Eur J Law Econ (2014) 38:7–28
DOI 10.1007/s10657-012-9376-6

Insurance models and European climate change policies: an assessment

Donatella Porrini · Reimund Schwarze

Published online: 23 December 2012

Abstract The paper outlines the role of insurance as an economic policy tool that can be used to address the issue of climate change. The magnitude of potential loss, the adverse social and economic consequences for millions of people and considerable fiscal strain imposed on government budgets by extreme weather events all indicate that governments can benefit significantly from the use of an insurance instrument capable not only of covering damage but also of providing an incentive for risk reduction behaviours. By examining the diverse insurance systems that exist in European countries and grouping them into five stylised models, natural hazards insurance is examined in terms of private and public involvement. The paper analyses the performance of different insurance models in relation to information imperfections (i.e. adverse selection and moral hazard) and market imperfections (i.e. charity hazard and transaction costs). In addition, the different models are examined in terms of the extent to which they incentivise mechanisms that facilitate the mitigation of greenhouse gas emissions, adaptation to the inevitable impacts of climate change and the development of climate risk finance management. Some concluding remarks are offered regarding the possible future development of a European insurance model as a means of developing an economically effective response to natural hazards caused by climate change.

Keywords Climate change · Insurance · Environmental policy choice

JEL Classification K32 · L51 · P16 · Q28

D. Porrini (✉)
Università del Salento, Lecce, Italy
e-mail: donatella.porrini@unisalento.it

R. Schwarze
UFZ, Helmholtz Center for Environmental Research, Leipzig, Germany

1 Introduction

As stated in the European Commission Green Paper on adapting to climate change (2007), Europe has an important role to play in tackling climate change and should maintain a leading role in international efforts to do so, particularly given the cross-border aspects of disasters and regional differences in risk exposure.

On 1 April 2009, the European Commission published a White Paper on adapting to climate change. This paper showed that, despite the economic crisis, climate change remains at the top of the European and international political agenda and that urgent action is needed to address the future problems predicted to arise from weather-related disasters, as outlined by case scenarios provided by the Intergovernmental Panel on Climate Change (IPCC).[1] Specifically, the White Paper (2009, p. 4) states that insurance is an instrument for income-smoothing in response to the damages that occur as a result of sudden extreme weather events. This function is of crucial importance for the economy because it allows forward planning to be undertaken with greater certainty and specific risks to be covered that might otherwise threaten business continuity. According to the White Paper (2009, p. 13), consideration should be given to "whether certain private actors/sectors need to be covered by compulsory standard weather-related insurance. In cases where insurance is not available, for example for buildings located in flood plains, publicly supported insurance schemes may be required."

As Table 1 shows, however, significant differences still exist between European countries[2] with regard to the percentage of insured losses to total losses (insurance coverage) for extreme events that have adverse economic impacts on millions of people and place considerable fiscal strain on government budgets.

We suggest that, in order to address the ever increasing impacts of natural catastrophes,[3] especially those deriving from climate change, environmental policy makers should pay more attention to insurance as an instrument of economic policy suitable to manage risk and limit economic vulnerability. This is the argument we present in this paper.

In the next section we explain the theoretical structure of the paper together with the choice to follow a law and economics approach.

We then show how different insurance systems adopted in a number of European countries (Austria, Denmark, France, Germany, Italy, the Netherlands, Poland, Spain, Switzerland and Great Britain) operate, and what their advantages and disadvantages are. In particular, we look at the range of existing natural hazards insurance systems, paying special attention to the issue of private and public involvement.

[1] The IPCC is currently starting to outline its Fifth Assessment Report (AR5) which will be finalised in 2014. The new assessment will take into account recent scientific and policy developments and will be organised around a revised set of socio-economic, climate and environmental scenarios.

[2] For a survey of events in other countries, see Höppe and Löw (2012).

[3] A "natural catastrophe" refers to a natural event that causes damages which exceed the social and economic coping capacity of a region or nation. For statistical reasons, the definition of natural disaster is often simplified. For example, Munich Re considers a natural event a "major disaster" if fatalities (deaths) exceed ten, personal injuries exceed thirty, and the economic loss caused by the event exceeds 15 million euros. For a survey of different concepts and definitions of natural catastrophe, see Mueller (2000).

Table 1 Insurance coverage for costliest weather catastrophes in Europe

Date	Event	Areas affected	Deaths	Total losses (million euros)	Losses insured (million euros)	Percentage of insured losses to total losses (%)
26.12.1999	Winter storm Lothar	Austria, Belgium, France, Germany, Switzerland	110	11,500	5,900	51.3
18–20.1.2007	Winter storm Kyrill	Austria, Belgium, Belarus, Czech Rep, Denmark, France, Germany, Netherland, Poland, Slovenia, Switzerland, UK, Ukraine	49	7,800	4,500	57.6
25–26.1.1990	Winter storm Daria	Belgium, Denmark, Finland, France, Germany, Ireland, Luxemburg. Netherland, Norway, Poland, Sweden, UK	94	5,900	4,400	74.6
12–20.8.2002	Floods, severe storm	Austria,, Czech Rep, Germany, Hungary, Italy, Moldova, Slovakia, Switzerland	39	16,800	3,500	20.8
15–16.10.1987	Winter storm 87 J	France, Norway, Spain, UK	18	3,500	2,750	78.5
27–28.12.1999	Winter storm Martin	France, Spain, Switzerland	30	4,100	2,500	61.0
3–4.12.1999	Winter storm Anatol	Denmark, Germany, Latvia, Lithuania, Poland, Russia, Sweden, UK	20	3,000	2,400	80.0
25–30.6.2007	Floods, severe storm	UK	4	3,000	2,200	73.3
7–9.1.2005	Winter storm Erwin	Denmark, Estonia, Finland, Germany, Ireland, Latvia, Lithuania, Norway, Russia, Sweden, UK	18	4,500	2,000	44.4
15–17.5.2010	Flood	Czech Rep, Hungary, Poland, Slovakia	19	2,888	216	7.5

Source: CEA (2009, p. 12), authors' calculations

The sections that follow outline different insurance models and analyse their performance in relation to information imperfections, i.e. adverse selection and moral hazard, and market imperfections, i.e. charity hazard and transaction costs.

Finally, the last section looks at the way the different models address climate change seeking mechanism to facilitate the mitigation of greenhouse gas emissions,

the adaptation to the inevitable impacts of climate change, and the development of climate risk financial management.

In conclusion, the possible future development of a European insurance model is considered as a means of developing an economically effective response to natural hazards caused by climate change.

2 The insurance models from a law and economics point of view

According to Abraham (1995), insurance serves three economic functions. The first is risk transfer: risk is transferred from a risk-averse individual to the risk-neutral insurer. The second function is risk pooling: by insuring numerous policy holders, the individual's insured "uncertainty" is converted by the insurer's "certainty" that such a risk will occur into a premium paid by the latter's customers. The third function is risk allocation: the price or premium paid by each insured party should reflect the risk to which it is exposed.

Given the three economic functions just mentioned, it seems clear that insurance contracts enhance social welfare while at the same time inducing their holders to take reasonable (i.e. cost-effective) precautions, namely, by internalising the expected damage or risk. This is particularly relevant in the case of extreme events related to climate change. Furthermore, insurance encourages the risk-averse insured party to make investments because the pricing of risks generates a clear economic benefit from precautionary spending.[4] In fact, risk transfer, risk pooling and precautionary risk mitigation constitute the optimal portfolio of economic risk management.

From a macroeconomic perspective insurance can be seen as a means to even out the flow of income, that is, a way of buffering the insured party from economic shocks resulting from disasters by providing businesses and households with the resources they need to recover and rebuild after a disaster strikes. Insurance is one of several ways—along with post-disaster assistance and tax deductions for disaster losses—for residents in a high risk area to shift a portion of the costs of a disaster to their fellow citizens.

With regard to handling the impacts of climate change, an insurance system plays a direct role by providing coverage for climate-related extreme events. It also plays an indirect role by predicting changes in the intensity and distribution of such events insofar as these entail additional risks relevant to life and non-life insurance, the latter related mainly to property and business interruption claims.[5]

Insurance companies are well placed to calculate actuarial risks and to set adequate premiums and contractual conditions, such as cover and deductibles. Insurance companies are also inclined to gear their calculations towards a long time horizon, which enables valuation of and planning for low probability-high loss events.[6]

[4] Shavell (1982, 2000).

[5] Agrawala and Fankhauser (2008).

[6] Charpentier (2008).

Bearing in mind these multiple benefits deriving from the implementation of an insurance system, many different models currently characterise the insurance landscape in Europe, and this paper addresses the question of which might perform better as an economic policy tool in the face of climate change.

For the comparison of different insurance models, in this paper we follow a law and economics approach: we consider ex ante and ex post effects deriving from the use of insurance as an economic policy tool, considering the problems connected with imperfections in information and in market functioning.

Thus in contrast to the existing literature, which is devoted mainly to analysing the role of insurance in ex post action (that is, the provision of financial support after events as a means of mitigating its economic impacts), in this paper we also consider ex ante action, specifically risk management, mitigation and adaptation to climate change.

We also suggest that the insurance market is not a perfect market in which risk-based insurance products send the correct signals to the market and to households and enterprises regarding the actual economic cost of managing risks. In reality, insurance markets are rather imperfect. Applying a law and economics approach, we evaluate the relative efficiency of the different insurance models that exist in Europe, looking at information imperfections, i.e. adverse selection and moral hazard, and market imperfection, i.e. charity hazard and transaction costs.

3 The state-of-the-art of insurance in Europe and the varied roles played by the public sector

In this section we highlight a number of different insurance systems used in selected European countries (Austria, Denmark, France, Germany, Italy, the Netherlands, Poland, Spain, Switzerland and Great Britain), looking in particular at the diversity of existing natural hazards insurance systems in terms of private and public involvement.

In fact, one key issue in the case of climate change impacts is the assignment of roles to the private and public sector respectively as regards providing compensation, setting incentives for reducing the risk of catastrophic losses, and organising the financial management of risks of large scale disasters.[7]

This point is essential given that, in cases where the government has no policy instruments available to prevent the impacts from events or to compensate the victims, the costs incurred through natural catastrophes fall on the individuals affected.[8] In many cases, these costs may constitute a substantial portion of an individual's wealth, leading to devastating personal and business liabilities.

Alternatively, the government can bear the risk directly, as an "insurer of last resort". In this case, the costs of weather events are borne by taxpayers, who contribute according to the tax regime of the country concerned. In addition, the private sector can (at least partially) cover weather risks, with the costs of climate

[7] Grossi and Kunreuther (2005).

[8] Kaplow (1991).

change being shared among certain sections of society. With risk-based pricing, those at greatest risk pay most for this risk sharing, while those who avoid or minimise risk pay least. This latter "private" solution can be achieved through the involvement of the insurance industry.

The involvement of the insurance industry is based on the implementation of insurance systems that are financed from premiums paid before the event. Such systems may additionally be supported by the government, for instance through state-guaranteed reinsurance. So the government could have a considerable role.

Our analysis of the insurance landscape in Europe reveals that there are differences in national insurance systems, depending on the role of the insurance industry and the state respectively.

For example, in the Netherlands and Denmark insurers play a minimal, optional role in the provision of cover for natural hazards. The state provides cover funded either from its annual budget or through a tax levied on fire damage policies which are managed by a specific fund.

In Switzerland the state does not intervene in the provision of insurance but instead makes the insurance of certain risks compulsory, largely through fire contracts. Specifically, there is a dual system of private and public insurance that is monopolistic in character. In all cantons, fire insurance and insurance against damage caused by climatic conditions is mandatory for all buildings and household contents (at replacement value) with an excess of 10 % per incident of damage or at least 200 CHF up to a maximum of 1,000 CHF (680 euros). Reinsurance is provided via two pools of direct insurers with compulsory membership. The pool system for cantonal property insurance offers unlimited cover, whereas the private insurance pool for climate-related damage provides coverage for up to only 25 billion CHF (17 billion euros). The private and the public insurers link the transfer of risk with the maintenance of the emergency services (fire service) and have the right to participate in Federal State Planning and Land Use Planning.

In France there is a mix of compulsory insurance and state intervention. Every insurance contract contains mandatory cover for all 'uninsurable' natural hazards (not including storm, frost, hail and snow load) in the form of a unitary surcharge of 12 % on the insurance premium along with a low excess (e.g. 380 euros per incident of damage to buildings and cars). Reinsurance is offered at a fixed price through the state Caisse Centrale de Réassurance (CCR) with an unlimited state guarantee. The rate of insurance penetration in France is high, close to 100 %.

In most of these countries, natural catastrophe cover has to be included in certain insurance policies (e.g. home insurance), but purchase of these policies is voluntary. A similar approach is currently being considered in Italy where, up till now, insurance against natural disasters occurs through fully private contracts that are not subject to government regulation; state relief payments are allocated after certain events. Over the years, the state authorities have developed various schemes for covering natural risks (most notably providing the inclusion in a fire coverage for buildings).

In Spain, there is a legal obligation to insure property against damages caused by natural hazards and other 'unusual events' (terrorist attack, political unrest). Premiums are collected by private insurers as an add-on premium in building,

contents, accident, life and occupational incapacity insurance and are passed on to the so-called Consorcio de Compensación de Seguros (Consorcio), which is a state monopoly insurer. The Consorcio is subsidised by an unlimited government guarantee. The penetration rate for coverage is high, reaching as much as 80 % depending on the density in the individual sectors. Insurers' excess is usually around 10 %.

Where there are state insurance schemes, these differ from country to country depending on the degree of freedom given to insurers in their pricing strategies. For example, insurance pricing is not regulated in Great Britain. Germany has a system of exclusively private insurance, with tailored premiums calculated in the case of flood damage only (ZÜRS). Insurance against storm and hail is prevalent (95 %). However, insurance density for other natural hazards is less than 10 %. German banks regularly require fire insurance cover for mortgages but no insurance against natural hazards. If an extreme, one-off event occurs, compensation is often provided for emergency relief and reconstruction efforts. Victims of damage do not have a legal right to this government relief, however, and it is subsidiary to the provisions of private insurance.

Poland, rather like Germany, has an exclusively private insurance market. An obligation to insure against disaster risks exists only for the agriculture sector. Insurance density against storm and flood damage is generally higher than in Germany; in the case of flood risks it is estimated to be between 25 and 50 %. This means that there are still a considerable number of uninsured victims of such damage, for whom public ad-hoc relief must be provided. Generally speaking, current risk management in Poland is characterised by a high degree of uncertainty. Victims can neither rely on government relief nor can they expect to receive sufficient compensation to repair their damaged properties.

In Austria, insurance against storm, hail and snow load damage is fully privatised in contracts. Additional coverage against other natural hazards (flooding, avalanche, landslides, etc.) is available on the insurance market but is rarely utilised. Since 1986 Austria has had a government-administered disaster fund financed by taxpayers. Victims of damage do not have a legal right to access this fund. It covers approximately 50 % of damages (on average) if the claimant is not privately insured.

Another significant aspect of divergences between insurance systems is risk exposure and thus the availability of specific types of coverage.

Europe's diverse climatic conditions make it vulnerable to a wide range of weather-related risks: some areas of western, central and eastern Europe with large rivers are vulnerable to flooding; southern Europe is susceptible to drought and forest fires, western Europe to storms, and mountainous areas such as the Alps and the Pyrenees to landslides and avalanches.

Consequently, while almost all European countries are affected by the adverse consequences of climate change, they are not necessarily exposed to the same types of risk. Some northern and most southern and eastern European countries are also exposed to catastrophes of geophysical origin (such as earthquakes, tsunamis and volcanic eruptions). In these countries, most insurers combine coverage for these events with coverage for extreme weather catastrophes and extend the insurance

coverage for property to both weather-related and geophysical hazards, as we shown in Table 2.

To some extent the differences in coverage may reflect the differences in risk exposure and the difficulty in meeting the conditions for obtaining insurance. However, given the widely differing penetration rates of insurance cover, there must be other reasons, such as underestimation or lack of awareness of the magnitude of risk exposure, or the anticipated receipt of compensation from public authorities.

It is also worth taking note of empirical studies which have demonstrated that, in countries where state relief payments are implemented after disasters, the penetration of natural hazards insurance is very low (such as in Germany and in Italy), whereas in countries like Great Britain where there is no governmental disaster relief the penetration is high.[9] This is an example of the way "charity hazard" works: individuals choose not to buy insurance because they believe that they will receive government support if they suffer damage.[10] This will be examined in more detail in Sect. 5 below.

The diversity of insurance systems in European countries makes it very difficult to compare and evaluate their relative performance. A first step in doing so is presented in the next section, namely, the definition of five stylised models.

4 A description of different insurance models

To overcome the complexity of the range of insurance systems operating in different European countries, we propose five stylised models, based on work by Schwarze and Wagner (2009, p. 4). The models are based on insurance structure and on the extent to which a system implies the involvement of private companies and/or the government.

These models enable us to divide the different national systems described above into groups and to evaluate their performance in terms of information and market efficiency (in Sect. 4) and of mitigation, adaptation and financial management (in Sect. 5).

Table 3 gives a list of the insurance models and provides a brief description of each one's characteristics.

In *Model 1*, public monopoly insurance regulates the mandatory legal affiliation of individuals and legal entities to a specific public insurance provider, a so-called monopoly insurer. In most cases, these are regional monopolies. The monopoly insurer is guided by statutory provisions and public consultation processes in the way it draws up its contracts, but in practice it frequently also has rights of participation in public proceedings governed by public law, such as disaster mitigation planning, land-use planning and building regulations.

As a result of the Third EU Directive on Non- Life Insurance, such regional or national monopoly insurers are no longer permitted under European law.[11] On

[9] Faure (2006).

[10] Browne and Hoyt (2000).

[11] Directive 92/49/EEC of 18 June 1992 on the coordination of laws, regulations and administrative provisions relating to direct insurance other than life insurance.

Table 2 Natural catastrophe insurance coverage across Europe

	Austria	Denmark	France	Germany	Italy	Netherlands	Poland	Spain	Switzerland	UK
Storm	Opt (high)	Opt (high)	Comp (high)	Opt (high)	None	Opt (high)	Opt (high)	Pool (medium)	Comp (high)	Opt (high)
Cyclone hurricane	Opt (high)	Opt (high)	Comp (high)	Opt (high)	None	Opt (high)	None	Pool (medium)	Comp (high)	Opt (high)
Floods	Opt (low)	None	Comp (high)	Not taken (low)	Opt (low)	None	Opt (medium)	Pool (medium)	Comp (high)	Opt (high)
Hail	Opt (high)	Opt (high)	Opt (high)	Opt (high)	Opt (low)	Opt (high)	Opt (high)	Opt (medium)	Comp (high)	Opt (high)
Landslides	Opt (medium)	Opt (high)	Comp (high)	Not taken (low)	Opt (low)	Not taken (very low)	Opt (medium)	Not taken (very low)	Comp (high)	Opt (high)
Snow	Opt (medium)	Opt (high)	Opt (high)	Not taken (low)	Opt (low)	Opt (medium)	Opt (low)	Opt (medium)	Comp (high)	Opt (high)
Frost	Opt (high)	Opt (high)	Opt (high)	Opt (medium)	Opt (medium)	Opt (high)	Opt (medium)	Opt (medium)	Opt (low)	Opt (high)
Avalanche	Opt (medium)	None	Comp (high)	Not taken (low)	Opt (low)	None	Opt (high)	Opt (medium)	Comp (high)	None
Drought	Opt (low)	None	Comp (high)	None	None	None	None	Not taken (very low)	None	None
Subsidence	Opt (low)	None	Comp (high)	Not taken (low)	None	None	Opt (medium)	Not taken (very low)	None	Opt (high)
Earthquakes	None		Comp (very low)	Opt	None	None	Opt	Pool (high)	Opt	Opt
Forest fires	Not taken (very low)	Opt (high)	Not taken (very low)	Opt (high)	None	Opt (high)	Opt (high)	Not taken (very low)	None	None

Table 2 continued

	Austria	Denmark	France	Germany	Italy	Netherlands	Poland	Spain	Switzerland	UK
Volcanic eruption	None		Comp (high)	Opt	None	None	Opt	Pool (high)		None
Lightning	Opt		Opt (high)	Opt	Opt	Opt (high)		Opt		Opt

Type of insurance cover:

Comp = Compulsory cover by law; Pool = Obligatory pool; Opt = Optional cover; Not taken = Cover offered but not widely taken up; None = Non-existent. Penetration rate: high $\leq$75 %; medium = 25–75 %; low = 10–25 %; very low $\geq$10 %

Source: CEA (2009, p. 18), authors' calculations

Table 3 Five stylised models

Model	Description
M1	(Regional) public monopoly insurer of natural hazards
M2	Compulsory insurance for all natural hazards
M3	Compulsory inclusion of (all) natural hazards into general house ownership insurance (coupling of contracts)
M4	Free market natural hazard insurance with ad-hoc governmental relief programmes
M5	Taxpayer financed governmental relief funds

account of their special status as institutions of public service provision and the fact that these companies also fulfil the integrated task of damage prevention and mitigation, however, they may be permissible under European law by virtue of the special status of "*service publique*", despite the prohibition on monopolies mentioned above.

Model 2 is a form of compulsory insurance for all natural hazards, a mandatory insurance regulated by law. Mandatory insurance by its very nature constitutes a compulsory obligation for all those potentially affected by natural hazards to purchase a policy covering the related risks. It is almost always combined with an obligation to contract on the part of insurance providers, that is, the insurers are obliged to offer interested buyers the legally defined level of insurance at predetermined conditions. Within this regulatory framework different types of insurance can be offered by a large number of companies, i.e. supplier competition is possible in the context of mandatory insurance.

Model 3 is characterised by the bundling of insurance coverage and involves the obligatory inclusion of natural hazards in buildings and contents insurance contracts, e.g. fire insurance. It is ultimately also a form of mandatory insurance, in that the parties to the contract are not permitted to negotiate freely regarding the kinds of hazards that are to be insured. Consumer sovereignty is maintained, however, to the extent that the parties may decide whether an insurance contract should be concluded at all.

Model 4 provides a free market natural hazard insurance. This model is included here even if free market natural hazard insurance does not exist in practice. A detailed survey of practices in Europe[12] reveals that "free market natural hazard insurance" always co-exists with ad-hoc governmental relief programmes. The latter fill the gaps in coverage that become inevitable in a system of cream skimming and uninsurability limits operated by purely commercially oriented insurers.[13]

Model 5 consists of taxpayer financed governmental relief funds. Disaster funds are tax-based government funds used to compensate for damage caused by natural disasters up to a maximum fixed amount. Payments are made in cases where the claimant is not

[12] CEA (2005).

[13] In this regard, free market "natural hazardism", following Anderson and Leal's (2001) concept of "free market environmentalism", is a nirvana approach.

Table 4 Models adopted by European countries

Countries	Model adopted
Netherlands	M1/M2
Denmark	M1/M2
Switzerland	M1/M2
France	M2/M3
Spain	M2/M3
Great Britain	M3/M4
Germany	M4
Poland	M4/M5
Italy	M4/M5
Austria	M4/M5

privately insured. Supplementary comprehensive natural hazards coverage is possible through market-based voluntary private insurance, which in practice is usually offered as an add-on to buildings insurance. In contrast to the previous models, the disaster fund is an indirect obligation to take out insurance, enforced through the obligation to pay taxes into the fund. However, it should be noted that this "enforced solidarity"[14] in the case of damage entails no legal right to a transfer of risk. Although every taxpayer makes an obligatory payment, the payment received in the case of damage is not to be regarded as a service in return but as a relief measure provided upon "request" of the claimant. Thus it is important to distinguish clearly between an insurance payment based on a legal claim and disaster assistance applied for through a disaster fund, even if the claimant makes a prior payment in each case.

The most prominent example of Model 5 is the EU Solidarity Fund (EUSF), which was created after the floods in central Europe in summer 2002 and came into force on November 15 of that year. Member States and countries applying for EU accession can request aid in the event of a major natural or technological disaster, and the fund provides financial aid for emergency measures.

In Table 4, we divide the different European insurance systems into the five stylised models just described.

As the Table shows, the present situation in the European countries examined is that different insurance models co-exist—with the sole exception of Germany, which has a free market natural hazard insurance system with ad hoc governmental relief programmes.

5 Information and market imperfections in natural hazard insurance

The five models defined above, according to which we have grouped the different European countries' insurance systems, present advantages and disadvantages.

[14] For a detailed analysis of the concept of "solidarity" in the case of natural disaster insurance, see Van den Bergh and Faure (2006).

We turn now in particular to the presence of information imperfections in the insurance market, looking at the models' performance in relation to adverse selection, moral hazard, charity hazard and transaction costs.

Generally speaking, the insurance market is characterised by a situation of asymmetric information: insurance companies face the difficulty of collecting information about environmental risks while at the same time lacking important information regarding the level of risk attached to the insured parties. This latter aspect leads to two phenomena: adverse selection and moral hazard.[15]

Adverse selection arises if an insured party knows better than the insurer that it is likely to suffer a loss; the risk is known to it but is hidden from the insurer. An insurer can respond to a known high risk by charging a higher premium; but the potential for a hidden high risk can disrupt private insurance markets. "Good quality" risks are not prepared to insure themselves at a premium oriented towards the average costs of all policy holders, while "poor quality" risks are unwilling to reveal their character to the insurer. Adverse selection means that poor quality risks squeeze good quality risks out of the pool.[16]

Moral hazard occurs when knowledge that loss or damage will be compensated reduces the incentive for people to prevent the damage or loss.[17] Third-party payment after losses is an additional problem, as it lowers the out-of-pocket cost to the policy holder and leads to overspending (moral hazard ex post[18]), particularly if the contract cannot specify in precise terms what must be paid.

While information imperfections imply adverse selection and moral hazard, imperfections in market functioning imply charity hazard and transaction costs.

On the one hand, the so called "charity hazard" which, according to Browne and Hoyt (2000), arises out of a reduced incentive to insure oneself against disaster damage in anticipation of governmental and/or private assistance. On the other hand, the literature on insurance economics highlights problems deriving from the presence of transaction costs in insurance competition, that include both the costs of competition and the costs of settling claims.[19]

In the following we analyse how the different insurance models perform in terms of circumventing these information and market imperfections.

In *Model 1*, public monopoly insurers are one solution to the problem of adverse selection in insurance pools. Adverse selection, as we have seen above, occurs in drawing up contracts due to asymmetrical information between the insurance company and the policy holders with the consequences that poor quality risks squeeze good quality risks out of the pool. This problem does not arise in the context of monopoly insurance, because in this context all individuals and legal entities necessarily exert demand; thus "good risks" are not able to shift to self-insurance strategies and "bad risks" can be reduced to a level manageable for the

[15] Porrini (2005).

[16] Akerlof (1970); for an overview, see Milgrom and Roberts (1992).

[17] Shavell (1979).

[18] For an overview of different forms of moral hazard, see Baker (1996).

[19] Von Ungern-Sternberg (2002).

pool of those who are compulsorily insured by means of the power of disposition held by the monopoly insurer in damage prevention.

This obligation to take out insurance also makes it possible to avoid "charity hazard", which refers to the reduced incentive to insure oneself against disaster damage in anticipation of governmental and/or private assistance.

The problem of moral hazard—where there is a reduced incentive for the policy holder to take preventive action against damage on account of possessing insurance—is minimised through the regulation and observation of prevention measures. A monopoly insurer involved in governmental precautionary action on risk prevention has an existential interest in prevention measures and will monitor their enforcement in order to reduce the extent of potential damages ex ante.

With regard to the problems associated with transaction costs (including both the costs of competition and the costs of settling claims), competition costs are minimal on a monopoly market, as there is practically no need for advertising here, whereas considerable settlement costs certainly can arise in the monopoly insurance model, as demonstrated by numerous examples from social welfare insurance (most famously the explosion of costs in the health care system). However, damage management is combined systematically with precautionary action to prevent damage, as in some existing public monopolies (e.g. in Switzerland the expense associated with settling claims is correspondingly much smaller).

In *Model 2*, the mandatory insurance model, adverse selection is avoided by the "obligation to buy". A similar positive result emerges with regard to the "charity hazard" problem, in that the obligation to insure counteracts the squeezing of insurance demand through (anticipated) ex post assistance. However, the problem of moral hazard comes fully into play in the mandatory insurance model, in that the insurance companies have no right to participate in prevention planning at the individual or collective level. Transaction costs in Model 2 also exceed those in monopoly insurance, because insurance is supplied by a large number of competing companies so that, in addition to the costs of settling claims, competition costs arise, as described by Von Ungern-Sternberg (2002).

Model 3 shows that, in principle, adverse selection and the problem of charity hazard may potentially arise—or at least they cannot be ruled out entirely. In addition, the problem of moral hazard may arise, as in Model 2. With mandatory coverage, competition costs as well as claims settlement costs are also incurred.

With regard to *Model 4*, there are good reasons to believe that ad hoc relief is inferior to any systematic ex ante (M1–M3) and even to systematic ex post systems of risk transfer (M5) in terms of the objectives stated above (prevention of moral hazard, transaction costs, and so forth).

Given that taxpayers cannot avoid the payment obligation entailed by *Model 5*, the problem of adverse selection does not arise. The problem of moral hazard does arise, however, in that the incentive to obtain private preventive insurance is reduced on account of the general safety net provided by the disaster fund. What is particularly evident in this model is the problem of "charity hazard", i.e. a reduced willingness to obtain private insurance. The reason for this is, first, that government assistance is anticipated due to its institutionalisation through the disaster fund and, second, that only those claimants who have no private insurance benefit from this

Table 5 Models performance in relation to information and market imperfections

Model	Avoiding adverse selection	Avoiding moral hazard	Avoiding charity hazard	Avoiding transaction costs
M1	Yes	Yes/No	Yes	Yes/no
M2	Yes	No	Yes	No
M3	Yes/No	No	Yes/No	No
M4	No	No	Yes	No
M5	Yes	No	No	No

assistance. Both elements contribute to a situation in which this system, in principle, completely undermines the incentive to acquire insurance. In terms of transaction costs as well there are considerable differences compared with the previous models. On the one hand, no competition costs arise in a disaster fund system. On the other hand, the costs of settling claims may be much higher compared with claims processed by insurance companies. There is likely to be a longer waiting period as well as lower coverage.[20] As a result, macroeconomic disruptions are eliminated less promptly and to a lesser extent.

Table 5 summarises the performance of the different insurance models described in the previous section. The dimensions for assessment that have been selected here are the capacity to avoid adverse selection, moral and charity hazard, and transaction costs, as listed in the columns. The alternative stylised models depicted in the rows are public insurance monopoly (M1), compulsory insurance (M2), the obligatory inclusion of natural hazards insurance in other insurance contracts (M3), a free insurance market (M4), and a governmental disaster fund (M5). The cells contain either "yes" or "no" (or both) according to whether or not the model in question is capable of avoiding information or market imperfections.

The Table above summarises the results of our analysis of how each model performs in a way that facilitates comparison. It shows that there are some differences in the performance of the models.

The "Public Monopoly Insurance" model (M1) is the only one that can avoid all information and market imperfections.

The following two models (M2, M3), which encompass a compulsory insurance system, perform well in terms of adverse selection and charity hazard but present problems with regard to moral hazard and transaction costs. As they face the same problems, the last two models (M4, M5) do not perform very well. Specifically, the model with a governmental disaster fund (M5) enables only adverse selection to be avoided, while the "free market insurance" model (M4) avoids charity hazard only.

In the next section, a further stage of analysis will be conducted on the five insurance models, this time with reference to mitigation, adaptation and management of climate risks.

[20] Evidence of this sort is to be found in Raschky et al. (2010).

6 Mitigation, adaptation and the financial management of climate extremes

The insurance models described above will now be analysed according to their role in incentivising adaptation, mitigation, and financial risk management for climate-related risks.

The insurance industry can act to tackle the impacts of climate change by playing its part in climate change mitigation and, specifically, by promoting measures aimed at reducing greenhouse gas emissions. In addition, however, insurers are well placed to help society to adapt to the impacts of climate change by promoting an effective limitation and management of risks from extreme climate-related hazards.[21]

As we have seen above, the insurance sector can make a significant contribution to risk and loss reduction measures as a means of reducing as far as possible the social and economic impacts of natural catastrophes. Insurers have expertise in identifying and analysing risk, developing sustainable financial solutions and encouraging risk-reducing behaviour by both individuals and businesses. Such measures are of great value to private insurers because they can reduce claim costs and ensure that insurance coverage can remain sustainable.[22]

In his 2009 report entitled "From Risk to Opportunity: Insurer Responses to Climate Change", Evan Mills affirms that "[t]he climate-policy community has concluded that the only effective response to climate change requires a combination of loss prevention (adaptation) coupled with emissions reductions (mitigation). Most of the examples from the insurance sector […] pertain to the latter, but insurers have long been involved in loss prevention as well, which traditionally often takes place at the individual customer level (improved storm shutters, fire suppression, etc.). Climate change certainly calls for more of this, but also for prevention at much larger scales, especially for regional defensive infrastructure".[23]

As this suggests, prevention and mitigation measures will not only reduce direct losses when a disaster occurs but will also act to lower other risks such as health risks and business interruption risks.[24]

The challenge facing insurance as an instrument of economic policy is not only to place the burden of recovery on those who suffer losses from natural disasters but also to promote investments in cost effective loss reduction mechanisms. Insurers generally encourage safe building and manufacturing practices, as they are the ones who must pay claims when accidents occur. In practice, insurers can charge premiums which encourage policy holders to enact loss prevention measures: the latter are then likely to voluntarily adopt these measures based on the annual premium reduction.[25]

[21] Extreme weather or climate-related events (in short: "climate risks") are defined as the occurrence of a value of a weather or climate variable above (or, for example in the case of droughts, below) a threshold value near the upper (or lower) end of the range of observed values of the variable, in accordance with the IPCC SREX (forthcoming).

[22] For a critical analysis of the role of the insurance sector in addressing mitigation, see Phelan et al. (2011).

[23] Mills (2009, pp. 18–19).

[24] Aakre et al. (2010).

[25] Numerous EC documents look at the need for a consolidated EU climate adaptation strategy: European Commission Green Paper on adaptation, 2007; see also EC White Paper, 2009.

In this sense the insurance industry's role goes far beyond simply compensating climate change's victims for their losses ex post. Actions taken by insurance companies can contribute towards developing economic policy instruments within an ex ante strategy with the aim of financially managing large-scale catastrophes, as a complement to ex post instruments designed to compensate for losses.[26]

Adaptation and mitigation are closely connected to the financial management of climate change risks, which is geared towards ensuring that the necessary economic resources are available. In relation to weather risks in particular, risk management options are used to augment traditional insurance. Examples include alternative risk transfer mechanisms such as financial derivatives, options and futures to hedge against losses, and catastrophe bonds. To avoid the high transaction costs of indemnity-based insurance systems, index-based or parametric schemes make payouts contingent on a physical trigger, circumventing expensive claims settling. In the case of weather derivatives, insured parties can claim an insurance payment if the index reaches a certain measure or "trigger", regardless of actual losses.

According to the European Commission's strategy for adaptation, climate change demands "innovative solutions on the financial services and insurance markets" as well as the "further integration of these solutions into the framework of EU financial services policy" and a "review of the risk structure of existing public and private disaster funds including the EU's solidarity funds" (Commission of the European Communities, Green Paper 2007, p. 23). The reform of natural hazard insurance is, it seems, becoming a cornerstone of the EU's strategy for adapting to climate change.

The insurance industry is developing innovative ways to respond efficiently to increasing exposure to climate-related risks, and there are already new financial products on the market, such as catastrophe bonds and weather derivatives.[27]

Catastrophe (cat) bonds work by securitising some of the risk in bonds which can be sold to high-yield investors.[28] Cat bonds are able to transfer risk to investors who then receive coupons that are normally valued at a reference rate plus an appropriate risk premium. These products enable insurers to limit their risk exposure by transferring natural catastrophe risk onto the capital markets.

Weather derivatives are another kind of financial instrument used by companies to hedge against the risk of weather-related losses. Weather derivatives pay out when a specific trigger is activated, e.g. temperature over a specified period rather than proof of loss. The investor providing a weather derivative charges the buyer a premium for access to capital. If nothing happens, the investor makes a profit.[29]

In creating these kinds of financial products the insurance industry is seeking to achieve two goals. One is to generate extra capital and to spread risks beyond the insurance sector. Cat bonds in particular are used to spread insurance risk in the financial sector. The other goal is to improve the accuracy and resolution of hazard

[26] Boyer and Porrini (2002).

[27] Association of British Insurers (2005).

[28] Lewis (2007).

[29] Dischel (2002).

data regarding the likely impacts of climate change by making use of the financial market's capacity to produce forecasts.[30]

We can now consider the different insurance models described in the previous sections in relation to their capacity to develop mitigation and adaptation measures and to induce the financial management of risks.

Regarding *Model 1*, the public insurance monopoly performs well given that the measures to reduce damages related to natural catastrophes should be undertaken not only at the private level but also has as a collective effort, which requires political support from the authorities. For example, it is usually public institutions that decide on land-use planning (e.g. whether to permit or prohibit building in areas with a high risk exposure), enforce construction codes (e.g. to reduce damage caused by extreme weather) and are responsible for investing in general prevention measures. Managing financial risks depends on the financial efforts and the capacity of the public insurance company in question. Compared to the reinsurance market as a whole, this capacity is generally limited, which makes the task of financial risk management difficult.

With regard to *Model 2* we can note that, although many of the risk financing modalities are conventional, some (most notably index insurance and catastrophe bonds) are rather novel and have been made possible by new developments in modelling risks and financial transactions by private insurance companies. While conventional insurance is written against actual losses, index-based insurance is written against physical or economic triggers. Index-based insurance is against disaster events that cause loss, not against the loss itself. The fact that the insurance is compulsory makes it possible to overcome the problem that index-based insurance implies a substantial decrease in transaction costs that, particularly for developing countries, have limited the development of these kind of insurance products.

Model 3 entails the problem that weather-related disaster insurance is included in other kinds of contracts, thus making it difficult to financially manage risks using separate insurance market mechanisms. For example, actions taken to prevent climate-related crop risks will be different to those taken for the prevention of fire in agricultural businesses.

In the case of *Model 4*, characterised by a free market, it is likely that investments in adaptation and mitigation will be moderate; instead, there would probably be a diffusion of catastrophe bonds. With this instrument, disaster risks are packaged (securitised) in the financial markets: the investor receives an above-market return if a specific catastrophe does not occur within a specified period of time but sacrifices interest or part of the principal if an event does occur. Disaster risk is thus transferred to international financial markets, which have many times the capacity of the reinsurance market. Another advantage accrues to investors: by adding catastrophe risk to their investment portfolios they enhance the diversification of the latter, since natural catastrophes are not correlated with stocks or other investments tied to economic performance.

[30] For a survey of the diffusion and the characteristics of catastrophe bonds, see Carpenter (2010).

Table 6 Models performance in relation to adaptation, mitigation and financial risks management

Model	Adaptation	Mitigation	Managing financial risks
M1	Yes	Yes	Low
M2	Low	Low	Yes
M3	Low	Low	Low
M4	Very low	Very low	Yes
M5	No	No	No

Finally, the governmental disaster funds that characterise *Model 5* constitute a typical ex post mechanism that is not connected with any investment in mitigation or adaptation and not even with the development of financial management of the risks associated with climate change.

Table 6 presents an evaluation of the five models in terms of adaptation, mitigation and financial risk management.

The cells contain either "yes" or "no" according to whether or not the model performs positively. In some cases we highlight "low" or "very low" performance.

The results are similar to the ones presented in Table 5 above.

The "public monopoly insurance" model (M1) is the one that shows the best performance. In addition, there is a big difference between the first three models and the last two ones.

The first group of models (M1, M2, M3) performs positively in terms of adaptation, mitigation and financial risks management.

By contrast, the last two (M4, M5) do not perform particularly well. The "governmental disaster fund" model (M5) is shown to perform the worst.

7 Concluding remarks

In analysing the different insurance models available in natural hazard insurance, we encountered the classic tensions between private and societal responsibility for risk, that is, between free market and state intervention - just as in many other fields of economic policy. The varied insurance systems that exist in Europe are seen to be associated with differing degrees of regulatory intervention in private insurance markets. Such intervention is mainly geared towards enforcing private responsibility for risk,[31] as opposed to unregulated commercial natural hazard insurance which always comes with a degree of 'socialisation of risks', usually driven by the availability of government aid after disasters.

As the White Paper on adaptation states, "[d]ue to the cross-border effects of climate change, there may be benefits in promoting EU-wide insurance as opposed to national or regional schemes" (Commission of the European Communities 2009, p. 13).

[31] Porrini (2012).

In Sect. 3, we saw that European countries are characterised by very different natural hazard insurance systems. And in Sects. 4 and 5, the analysis of five stylised models showed that the first three models (particularly the first one) are the most efficient in terms of avoiding information and market imperfections and in implementing mitigation, adaptation and risk management strategies.

Thus the model that should be introduced at European level is one that offers robust public control (M1), a compulsory insurance system of all natural hazards (M2), and one that is possibly included in general house owner insurance (M3).

However, any such European programme for comprehensive disaster insurance to reduce losses from future disasters needs to be linked at the national level with other private–public sector initiatives. The importance of well-enforced building codes and land-use regulations to control development in hazard-prone areas is a crucial component of such a programme. If each country provides protection against catastrophic losses, it can also require that such risk reduction measures are enacted as part of a private–public partnership. Tax incentives can also be offered in order to encourage individuals to adopt mitigation measures.

Furthermore, such an insurance system could be implemented more effectively if insurance companies were able to obtain more accurate data and thus to reduce the uncertainties surrounding the risk assessment process. This could be achieved if the different interested parties (ranging from potential victims to government agencies) were to provide insurers with more reliable information regarding the risks and alternative ways of reducing them.

The implementation of a mandatory system requiring everyone to purchase coverage will give regulators fewer reasons to bow to political pressure to cross-subsidise rates from minorities, such as high-income residents with large homes in high-risk areas, who can afford this coverage. There are also distributional issues that have to be dealt with under such a system.

A public process of decision making on all these issues is also important in terms of implementation.[32] Politicians tend to discount future hazards—possibly even more so than their electorates—because they regard current economic issues as more important than long-term fundamental changes in the existing risk transfer system.

In conclusion, natural hazard insurance in each country has developed over a period of years, indeed in many cases over decades. However, it has a long and difficult path ahead of it before it can be reconstructed to adequately address the circumstances of climate change. In order to develop a common European model of insurance, the very first thing that must change is risk awareness among citizens and politicians alike. This is a protracted process which can only be sustained through credible risk studies conducted on a sound scholarly basis.

Acknowledgments We would like to thank the participants of the European Association of Law and Economics (EALE) Annual Conference, Hamburg, 22–25 September 2011 and of the 14th Joint Seminar of the European Association of Law and Economics and the Geneva Association, University of Innsbruck, 24–25 February 2011 for their useful comments.

[32] Schwarze and Wagner (2007).

References

Aakre, S., Banaszak, I., Mechler, R., Rübbelke, D., Wreford A., & Kalirai H. (2010). Financial adaptation to disaster risk in the European Union—Identifying roles of the public sector, *Mitigation Adaption Strategy Global Change*, Springer.

Abraham, K. (1995). Efficiency and fairness in insurance risk classification. *Virginia Law Review, 71*, 403–451.

Akerlof, G. A. (1970). The market for 'Lemons': Quality uncertainty and the market mechanism. *The Quarterly Journal of Economics, 84*(3), 488–500.

Anderson, T. L., & Leal, D. (2001). *Free market environmentalism*. New York: Palgrave.

Association of British Insurers. (2005). *Financial Risk of Climate Change—Summary Report*. June.

Baker, T. (1996). On the genealogy of moral hazard. *Texas Law Review, 75*(2), 237–292.

Boyer, M., & Porrini, D. (2002). The choice of instruments for environmental policy: liability or regulation? In T. Swanson & R. Zerbe (Eds.). *An introduction to the law and economics of environmental policy: Issues in institutional design*, Research in Law and Economics, Vol. 20 (pp. 247–69). Oxford: JAI-Elsevier.

Browne, M. J., & Hoyt, R. E. (2000). The demand for flood insurance: Empirical evidence. *Journal of Risk and Uncertainty, 20*(3), 291–306.

Carpenter, G. (2010). *World Catastrophe Reinsurance Market*, September.

CEA—Comitè Europèen Des Assurances. (2005). *The insurance of natural events on European markets*, AB 5050 (06/05).

Agrawala. S., & Fankhauser, S. (2008). *Economics Aspects of Adaptation to Climate Change*, OECD.

CEA—Comitè Europèen Des Assurances. (2009). *Tackling climate change—The vital contribution of insurers*.

Charpentier, A. (2008). Insurability of climate risks. *The Geneva Papers on Risk and Insurance—Issues and Practice, 33*, 91–109.

Commission of the European Communities. (2007). *Green Paper Adapting to climate change in Europe—Options for EU action*, COM (2007) 354, 29 June 2007.

Commission of the European Communities. (2009). *White Paper Adapting to climate change: Towards a European framework for action*, COM (2009)147/4, 1 April 2009.

Dischel, R. S. (2002). *Climate risk and the weather market, risk*. London: Book.

Faure, M. (2006). Comparative and policy conclusions. In M. Faure & T. Hartlief (Eds.), *Financial compensation for victims of catastrophes—A comparative legal approach* (pp. 83–93). Wein: Springer.

Grossi, P., & Kunreuther, H. (2005). *Catastrophe modeling: A new approach to managing risk*. New York: Springer.

Höppe, P., & Löw, P. (2012). Characteristics of the extreme events in 2011 and their impact on the insurance industry. In C. Coubarge & W. R. Stahel (Eds.), *The Geneva Reports, n. 5* (pp. 7–15).

Kaplow, L. (1991). Incentives and government relief for risk. *Journal of Risk and Uncertainty, 4*, 167–175.

Lewis, M. (2007, August 26). The Nature's Casino, *New York Times.*

Milgrom, P., & Roberts, J. (1992). *Economics, organization and management*. Englewood Cliffs, NJ: Prentice Hall.

Mills, E. (2009). From risk to opportunity: Insurers responses to climate change, *CERES Report*, April.

Mueller, M. (2000). *Naturkatastrophen als geophysikalische Vorgaenge, geographie heute 183/2000* (www.geomjm.de/download/naturkatastrophen.pdf).

Phelan, L., Taplin, R., Henderson-Sellers, A., & Albrecht, G. (2011). Ecological viability or liability? Insurance system responses to climate change. *Environmental Policy and Governance, 21*(2), 112–130.

Porrini, D. (2005). Environmental policies choice as an issue of informational efficiency. In Jurgen. G. Backhaus (Ed.), *The Elgar companion to law and economics* (pp. 350–363). Camberley: Edwar Elgar Publishing.

Porrini, D. (2012). Insurance regulation. In Roger. J. Van den Bergh & Alessio. M. Pacces (Eds.), *Encyclopedia of law and economics – regulation and economics* (pp. 529–557). Camberley: Edward Elgar Publishing.

Raschky, P., Schwarze, R., Schwindt, M., & Weck-Hannemann, H. (2010). *Alternative Financing and Insurance Solutions for Natural Hazards. A comparison of different risk transfer systems in three*

countries—Germany, Austria and Switzerland—affected by the August 2005 floods. Chur: PIB Prevention Foundation.

Schwarze, R., & Wagner, G. (2007). The political economy of natural disaster insurance: Lessons from the failure of a proposed compulsory insurance scheme in Germany. *European Environment, 17*(6), 403–415.

Schwarze, R., & Wagner, G. (2009). Natural hazards insurance in Europe—Tailored responses to climate change needed, *Working Papers in Economics and Statistics*, University of Innsbruck, 2009-06.

Shavell, S. (1979). On moral hazard and insurance. *Quarterly Journal of Economics, 93*(4), 541–562.

Shavell, S. (1982). On liability and insurance. *Bell Journal of Economics, 13*, 120–132.

Shavell, S. (2000). On the social function and regulation of liability insurance. *The Geneva Papers on Risk and Insurance, 25*(2), 166–179.

Van den Bergh, R., & Faure, M. (2006). Compulsory insurance of loss to property caused by natural disasters: competition or solidarity? *World Competition, 29*(1), 25–54.

Von Ungern-Sternberg, T. (2002). *Gebäudeversicherung in Europa: Die Grenzen des Wettbewerbs*. Haupt Verlag: Bern.