) and 30 % (Table 6), respectively.

Measured in percentage of the building value, the highest annual needed premium volumes according to these principles are found for the Czech Republic, followed by Austria, Bulgaria, Romania and Poland, whereas Greece, Belgium and Sweden show the lowest annual premiums. In absolute terms, flood risk in Austria is associated with the highest annual premium volumes, followed by Germany, Italy, the Czech Republic and Poland. The lowest premium volumes are required for Croatia, Sweden and Cyprus. Adding up the annual premium volumes of the 20 individual EU member states results in a total volume that is about 3.6 (Table 5) or 3.4 (Table 6) times larger than the premium volume required for the aggregated flood risk.

Table 5: Building values, moments of fitted distributions and annual EVP premiums (with θ=1.15) together with the associated loading factors α (SDP) and the associated risk indices ρ (RAP)

Country	Building Value	Moments of fitted distributions [% of BV]		EVP Premiums (Θ=1.15)[1]		Equivalent to (Θ=1.15)[2]	
	[MEUR]	E	Var	[% of BV]	[MEUR]	α (SDP)	ρ (RAP)
Austria	914,593	0.208	0.344	0.447	4,092	0.408	1.423
Belgium	792,452	0.008	0.000	0.017	132	0.543	1.570
Bulgaria	141,053	0.148	0.148	0.319	450	0.444	1.457
Croatia	197,198	0.011	0.241	0.024	48	0.026	1.149
Cyprus	40,062	0.009	0.000	0.020	8	0.579	1.612
Czech Republic	323,412	0.410	0.478	0.882	2,853	0.683	1.753
France	6,001,039	0.014	0.000	0.030	1,829	0.890	1.727
Germany	8,704,763	0.019	0.002	0.041	3,593	0.466	1.480
Greece	511,834	0.009	0.001	0.018	94	0.318	1.339
Hungary	-	-	-	-	-	-	-
Ireland	286,464	0.047	0.007	0.101	289	0.655	1.555
Italy	3,366,374	0.042	0.011	0.090	3,031	0.458	1.475
Netherlands	-	-	-	-	-	-	-
Poland	1,065,883	0.106	0.099	0.228	2,426	0.386	1.402
Portugal	513,923	0.084	0.143	0.180	924	0.254	1.287
Romania	266,283	0.144	0.049	0.310	824	0.751	1.873
Slovakia	175,723	0.046	0.008	0.098	173	0.590	1.527
Spain	2,161,979	0.022	0.003	0.048	1,041	0.453	1.469
Sweden	1,175,719	0.001	0.000	0.002	23	0.587	1.628
United Kingdom	4,583,064	0.016	0.001	0.035	1,600	0.486	1.503
Sum					**23,429**		
Europe	**31,221,818**	**0.018**	**0.001**		**6,437**	**0.105**	**1.145**

1- Expected value principles for relative safety loading of 15%

2- α is the loading factor for standard deviation principle (SDP), ρ the risk index for risk-adjusted principle (RAP) with premiums equal to those of EVP with θ=1.15

Table 6: Building values, moments of fitted distributions and annual EVP premiums (with θ=1.3) together with the associated loading factors α (SDP) and the associated risk indices ρ (RAP)

Country	Building Value	Moments of fitted distributions [% of BV]		EVP Premiums (Θ=1.3)[1]		Equivalent to (Θ=1.3)[2]	
	[MEUR]	E	Var	[% of BV]	[MEUR]	α (SDP)	ρ (RAP)
Austria	914,593	0.208	0.344	0.479	4,377	0.461	1.471
Belgium	792,452	0.008	0.000	0.018	141	0.614	1.647
Bulgaria	141,053	0.148	0.148	0.341	481	0.502	1.514
Croatia	197,198	0.011	0.241	0.026	51	0.030	1.162
Cyprus	40,062	0.009	0.000	0.022	9	0.655	1.696
Czech Republic	323,412	0.410	0.478	0.944	3,052	0.772	1.857
France	6,001,039	0.014	0.000	0.033	1,956	1.006	1.800
Germany	8,704,763	0.019	0.002	0.044	3,844	0.527	1.542
Greece	511,834	0.009	0.001	0.020	100	0.359	1.378
Hungary	-	-	-	-	-	-	-
Ireland	286,464	0.047	0.007	0.108	310	0.740	1.609
Italy	3,366,374	0.042	0.011	0.096	3,243	0.518	1.536
Netherlands	-	-	-	-	-	-	-
Poland	1,065,883	0.106	0.099	0.243	2,595	0.436	1.451
Portugal	513,923	0.084	0.143	0.192	988	0.287	1.319
Romania	266,283	0.144	0.049	0.331	882	0.849	2.008
Slovakia	175,723	0.046	0.008	0.105	185	0.667	1.585
Spain	2,161,979	0.022	0.003	0.052	1,114	0.512	1.529
Sweden	1,175,719	0.001	0.000	0.002	24	0.664	1.715
United Kingdom	4,583,064	0.016	0.001	0.037	1,711	0.549	1.568
Sum					**25,064**		
Europe	**31,221,818**	**0.018**	**0.001**		**7,276**	**0.209**	**1.256**

1- Expected value principles for relative safety loading of 30%

2- α is the loading factor for standard deviation principle (SDP), ρ the risk index for risk-adjusted principle (RAP) with premiums equal to those of EVP with θ=1.3

4.2 "Optimal" grouping of EU member states

As illustrated in Table 4 to Table 6, pooling the flood risk across the 20 considered EU member states may lead to considerable benefits. But what if pooling across all EU countries is not possible for some reason? Which voluntary "Joint Risk Pooling Initiatives" (JRPIs) between various EU member states would be particularly beneficial? Or in other words: which clusters of EU countries would be optimal in terms of risk reduction?

Due to very limited and coarse loss data for many countries in this study, and due to significant differences in terms of the magnitude of losses, we divide the 20 EU member states into two groups. The first group has a more satisfactory data base available and constitutes the countries with bigger losses. This group includes the seven countries Austria, France, Germany, Italy, Portugal, Spain and United Kingdom. The second group consists of the remaining 13 countries. This division is useful, also by mere numbers: The seven countries of the first group collect 78 % of the total building value of all countries, and in terms of the magnitude of losses, Table 7 shows the largest three losses of the available data history, which makes clear that these seven countries seem to account for the majority of flood losses.

Table 7: The three largest annual losses (in MEUR) for the aggregate of the seven countries of group 1 and for the aggregate of all 20 countries

	Largest annual loss (MEUR)	**2nd largest annual loss (MEUR)**	**3rd largest annual loss (MEUR)**
7 Countries	25,721	14,193	10,128
20 Countries	29,842	14,766	10,931

4.2.1 Pooling of countries of Group 1

As the countries of Group 1 have more data points, one can formulate more reliable models and in fact the quality of goodness-of-fit of the used parametric distribution is quite satisfactory (and considerably better than for Group 2). We hence also use the value at risk at safety level of 99.5% obtained by the distributional fit for the further clustering of these countries.

If $X_1, X_2, \ldots, X_7$ denotes the random losses of these seven countries (of for instance next year), then the goal of the present clustering is to find the number of clusters G (and the number N_g of member countries in cluster g) to minimize the sum of values at risk of the G clusters:

$$min \sum_{i=1}^{G} VaR\left(\sum_{j \in N_g} X_j\right)$$

For each cluster, we aggregate the loss data of the N_g countries, fit a truncated Pareto distribution to these and compute the respective VaR. The optimal number of clusters turns out to be 3 and Table 8 shows the countries and VaR figures of each cluster.

Table 8: Countries and VaR figures per cluster resulting from the pooling of countries of Group 1

Clusters	**Countries**	**Individual VaR (MEUR)**	**Cluster VaR (MEUR)**
1	Austria	23,139	7,966
	UK	9,395	
2	Portugal	10,710	6,607
	Spain	6,798	
3	France	3,078	27,827
	Germany	22,632	
	Italy	19,188	
Sum		**94,940**	**42,400**

4.2.2 Pooling of countries of Group 2

Group 2 includes the remaining 13 countries (Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Greece, Hungary, Ireland, Netherlands, Poland, Romania, Slovakia and Sweden). As mentioned, for these countries there are less data points available, which makes the approach as applied to Group 1 less feasible. We decided to use instead a hierarchical clustering algorithm (see e.g. Kaufman and Rousseeuw 2009). In general, in such an algorithm clustering is based on a certain measure of distance between the clustering objects, with the goal to minimize the distance within and maximize the distance between clusters. In the present context, this distance is the correlation, so that each cluster consists of the countries which the least correlated with each other, in view of diversification benefits. To determine the correlation between losses of the countries, one can use various correlation concepts. Among the most prominent ones are the Pearson and the Spearman correlation coefficient defined as follows:

Classical Pearson's correlation coefficient

$$r_{X,Y} = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2}\ \sqrt{\sum(y_i - \bar{y})^2}}$$

Pairwise Spearman Rank Correlation

$$r_S = \frac{\sum(rg(x_i) - \overline{rg}_x)\left(rg(y_i) - \overline{rg}_y\right)}{\sqrt{\sum(rg(x_i) - \overline{rg}_x)^2}\ \sqrt{\sum\left(rg(y_i) - \overline{rg}_y\right)^2}}$$

The Spearman rank correlation is in fact the Pearson correlation coefficient of the grades of the distribution, and in that way measures for monotonic relationships between two random variables, whereas the Pearson correlation coefficient itself measures linear relation only. Linear correlation is a very natural concept in the world of normal distributions, but in our present context our marginal random variables are strongly skewed and heavy-tailed so that the Spearman correlation is a more natural choice (see e.g. Embrechts et al. 2002), and we use it here (in the Appendix we depict both the Pearson and the Spearman correlation on the relative losses that we estimated from our data; we use the subset of countries of Group 2 of Table A.3 for the clustering). As we pooled Group 1 in three clusters, we choose three clusters for the second group as well. The result of the hierarchical clustering algorithm is shown in Figure 1.

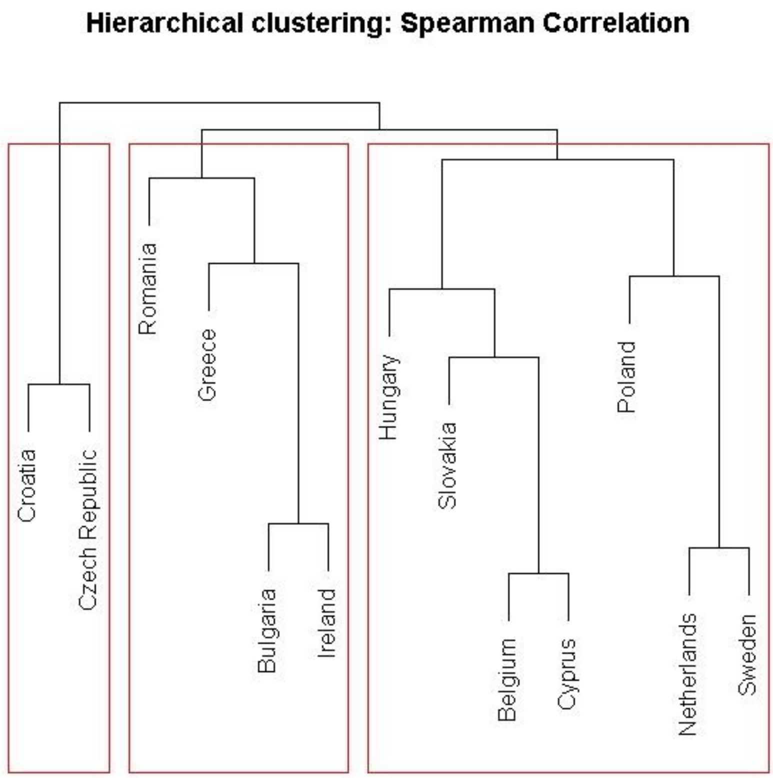

Figure 1: Result of the hierarchical clustering of Group 2 countries based on Spearman correlations

Although it would now be natural to just calculate the respective VaR-numbers for the resulting clusters, there are some practical difficulties due to the scarce data situation of these countries: whereas for the estimation of the bivariate correlations one can take all available years for which data are given for both countries, if we then aggregate more countries into a cluster, we have to restrict to the least common number of years for which data exist for each country. Unfortunately this reduces the number of available summed claim sizes too much to work out meaningful fits for these (and then estimate a 95% VaR). We hence refrain from this step in the present study and point out the fact that the methodological framework has been created to actually work out concrete diversification benefits of such Risk Pooling Initiatives once the involved countries are willing to provide detailed data.

5 Discussions with Stakeholders & Conclusions

On invitation by the FP7 project ENHANCE, we presented “Principles for Public-Private Partnerships” at a very high profile workshop meeting with participants of the insurance and re-insurance industry in Munich, on December 12, 2013. Given the strong occupation of work package 9 with modelling building data and using damage data, the discussion focused more on the issue of public-private cooperation in data provision and data pooling as well as the shortcomings that Europe has in this respect. However, some interim results of our thought experiment of reforming national risk transfer mechanisms by establishing Joint Risk Pooling Initiatives as described in section 4 of this deliverable were presented at the European Climate Change Adaptation Conference (ECCA 2015) in Copenhagen in May 2015. Attending stakeholders and scientists followed the thought experiment with great interest and contributed valuable ideas for further research, including the following recommendations and/or concerns:

1) Conducting the cluster analysis on a regional instead of a national basis, since flood risk may vary considerably between different regions of one and the same country as well as between countries.

2) Thinking about high flexibility dynamic components in the composition of the JRPs, since climate change may alter the flood damage correlations between single countries

Summarizing, our reform suggestion is to exploit Europe's magnitude and diversity related to flood risk by jointly buying reinsurance or forming a risk pool. In the present study we have not only created the methodological framework to actually work out concrete diversification benefits of such Joint Risk Pooling Initiatives, but also have done some explicit calculations where feasible by the data.

6 References

Botzen, W.J.W. (2013). Managing Extreme Climate Change Risks through Insurance. New York: Cambridge University Press.

Browne, M.J., Hoyt, R.E. (2000). The Demand for Flood Insurance: Empirical Evidence. Journal of risk and uncertainty, 20(3), 291–306.

CEA (2011). Position Paper Insurance of Natural Catastrophes in Europe [online]. Available at http://www.insuranceeurope.eu/uploads/Modules/Publications/climate-change-2011-web.pdf [accessed January 2014].

Embrechts, P., McNeil, A., Straumann, D. (2002). Correlation and dependence in risk management: properties and pitfalls. In: Risk Management: Value at Risk and Beyond, ed. M.A.H. Dempster, Cambridge University Press, Cambridge, pp. 176-223.

Freeman, P.K., Pflug, G.C. (2003). Infrastructure in Developing and Transition Countries: Risk and Protection. Risk Analysis, 23 (3), 601-609.

Gollier, C. (2005). Some Aspects of the Economics of Catastrophe Risk Insurance. CESifo Working Paper No. 1409, Category 3: Social Protection. Available at http://www.cesifo-group.de/portal/page/portal/DocBase_Content/WP/WP-CESifo_Working_Papers/wp-cesifo-2005/wp-cesifo-2005-02/cesifo1_wp1409.pdf [accessed March 2015].

Guha-Sapir, D., Below, R., Hoyois, Ph. (2015). EM-DAT: The CRED/OFDA International Disaster Database. Université Catholique de Louvain. Brussels, Belgium. Available at www.emdat.be [accessed July 2015].

IBC (2015). The financial management of flood risk – An international review: Lessons learned from flood management programs in G8 countries. Insurance Bureau of Canada. Available at http://assets.ibc.ca/Documents/Natural%20Disasters/The_Financial_Management_of_Flood_Risk.pdf [accessed June 2015].

IPCC (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Working Group II Contribution to the IPCC 5th Assessment Report. IPCC Working Group II: Stanford, USA.

Jongman, B., Koks, E.E., Husby, T.G., Ward, P.J. (2014). Increasing flood exposure in the Netherlands: implications for risk financing. Natural Hazards and Earth System Sciences, 14, 1245-1255.

Kaufman, L., Rousseeuw, P.J. (2009). Finding groups in data: an introduction to cluster analysis. Vol. 344. John Wiley & Sons.

Keskitalo, E.C.H., Vulturius, G., Scholten, P. (2014). Adaptation to climate change in the insurance sector: examples from the UK, Germany and the Netherlands. Natural Hazards, 71, 315-334.

Kunreuther, H., Freeman, P. (1996). The Insurability of Risks. In: Molek, V. (Ed.) Fundamentals of Risk Analysis and Risk Management. NJ: Lewis Publishers, p. 247-258.

Kunreuther, H. (2008) Insurability conditions. Encyclopedia of Quantitative Risk Analysis and Assessment. II. John Wiley & Sons, Ltd.

Lewis, T., Nickerson, D. (1989). Self-insurance against natural disasters. Journal of Environmental Economics and Management, 16, 209-223.

Maccaferri, S., Carboni, F., Campolongo, F. (2012). Natural Catastrophes: Risk relevance and Insurance Coverage in the EU. JRC Scientific and Technical Reports. European Commission Joint Research Centre.

Munich Re. NatCatSERVICES – Natural catastrophe loss database. 2014.

Paudel, Y. (2012). A Comparative Study of Public-Private Catastrophe Insurance Systems: Lessons from Current Practice. The Geneva Papers, 37, 257-285.

Prettenthaler, F., Albrecher, H. (Ed.) (2009). Hochwasser und dessen Versicherung in Österreich. Studien zum Klimawandel Band III, Vienna: Verlag der Österreichischen Akademie der Wissenschaften.

Rytkönen, A.-M., Mäkinen, K., Mäenää, M. (2014). Shifting responsibilities for flood damages in Finland [online]. Available at http://base-adaptation.eu/shifting-responsibilities-flood-damages-finland [accessed November 2014].

Schwarze, R., Schwindt, M., Wagner, G.G., Weck-Hannemann, H. (2012). Ökonomische Strategien des Naturgefahrenmanagements – Konzepte, Erfahrungen und Herausforderungen. Alpine Space – Man & Environment 14. Innsbruck: Innsbruck University Press.

Schwarze, R., Wagner, G.G. (2009). Natural Hazards Insurance in Europe – Tailored Responses to Climate Change Needed. Working Papers in Economics and Statistics. University of Innsbruck.

Seifert, I., Botzen, W.J.W., Kreibich, H., Aerts, J.C.J.H. (2013). Influence of Flood Risk Characteristics on Flood Insurance Demand: A Comparison between Germany and the Netherlands. Natural Hazards and Earth System Sciences, 13(7), 1691-1705.

Surminski, S. (2013). The Role of Insurance in Reducing Direct Risk – The Case of Flood Insurance. International Review of Environmental and Resource Economics, 7, 241-278.

Surminski, S., Crick, F. (2013). Response to European Commission's Green Paper on the Insurance of Natural and Man-made Disasters [online]. Available at http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2014/02/Response-to-European-commissions-green-paper-on-insurance.pdf [accessed September 2014].

Surminski, S., Aerst, J., Botzen, W., Hudson, P., Mysiak J., Pérez-Blanco, C.D. (2014). Reflection on the current debate on how to link flood insurance and disaster risk reduction in the European Union. Centre for Climate Change Economics and Policy Working Paper No. 184. Grantham Research Institute on Climate Change and the Environment Working Paper No. 162. Available at http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2014/08/Working-paper-162-Surminski-et-al.pdf [accessed January 2015].

Surminski, S., Eldridge, J. (2014). Flood insurance in England – an assessment of the current and newly proposed insurance scheme in the context of rising flood risk. Centre for Climate Change Economics and Policy Working Paper No. 161. Grantham Research Institute on Climate Change and the Environment Working Paper No. 144. Available at http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2014/02/WP144-Flood-insurance-in-England.pdf [accessed January 2015].

UNISDR-EC-OECD (2014). Finland Peer Review 2014 – Building resilience to disasters: Implementation of the Hyogo Framwork for Action (2005-2015). Available at http://www.unisdr.org/files/38523_20140717finlandpeerreport.pdf [accessed January 2015].

Vetters, N. (2006). Finanzieller Risikotransfer von Hochwasserrisiken. Scientific Report N. 9-2006. Wegener Center for Climate and Global Change. Available at http://wegcwww.uni-graz.at/publ/wegcreports/2006/WCV-WissBer-No09-NVetters-Jul2006.pdf [accessed January 2014].

Appendix

Table A.1: Classical Pearson Correlation Coefficient (Relative Losses)

	AT	BE	BG	HR	CY	CZ	FR	DE	GR	IE	IT	PL	PT	RO	SK	ES	SE	UK
AT	1.00	-0.13	0.06	-0.12	-0.09	0.74	0.31	0.92	-0.02	0.10	0.23	-0.08	-0.08	0.00	-0.12	-0.06	-0.08	-0.08
BE		1.00	-0.10	1.00	-0.12	-0.14	0.40	-0.06	-0.06	-0.20	-0.14	0.30	0.87	0.32	-0.06	-0.10	-0.13	-0.11
BG			1.00	-0.12	-0.11	-0.12	-0.10	-0.08	-0.07	-0.14	-0.11	-0.09	-0.06	0.86	-0.14	-0.05	-0.08	-0.09
HR				1.00	-0.15	-0.08	0.31	-0.06	0.74	-0.17	-0.14	0.93	1.00	0.40	-0.08	-0.19	-0.14	-0.11
CY					1.00	-0.13	0.46	-0.09	-0.07	-0.15	-0.10	-0.10	-0.08	-0.12	-0.16	-0.06	-0.10	-0.06
CZ						1.00	0.15	0.66	0.64	0.04	0.10	0.55	-0.07	-0.09	0.01	-0.02	-0.05	-0.10
FR							1.00	0.29	-0.14	-0.04	0.02	-0.05	0.35	-0.02	-0.01	0.26	-0.15	-0.19
DE								1.00	-0.02	0.04	0.22	-0.07	-0.01	-0.11	-0.12	-0.07	-0.08	-0.09
GR									1.00	-0.08	-0.06	0.90	-0.03	0.02	0.19	-0.08	-0.06	-0.04
IE										1.00	0.16	-0.12	-0.13	-0.22	-0.22	-0.04	0.26	0.07
IT											1.00	-0.14	-0.08	-0.14	-0.17	-0.06	0.57	0.16
PL												1.00	0.38	0.17	0.13	-0.11	-0.06	-0.09
PT													1.00	0.42	-0.08	0.17	-0.08	-0.08
RO														1.00	-0.08	-0.14	-0.04	-0.12
SK															1.00	-0.25	-0.13	-0.14
ES																1.00	-0.03	0.01
SE																	1.00	0.31
UK																		1.00

Table A.2: Classical Pearson Correlation Coefficient (Absolute Losses)

	AT	BE	BG	HR	CY	CZ	FR	DE	GR	IE	IT	PL	PT	RO	SK	ES	SE	UK
AT	1.00	-0.13	0.06	-0.13	-0.09	0.73	0.32	0.93	-0.02	0.07	0.23	-0.08	-0.07	0.01	-0.12	-0.06	-0.08	-0.08
BE		1.00	-0.10	1.00	-0.12	-0.14	0.41	-0.05	-0.05	-0.19	-0.14	0.30	0.89	0.31	-0.06	-0.10	-0.13	-0.11
BG			1.00	-0.13	-0.11	-0.12	-0.10	-0.08	-0.07	-0.14	-0.11	-0.09	-0.06	0.87	-0.14	-0.05	-0.08	-0.09
HR				1.00	-0.15	-0.08	0.33	-0.06	0.74	-0.17	-0.14	0.93	1.00	0.38	-0.08	-0.19	-0.14	-0.11
CY					1.00	-0.13	0.47	-0.08	-0.07	-0.14	-0.10	-0.10	-0.08	-0.12	-0.16	-0.07	-0.10	-0.06
CZ						1.00	0.15	0.67	0.64	0.02	0.10	0.55	-0.07	-0.09	0.01	-0.02	-0.05	-0.10
FR							1.00	0.30	-0.14	-0.05	0.03	-0.04	0.36	-0.02	-0.02	0.23	-0.15	-0.19
DE								1.00	-0.02	0.02	0.23	-0.07	0.00	-0.11	-0.12	-0.07	-0.08	-0.09
GR									1.00	-0.09	-0.06	0.90	-0.02	0.03	0.19	-0.09	-0.06	-0.04
IE										1.00	0.12	-0.12	-0.13	-0.21	-0.22	-0.03	0.21	0.05
IT											1.00	-0.14	-0.08	-0.14	-0.17	-0.06	0.57	0.16
PL												1.00	0.38	0.17	0.13	-0.11	-0.06	-0.09
PT													1.00	0.39	-0.08	0.16	-0.08	-0.08
RO														1.00	-0.07	-0.15	-0.04	-0.12
SK															1.00	-0.25	-0.13	-0.14
ES																1.00	-0.02	0.00
SE																	1.00	0.30
UK																		1.00

Table A.3: Pairwise Spearman Rank Correlation (Relative Losses)

	AT	BE	BG	HR	CY	CZ	FR	DE	GR	IE	IT	PL	PT	RO	SK	ES	SE	UK
AT	1.00	-0.50	-0.07	-0.48	-0.30	0.61	-0.19	0.36	-0.09	-0.02	-0.11	0.24	-0.35	0.30	0.06	0.07	-0.36	0.00
BE		1.00	-0.27	0.05	-0.85	-0.20	-0.01	-0.11	-0.10	-0.21	-0.28	-0.16	0.23	-0.11	-0.25	0.09	-0.63	0.04
BG			1.00	0.14	-0.43	-0.38	-0.24	-0.10	-0.19	-0.73	-0.54	0.15	-0.22	0.30	0.17	-0.15	-0.55	-0.13
HR				1.00	-0.55	-0.34	-0.34	-0.04	0.37	-0.52	-0.78	0.33	0.55	0.11	0.37	-0.07	-0.10	-0.52
CY					1.00	-0.11	-0.06	-0.05	-0.31	-0.63	0.28	-0.56	-0.46	-0.45	-0.58	0.02	-0.77	-0.30
CZ						1.00	-0.15	0.40	0.26	0.06	0.06	0.20	-0.16	0.05	-0.05	0.25	-0.18	-0.06
FR							1.00	0.30	-0.28	-0.07	0.09	-0.39	0.07	-0.15	-0.23	0.12	-0.48	-0.18
DE								1.00	0.22	0.06	0.09	0.02	0.10	0.03	0.13	-0.05	-0.27	-0.11
GR									1.00	-0.19	-0.16	0.20	-0.19	0.22	0.26	-0.14	-0.10	0.38
IE										1.00	0.26	-0.34	-0.27	-0.47	-0.68	0.20	0.15	0.44
IT											1.00	-0.65	-0.29	-0.27	-0.65	0.39	-0.09	0.12
PL												1.00	-0.18	0.49	0.60	-0.39	-0.01	-0.11
PT													1.00	-0.25	-0.36	0.15	-0.55	-0.47
RO														1.00	0.57	-0.42	0.06	0.06
SK															1.00	-0.39	-0.19	-0.33
ES																1.00	-0.04	0.01
SE																	1.00	0.29
UK																		1.00