“The (potential) role of insurance sector in climate change economic policies”

AUTHORS	Donatella Porrini http://orcid.org/0000-0003-0305-5456 http://www.researcherid.com/rid/N-6000-2015

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Donatella Porrini (Italy)

The (potential) role of insurance sector in climate change economic policies

Abstract

In the past few years, unstable and extreme weather patterns are increasingly occurring as phenomena of climate change and the link to greenhouse gas emissions is scientifically accepted. Extreme weather patterns cause major damage on health, property and business. Thus, the question is who is going to pay. In this paper, following a law and economics approach, the problem is analysed starting from the consideration that emitters of greenhouse gases externalize the true costs of their contribution to climate change. Efforts to recover these costs, which manifest both through the costs of impacts and the costs of efforts to prevent impacts, could imply a relevant role for the insurance sector. Because the insurance sector is the world's largest industry, the response of insurers to the broader climate-change challenge will no doubt be extremely relevant to solve this internalization problem. Particularly the paper is about the role that insurance sector could play in the design of political economic solutions for climate change consequences. This role can be identified in different directions: (1) insurance coverage for claims of third-parties who allege injury or property damage; (2) insurance financial products to finance technological responses to climate change, such as mitigation and adaptation. Specifically the indirect effect of the insurers is discussed in proactively stimulating climate change prevention behavior related to their customers in the view of the choice of political economic instruments.

Key words: climate change, insurance, environmental policy choice.
JEL Classification: K32, L51, P16, Q28.

Introduction[1]

In the past few years, unstable and extreme weather patterns are increasingly occurring and the link between these climate change effects and greenhouse gas emissions is scientifically accepted[2]. Extreme weather patterns cause major damage on property and business and the question of who pays becomes a serious issue that should involve the insurance industry.

Recently climate change topic has become more relevant thanks to the new political leadership in U.S. and, despite the financial crisis, the insurance companies, together with the other financial institutions, are called for actions to reduce global warming effects.

A law and economics point of view focuses on the problem that emitters of greenhouse gases externalize the true costs of their contribution to climate change[3]. Efforts to recover these costs, which manifest both through the costs of impacts and the costs to prevent impacts, could imply a role for the insurance sector. Because the insurance sector is the world's largest industry, the response of insurers to the broader climate change challenge will no doubt be the key to, at least partially, solve this internalization problem.

Particularly, the insurance sector could play a relevant role in different directions: first of all, by supplying, as tradition, policies covering claims of third-parties who allege injury or property damage[4]. But not only this, insurance companies are in challenge to design financial products aiming to finance technological responses to climate change, such as mitigation and adaptation.

In this paper, the attention will be on the fact that insurers can induce indirect effects in proactively stimulating climate change prevention behavior related to their customers. Through their insurance products, they can play two primary roles in stimulating climate change prevention behavior. First, by supplying and pricing traditional insurance coverage for damage deriving from climate change insurers can promote actions by businesses and individuals to align policyholders with climate-positive behaviors.

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[1] The final version of this paper benefited of the comments of the participants at the 3th Joint Conference of the European Association of Law and Economics (EALE) and The Geneva Association on Law and Economics of Environmental Insurance, Università Bocconi, Milano 11/12 May 2009; XX Annual Conference of the European Association of Law and Economics, Università Luiss Guido Carli, Roma 17/19 September 2009.
I am very grateful for the comments and I am the only responsible for any mistake.

[2] "The scientific debate is over, with the Nobel-Prize-winning Intergovernmental Panel on Climate Change, representing the definitive scientific consensus, now using the considered term "unequivocal" in describing its certainty that climate change is here. The economic context has shifted as well. Reports like the UK government's "Stern Review" turn on its head the conventional wisdom that taking action on climate change will harm the economy. Companies and investors now increasingly realize that, in fact, it is the lack of action to combat climate change that is the true threat to the economy, while engaging with the problem and mounting solutions represents not only a duty to shareholders but also a boon for economic growth" (Mills, 2008, p. 132).

[3] For seminal contributions on the law and economics approach: see Calabresi (1970) and Shavell (1987).

[4] This issue is also connected with the definition of a liability system for the consequences of climate change, such as impacts of property damage from extreme weather events. The topic of liability for climate change will not be addressed in this paper (see Faure and Nollkaemper, 2007; Schwartze, 2007).

Secondly, by providing capital to new ventures and by reducing the financial risk to investors in these ventures, insurers can also facilitate the creation of new markets and services that will help to solve the climate change problem.

In all these directions, the insurance industry is dealing with management risk activities. Climate change affects insurers through the risks they accept from clients, since climate change causes increasing intensity and spreading distribution of extreme weather events, and because of the resultant risk of catastrophic property claims. So climate change will not only bring more demand for conventional risk transfer, but also will open opportunities in new areas such as emission reduction projects.

The aim of this paper is to examine the role that can be played by the insurance industry within the political economic instruments choice.

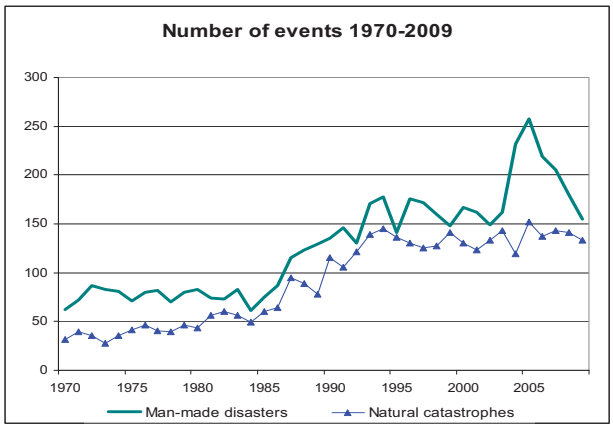
The next Section will address the issue of choosing between environmental policy instruments facing climate change consequences; so after a review of this issue in terms of defining efficient instruments, a characterization of the climate change consequences internalization problem will be discussed. Section 2 deals with the role of insurance industry in supplying different products. Finally in Section 3 this role will be analysed in connection to the issue of mitigation and adaptation. The last Section concludes the potential role of the insurance sector.

1. Facing climate change effects: choosing between environmental policy instruments

The global warming leads to increase in global mean temperatures which in turn would intensify the water cycle, reinforcing existing patterns of water scarcity and abundance and increasing the risk of droughts and floods. The changes in the distribution of heat around the world are likely to disrupt ocean and atmospheric circulations, leading to large and possibly abrupt shifts in regional weather patterns. Coastal areas are affected by sea level increase and there is a probability that some of the coastal cities may become submerged. Increase in precipitation would result in floods and flash-floods become recurrent.

"However, one should note that not only climate change is to blame, but that human actions also are partially responsible for these major natural catastrophes (e.g., flood events are not only due to rainfall but also linked to the stability of soil structures or natural slopes which can be influenced by human constructions). These two factors increase the risk simultaneously, both affecting frequency as well as loss amounts" (Charpentier, 2008, p. 94).

In the future climate change is going to originate an increasing quantity of natural disasters, together with "man-made" disasters, as we can see in Figure 1.



Source: Swiss Re (2010).

Fig. 1. Natural catastrophes and "man-made" disasters

So, in a sense, natural disasters, meaning events caused by natural forces, becomes "man-made" disasters, meaning events associated with human activities[1], given the role of greenhouse gases emitters. More precisely, we can speak of "unintended man-made" disasters originated by global warming (Posner, 2004, p. 43).

The rising costs associated with climate change effects pose serious challenges to governments to adopt efficient strategies to manage the increasing economic consequences. On a political economic point of view, governments are facing the issue to introduce policies to tackle the causes and combat all the effects of greenhouse gas emissions[2].

About the environmental policy choice, the ensuing debate has been conducted along different views: on the one hand, the choice of policy instruments to be applied is perceived as a public matter and the state, as policy designer, should select the optimal instruments and take responsibility for its imposition in the public interest; on the other, a role must be assigned to the private sector and market-based instruments must be implemented[3].

[1] For a complete definition, see Swiss Re (2007, p. 37).

[2] The choice of policy instruments is an issue already addressed by the economic literature and a large number of instruments have been considered to implement a given set of environmental policy objectives, given that the relative efficiency of these policy instruments has become an important question in environmental economics, as shown by the surveys of Cropper and Oates (1992), Segerson (1996). The need to look at political economy factors underlying the choice of instruments has gained some ground, at least since the early contribution of Buchanan and Tullock (1975). Boyer and Laffont (1996) provided some preliminary steps in developing a formal model of political economic choice of environmental instruments. They argued that economists' general preferences for sophisticated incentive regulation mechanisms must be reconsidered in a political economy approach explicitly considering the private information of economic agents.

[3] This is the issue of "judgement-proof" (see Shavell, 1986).

In the case of climate change consequences, the environmental policy choice involves the assignment of respective roles of private and public sector to provide compensation and incentives to reduce the risk of catastrophic losses and financial management of large-scale disaster risks[2].

The choice of both public and private instruments is essential given that in the case in which the government does not provide any policy instruments to prevent the events and to compensate the victims, the costs of natural catastrophes fall on the individuals. In many cases, these costs could be a substantial portion of an individual's wealth, leading to devastating personal and business liabilities[3].

Alternatively the government can carry the risk directly or as "insurer of last resort"; in this case, the costs of weather events are borne by the taxpayer, contributing according to the tax regime of the country, or private sector can, at least partially, cover weather risks and the costs of climate change is shared among a portion of society: with risk-based pricing, those at greatest risk pay most for this risk-sharing, while those who avoid risk pay less.

This last "private" solution can be achieved by the insurance industry involvement. The extent to which policy instruments choice implies the involvement of private insurance to cover property damage due to severe weather patterns can be seen in Table 1 in relation to different countries.

Table 1. Comparison of insurance coverage for storm and flood damage in major insurance markets

Country	Insurance coverage	Degree of state involvement
UK	Insurance covers all natural perils including floods, windstorms, and subsidence. Good uptake (> 90%) as required as a condition of mortgage.	None: primary insurance and reinsurance provided through private market.
France	Storm coverage included as standard. All policyholders pay premium surcharge set by the government (12% of the fire premium for most lines of business). Natural catastrophe coverage is mandatory.	Unlimited government guarantee for catastrophes provided through Caisse Centrale de Réassurance. Catastrophes Naturelles (CATNAT) is the national program which covers floods, subsidence, mud slides, earthquakes, tidal waves and avalanches.
Germany	Storm coverage included as standard. Insurance for natural catastrophe is optional and available from private insurers for an additional premium. Flood uptake is typically low (~ 5%). Natural catastrophe coverage is not mandatory.	None.
Rest of Europe	Each market has its own limitations on coverage. Extent of uptake varies by maturity of market, and degree to which cover is required by law or as a condition of other finance-providers (e.g., mortgage lenders).	State does not normally intervene in insurance provision but some countries have a pooled system through the government (e.g., Spain, Norway, Switzerland, Denmark). In the Netherlands, the government acts as insurer of last resort for flood, as the private market does not provide.
Japan	Property policies cover windstorm.	Primary insurance and reinsurance provided through private market.
Australia	Property insurance coverage is available for most perils, with subsidence generally excluded for residential policies. Scope of cover varies from company to company and can range from full (river) flood cover to local flash flood or stormwater only. Few companies offer however full cover for domestic risks.	Primary insurance and reinsurance provided through private market.
USA	Most property insurance policies cover wind damage. Flood is usually excluded.	The federal government covers flood perils. For hurricanes, insurance is provided through the private market. In Florida, primary insurers may purchase reinsurance from the Florida Hurricane Catastrophe Fund.

Source: Association of British Insurers (2005, p. 13).

In some cases, the private market covers much of the risk (e.g., UK), while in others, the government is more closely involved, either directly carrying the risk (e.g., USA for flood) or acting as "insurer of last resort" (e.g., France). The private insurance market generally covers windstorm risks, whereas flood risks are often provided through a pooled or government-backed insurance arrangement.

Public policies can support insurance sector in different ways. First of all by providing mandatory regime for insurance (e.g., mandatory catastrophe insurance coverage included in basic property insurance policies such as homeowners); then by providing State guarantee to limit private sector exposure and to reduce the cost of capital (e.g., special government disaster funds); finally by creating a regulatory framework that allows private insurance market to work properly (special fiscal treatment for disaster insurance premiums, possibility of tax-deductible reserve funds).

Moreover, insurance industry may have limited capacity, and a pooled or government-backed compensation system is the only way to deal with the substantial costs of natural catastrophes. To cover the most extreme events, insurers rely on reinsurance, either through the private market or from the state. Generally, the reinsurer assumes responsibility for covering a portion of the risk, especially for rare but extreme event losses. This enables insurers to access greater capital in a cost-effective way, and assist in managing liquidity following a large claim event. In most coun-

[1] See Lewis (1996).
[2] See Porrini (2005).

tries, regulation sets out capital requirements, ensuring solvency for all but the most unusual events.

Beyond the difference between private and public environmental policy instruments, another important distinction is between *ex ante* and *ex post* policy instruments and the identification of the role of insurance industry.

The political economy theory uses to compare two kinds of instruments, namely *ex ante* and *ex post* instruments: the first corresponds to regulatory instruments that *ex ante* fix precaution standards (i.e., command and control policies) to control environmental risks; the second corresponds to *ex post* intervention that provides compensation to victims while internalizing the social costs of harm producing activities (i.e., tort liability system)[1].

In the case of climate change consequences, the damages and the victims could receive compensation through an insurance provider. So, in this sense, insurance contributes to implement *ex post* policy instruments. But also insurance could give indirectly an incentive to take precaution with *ex ante* effects.

In fact property, casualty, health, and liability insurance for individuals and businesses all present opportunities for insurers to stimulate preventive policyholder behavior: in fact, insurance contract terms and conditions can create incentives to improve climate outcomes and the pricing structures can give financial advantages to policyholders who engage in climate-friendly behavior.

Within the debate about the political economic instruments choice, insurance can be considered as a market-based kind of instrument that contributes to reach an *ex post* compensation giving also *ex ante* incentive to preventive behaviors.

As a result of the large number of instruments that have been considered to implement environmental policy objectives, the relative efficiency of these policy instruments has become an important question in environmental economics. Looking at this problem from a law and economics perspective, the efficiency of different instruments indicates their practical, and so direct, potential to achieve concrete objectives. In particular, three objectives emerge as relevant in judging the practical efficiency of environmental policies: the first is paying accident compensation to the victims; the second is prevention, in the sense of providing incentives to improve safety standards; and the third is connected with technological change in the sense of encouraging to adopt lower-risk technologies[2].

[1] See Shavell (1984), Boyer, Porrini (2002).
[2] See Baumol, Oates (1975), Bohm, Russell (1985).

In the next Section, different insurance products will be analysed to see how they can efficiently contribute to the solution of the climate change issue.

2. The role of the insurance industry in relation to different products

2.1. Insurance in relation with climate change. Insurance is one of the main mechanisms used by individuals and business to manage the financial consequences of risk, including the threat posed by natural hazards such as windstorms and floods. Traditionally, insurance works by pooling risks across a large and diverse population. Each individual or business protects themselves against an uncertain loss by paying an annual premium towards the pool's expected losses. The insurer holds premiums in a fund that, along with investment income and supplementary capital (where necessary), compensates to those that experience losses.

So, first of all, climate change consequences are insured through the coverage of the risks that insurance industry accepts from clients, since climate experts predict changes in the intensity and distribution of extreme weather events (especially water-related and storms), and because of the resulting risk of catastrophic property claims.

In this sense insurers are influenced by climate change because weather patterns increase their clients' exposure and they are asked to adapt their risk assessment and review their underwriting (pricing, contract conditions and risk acceptance procedures) with a view to their specific risk exposure (line of business, geography, etc.).

This kind of products constitutes the core business of the insurance industry. But specifically in the case of climate change many problems arise.

First, climate change's relationship to global weather patterns increases the potential for losses so large that they threaten the solvency of insurers as more severe weather becomes more common and overall variability of conditions increases.

Second, uncertainties in assessing climate change's impacts are high, affecting property and casualty, business interruption, health, and liability insurance, among others. As a result, where a risk has significant ambiguous components, insurers are both more likely to charge a significantly higher premium and more likely to avoid insuring the risk entirely than where a risk is more well-defined.

Third, it is likely that many climate change-related risks are correlated, creating a skewed risk pool and exacerbating the risk of extremely large losses, and that some of these risks are not well-distributed across existing insureds.

Finally, as a result of insurers' uncertainty aversion and need to protect against extremely large losses from single or related events, it is not clear that insurers will be willing to insure against some climate change-related risks at a price that policyholders are willing to pay.

2.2. Insurance coverage and financial responsibility. Within the "traditional" activity of supplying coverage for the climate change consequences, other business opportunities emerge for all type of customers (private, commercial, industrial), as it is focused in Table 2.

Table 2. Important climate change-related risks and opportunities for insurers

Insurance class/ line of business	Risks (from climate impacts, policy implementation, or policy failure)	Opportunities (from proactive policy or climate impact)
Property	♦ Unprecedented accumulation of extreme events threaten solvency/liquidity. ♦ Getting cover may become harder. ♦ Lack of capital/reinsurance. ♦ Inaccurate risk pricing. ♦ Misinformed response from public sector. ♦ More costly repair work.	♦ More demand for insurance and alternative risk transfer. ♦ Risk differentials can be priced. ♦ Insurance of "Kyoto" projects. ♦ Administration of disaster recovery. ♦ Prototype equipment can be insured.
Casuality	♦ Unexpected claims for duty of care. ♦ Product failures in new conditions. ♦ Disruption to transport (extreme events).	♦ Cover for professional services to carbon markets. ♦ "Green" transport products such as low-mileage motor policies.
Life/health/savings	♦ Episodic impacts on human health. ♦ Underestimating human life expectancy due to warmer winter in northern hemisphere transfer. ♦ Reduced disposable income due to disasters.	♦ More demand for health cover savings. ♦ Growing wealth in developing markets due to technology tranfer.
Other under-writing	♦ Increased losses from business interruption, e.g. due to failure of public utilities. ♦ Disruption to leisure events. ♦ Increased losses in agrobusiness. ♦ Novel technology in energy sector.	♦ Alternative risk transfer (catastrophe bonds, etc.). ♦ R&D risks for low carbon technology. ♦ Consulting/advisory services. ♦ Insurance for emissions trading. ♦ Trade risks for technology exports. ♦ Carbon becomes an insurable asset.

Source: Allianz (2005, p. 26).

Climate change will affect, and in some cases is already affecting, most major types of insurance products. First, insurers will feel the impact of climate change on property and casualty insurance, where the insurer bears the risk of a loss suffered directly by the policyholder. These property and casualty claims include not only damage to insured property as a direct result of weather, but also claims for business interruptions and other consequences of weather-induced events. Second, health and life insurers will face increasing costs. Third, insurers will face claims based on liability insurance, where the insurer pays for legal claims brought by third parties against the policyholder.

Depending on the risk involved, all these types of insurance may be particularly affected by climate change-related losses or present unique opportunities to encourage the mitigation of such losses. And insurers will face challenges to insurability that may deeply impact the industry's ability to spread risk.

To cover the economic costs of natural disasters, in some countries not only insurance companies supply catastrophe insurance coverage, but also a system of compensation fund is established, such as a special government disaster funds within the target to promote framework of contingency measures to tackle climate change consequences[1].

Also compensation funds, together with the traditional insurance products, are internalization instruments. These funds created in connection with a regulatory system to cover environmental damage, and victim compensations, can be financed by a taxation system or by a firms' contribution system. But both products deals with the issue of emergency assistance and compensation for disaster losses on an *ex post* basis.

Other insurance products provide also *ex ante* commitment of financial resources, such as the so-called "financial responsibility" products. This term defines all the tools that require polluters to demonstrate *ex ante* sufficient financial resources to correct and compensate for environmental damage that may arise through the activities of a firm. In its common application, financial responsibility implies that the operation of hazardous plants and other business is authorized only if firms can prove that future claims will be financially covered, for example, through letters of credit and surety bonds, cash accounts and certificates of deposit, self-insurance and corporate guarantees[2].

[1] See Mills and Lecomte (2006).
[2] About financial responsibility, see Faure and Grimeaud (2003), Boyd (2001).

Generally, financial responsibility may be complementary, sometimes mandatory, to the legislation on environmental accidents. It is usually required as an integral part of some kind of *ex ante* regulation, to ensure that the damaged natural resources are made good. In its different applications, it has a common motivation: to ensure the future internalization of the costs in order to indemnify the victims and discourage different forms of environmental deterioration.

In the presence of informational issues, financial responsibility can also be seen as a solution to asymmetric information problems that can arise in the relationship between insureds and insurers[1]. First, there is an incentive for the insurance companies to check that the insureds are taking adequate preventive measures. Second, the insureds are motivated to take precautions because financial responsibility garantees that the expected costs of environmental risks appear on their balance sheet and business calculation[2].

2.3. Risk tranfer insurance products. Recently, there has been the creation of differentiated insurance products more suitable for dealing with climate change related risks. In this sense the insurance industry's role is far beyond simply compensating climate change's victims for their losses *ex post*. The activity of the insurance companies becomes relevant to develop political economic instruments within an *ex ante* strategy targeted to financially manage large-scale catastrophes, as a complement of *ex post* instruments for the compensation of disaster losses.

"Possible *ex ante* solutions include the establishment of dedicated catastrophe funds, market-based or state-sponsored disaster insurance and reinsurance programs, alternative risk transfer (ART) and alternative risk financing (ARF) tools – such as risk securitization and contingent capital arrangements – allowing broader risk spreading through capital markets. The establishment of dedicated catastrophe reserve funds, with special appropriations in the public budget or prior legislated spending authorities, requires some degree of *ex ante* financial planning and a commitment of public money to cover emergency relief costs and, sometimes, post-disaster reconstruction costs. Since rules on the use of such funds in case of a disaster are established *ex ante*, money can be disbursed promptly and a relatively consistent treatment of similar situations is ensured across time. Such rules may also limit moral hazard by limiting the scope of government compensation (e.g., strictly defining eligible damages and placing a cap on the level of public assistance)" (Monti, 2009, p. 8).

So, insurance industry is also developing alternative risk transfer products, given that conventional reinsurance arrangements may in future cover a smaller proportion of total losses and there may be insufficient capital available to insurance markets to cover these losses. Among this kind of alternative risk transfer mechanisms that help diversify the capital and involve the financial market, particularly two are described in Table 3.

Table 3. Comparison of alternative risk transfer mechanisms

	Catastrophe bonds	Weather derivatives
Description	Financial contracts which pay out on fulfilment of a trigger condition. They are usually triggered by a loss from a particular pre-defined catastrophe.	Pay out in a specific trigger but usually cover a period of time.
Seller/buyer	Sellers are mostly insurance companies. Buyers are major investors such as mutual and pension funds. The investors provide the capital in return for superior interest rates.	Sellers are usually energy companies. Buyers are pension funds, mutual funds and insurance companies.
Advantages	Simple to administer once set up. Yield is high. Risk is uncorrelated with other asset classes	Difficult to insure risks can be covered. Cedant loss history is irrelevant as payout determined by index of objective measurements. Catastrophe software modelling error eliminated.
Disadvantage	Expensive to set up as Special Purpose Vehicle is required by accessing capital. Risk of loss of return on capital.	Accurate prediction of information is required. Expensive to set up. Damage incurred may exceed the indemnity covered.
Comment	Diversify funding base for catastrophic risk by accessing capital not normally available to insurance. Help to increase capacity in the market.	Access investor capital not normally available to insurance. Used to hedge or diversify risk.

Source: Association of British Insurers (2005, p. 14).

A first kind of insurance products are catastrophe bonds, consisting in securitising some of the risk in bonds, which could be sold to high-yield investors. The so-called cat bonds are able to transfer risk to investors that receive coupons that are normally a reference rate plus an appropriate risk premium. By these products, insurers limit risk exposure transferring natural catastrophe risk into the capital markets. Due to their size, financial markets offer enormous potential for insurers to diversify risks. But transaction costs can be considerable, and the unfamiliarity of investors with insurance risks means that they currently demand a relatively large risk premium[3].

Weather derivatives are another kind of financial instrument used by companies to hedge against the risk of weather-related losses. Weather derivatives pay out on a specified trigger, e.g., temperature over

[1] See Porrini (2001).
[2] See Feess, Hege (2000).
[3] See Agrawala, Fankhauser (2008).

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, then the investor makes a profit.

With this kind of financial products the insurance industry tries to reach two goals. First of all, there is the need for extra capital and to spread risks beyond the insurance sector. Particularly cat bonds are used to spread insurance risk in the financial sector. The second goal is to improve the accuracy and the resolution of hazard data and the likely impacts on climate change with the involvement of financial market forecast ability.

These products, such as cat bonds and weather derivatives, are also connected with the need to finance mitigation and adaptation policies for climate change consequences that will be specifically addressed in the next Section.

3. Mitigation, adaptation policies and the insurance sector

The insurance industry can act to tackle the consequences of climate change by playing its part in climate change mitigation, through the promotion of ways to reduce greenhouse gas emissions. Insurers are also well placed to help society to adapt to the impacts of climate change, by promoting the effective limitation and management of risks from extreme weather-related hazards.

"The 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" (Mills, 2009, pp. 18-19).

Insurance products will likely affect incentives for individuals to address climate change seeking mechanism to facilitate mitigation of greenhouse gas emissions and adaptation to the inevitable impacts of climate change. Additionally, insurance companies are motivated to take significant actions aimed at mitigating overall societal greenhouse gas emissions and increasing adaptive capacity because these actions would reduce overall uncertainty and other barriers to insurability, by reducing insurers potential exposure to catastrophic risks in excess of their capacity as well as the potential for property and liability claims in excess of current pricing structures.

Insurance products that may help society to mitigate or adapt to climate change are different and involve many insurance lines of business, as we can see in Table 4.

Table 4. Characterization of climate change adaptation and mitigation benefits, and insurance lines of business affected

Sector/strategy	Mitigation benefit	Adaptation benefit	Types of insurance benefits
Energy sector demand side			
Energy efficiency generally	Reduced energy use	Grid reliability	Business interruption, contingent business interruption, service interruption, boiler and machinery, perisha
Natural ventilation; daylighting	Reduced energy use	Allows continued facility occupancy During power outage	Business interruption
Insulated ceilings in cold climates	Reduced heating energy	Structural integrity and extended habitability of structures during natural disaster	Property, business interruption
Concrete-polystyrene wall systems	Reduced heating and cooling energy use	Resistent to wind and water damage	Property, life/health, mold liability
Heat island mitigation, e.g., via reduced roof albedo and urban forestry	Reduced cooling energy use	Extended habitability of structures during heat waves; moderation of precipitation (urban trees) and reduced flash flooding, reduced smog formation due to lower temperatures	Health, life, relocation expenses; business interruption
Efficient grid-independent lighting	Reduced electricity use	Disaster recovery	Business interruption
Efficient windows	Reduced space-cooling energy	Improved fire-resistance and reduced vulnerability to wind-blown debris	Property
Energy sector supply side			
Renewable energy systems	Reduced energy use	Grid reliability	Business interruption, service interruption, cyber-risk insurance (data loss), worker's compensation, property loss, liability, perishable goods interruption

Table 4 (cont.). Characterization of climate change adaptation and mitigation benefits, and insurance lines of business affected

Distributed energy systems	Reduced electricity transmission losses (and thus energy use)	Grid reliability	Business interruption; more reliabie power for earlly warning systems and post-event operations
Hydroelectric systems	Reduced ghg emissions	Flood control	Property, life/health
Biomass energy plantations	Carbon sinks		
Agriculture, forestry, and land use			
Agricultural soil management	Increased soil carbon content	Enhanced drought-resistence	Crop
Land restoration and afforestation	Carbon sinks	Reduced flood/mudslide risk	Property, crop
Health (human and other systems)			
Improved forest management	Reduced wildfires (carbon emissions)	Reduced habitat for malaria vectors; flood control; reduced vulnerability to forest pests; retention of disease vectors (e.g., Bats--Nipah virus) otherwise hazardous to humans	Health, life, property
Ultraviolet water disinfection	Reduced commercial energy use; reduced deforestation associated with water boiling	Ability to respond to water quality crises following extreme weather events	Health, life

Source: Mills, Lecomte (2006 p. 38).

Broadly, the products that facilitate mitigation can be classified into three groups. First, some insurance products have the potential, either incidentally or by design, to reduce greenhouse gas emission directly. Second, some insurance products facilitate mitigation to climate change impacts by providing incentives or capital to build resilience to those impacts. And finally, other insurance products help to develop new markets for private ventures to create climate change-related solutions[1].

Insurers are also developing new products that facilitate adaptation to climate change that can be divided into two types: products that help to create the conditions for active adaptation to building physically resilient communities, and products that provide capital and liquidity to help communities to cope with losses caused by climate change catastrophes.

Insurance innovations with the most promise to build adaptive capacity might simply involve insurers pricing their policies to reflect the level of climate change-related risk assumed by the insurer. These products tend to reward behavior that reduces risk of financial losses from climate change, and thus encourage adaptive behavior. Products that incorporate these features include, for example, offering premium discounts on property insurance for climate-resilient commercial or residential buildings.

Offering differential premiums to customers depending on the customers' level of protection from loss caused by weather-related disasters would seem to be a clear opportunity for insurers to reduce their own overall and maximum possible loss exposure while promoting communities overall resilience in the face of climate change's impacts. For example, risks could potentially be reflected in discounts for businesses or homeowners that have taken specific steps to ensure that their buildings are resistant to floods, or other hazards. Insurers can also condition their policies on compliance with laws such as building codes, thus playing a role in enforcing laws that promote climate change resilience.

The second type of insurance products that facilitate adaptation provides capital to cope with catastrophes after the fact. Financial products supplied by the insurance companies are examples of this type of product. These insurance arrangements are intended to bring needed capital that will reduce the risk posed by future climate-related hazards to those who are most likely to be in peril.

These products can be defined as adaptation-oriented because they help to build the capacity of nations, communities, and businesses to cope with climate change impacts. "Insurance is adaptation; there are surprisingly large number of small to medium companies that do not have catastrophe cover, so increasing insurance penetration of these market would be an adaptive measure" (Maynard, 2008, p.140).

Generally, private contracting has increasingly been recognized as a significant and potentially effective means of influencing private actors behavior, and even as a form of environmental policy instrument. So the insurance industry, in particular, has significant potential to influence the behavior of individuals through its contracting and this implies that the

[1] Despite the opportunity and need for the insurance industry to play a leading role in society's adaptation to climate change impacts, it appears that it is receiving less attention from companies than measures to mitigate through reducing greenhouse gas emissions. Of 25 types of activity undertaken by private insurers that were identified in a recent survey (Mills and Lecomte, 2006) fewer than a quarter focused on adaptation rather than mitigation.

insurance industry has to play a role within the future mitigation and adaptation policies.

As a final remark, it should be taken into account that the involvement of the insurance sector can be limited by problems that can be framed as collective action problems or as a tragedy of the commons[1]. In fact climate change issue will be solved only if many large actors all contribute to the solution. But, while insurers as a group will likely benefit from measures to mitigate greenhouse gas emissions and to adapt to impacts of climate change, each insurer would gain little from its own contribution if others do not participate. And solution-oriented behavior will often produce positive externalities instead of benefits for an insurer itself and, as a consequence, individuals may lack motivation to insure.

This is the demand-side issue connected with the diffusion of insurance products. For the insurance sector to play a role within the environmental political economic policies it is crucial the incentive for the individuals to buy climate change related insurance products. And this could be an argument for future research.

Conclusion

This paper aims to show that insurance could play a core role in environmental policy choice to face the climate change consequences. Governments need to utilise the acivities of the insurance industry in the fight against climate change as much as the insurance industry requires an effective government strategy in order to be supported. Insurance is part of the overall policy of mitigation and adaptation that aims at reducing the severity of many impacts that could result from climate change if current adverse conditions prevail. Insurance sector can contribute to develop risk management strategy to minimise climate change consequences on an urgent basis to prevent further escalation of global warming.

The challenge is to define an efficient mix of government policy interventions to provide the right incentives to invest in cost-effective preventive measures to reduce the final cost of disasters. To enable insurance companies to play a responsible role in tackling climate change consequences, they require a reliable, transparent and international coordinated policy framework as well as long-term, appropriated greenhouse emissions reduction goals. That gives certainty for investment decisions and provides business opportunities for clients. In order to organize their own operations to the new challenge, insurance industry should include climate change risk in its internal governance procedures, in line with the existing financial corporate risk identification.

References

1. Agrawala S., Fankhauser S. (2008). "Economics Aspects of Adaptation to Climate Change", OECD, Paris.
2. Allianz Group (2005). "Climate Change & Financial Sector: an Agenda for Action", edited by Allianz and WWF, June.
3. Association of British Insurers (2005). "Financial Risk of Climate Change – Summary Report", London, June.
4. Baumol W.J, Oates W.E. (1975). "The Theory of Environmental Policy", Englewood Cliffs, NJ: Prentice-Hall.
5. Bohm, P., Russell C.S. (1985). "Comparative analysis of alternative policy instruments", in A.V.Kneese and J.L. Sweeney (eds.), "Handbook of Natural Resource and Energy Economics", Vol. 1, Ch. 10, Amsterdam: North-Holland.
6. Boyd J. (2001). "Financial Responsibility for Environmental Obligations: an Analysis of Environmental Bonding and Assurance Rules", in "Law and Economics of Environmental Policy", Research in Law and Economics, edited by T. Swanson, Cambridge University Press.
7. Boyer M., Laffont J.J. (1996). "Environmental Protection, Producer Insolvency and Lender Liability," Chapter 1 in A. Xepapadeas (ed.), "Economic Policy for the Environment and Natural Resources", Edward Elgar Pub. Ltd.
8. Boyer, M., D. Porrini (2002). "The choice of instruments for environmental policy: liability or regulation?" in T. Swanson and R. Zerbe (eds), "An Introduction to the Law and Economics of Environmental Policy: Issues in Institutional Design", Research in Law and Economics, 20, Oxford: JAI-Elsevier, pp. 247-69.
9. Buchanan J.M., Tullock G. (1975). "Polluters' Profits and Political Response", *American Economic Review*, 65, pp. 976-978.
10. Calabresi G. (1970). "The Cost of Accident", Yale University Press, New Haven.
11. Charpentier A. (2008). "Insurability of Climate Risks", *The Geneva Papers of Risk and Insurance*, 33, pp. 91-104.
12. Cropper, M.L., Oates W.E. (1992). "Environmental Economics: a Survey", *Journal of Economic Literature*, 30, pp. 675-740.
13. Faure, M., Grimeaud, D. (2003). "Financial assurance issues of environmental liability", in Faure, M. (ed.), Deterrence, insurability, and compensation in environmental liability. Future developments in the European Union, Wien, Springer, pp. 7-255.
14. Faure M., Nollkaemper A. (2007). "International Liability as an Instrument to Prevent and Compensate for Climate Change", *Stanford Journal of International Law*, 43, pp. 124-179.

[1] About the "tragedy of the commons", see Ostrom (1990).

15. Feess E., Hege U. (2000). "Environmental Harm, and Financial Responsibility", *Geneva Papers of Risk and Insurance: Issue and Practice*, 25, pp. 220-234.
16. Lewis, T. (1996). "Protecting The Environment When Costs And Benefits Are Privately Known", *Rand Journal of Economics*, 27 (4), pp. 819-47.
17. Maynard T. (2008). "Climate Change: Impacts on Insurers and How They Can Help With Adaptation and Mitigation", *Geneva Papers on Risks and Insurance*, 33, pp. 140-146.
18. Mills E. (2008). "The Role of U.S. Insurance Regulators in Responding to Climate Change", *UCLA Journal of Environmental Law and Policy*, 22 (1), pp. 129-168.
19. Mills E. (2009). "From Risk to Opportunity – Insurers Responses to Climate Change", Ceeres Report 2008, Boston, April.
20. Mills E., Lecomte E. (2006). "From Risk to Opportunity: how Insurers Can Proactively and Profitably Manage Climate Change", Ceres Report, Boston, August.
21. Monti A. (2009). "Climate Change And Weather-Related Disasters: what Role For Insurance, Reinsurance And Financial Sectors?, Climate Change Symposium joint edition between Hastings International and Comparative Law Journal and West-Northwest Environmental Law and Policy Journal, Winter.
22. Ostrom E. (1990). "Governing the Commons: the Evolution of Institutions for Collective Action", Cambridge University Press.
23. Porrini, D. (2001). "Economic Analysis of Liability for Environmental Accidents", *Rivista Internazionale di Scienze Economiche e Commerciali*, 2, pp. 189-218.
24. Porrini D. (2005). "Environmental Policies Choice as an Issue of Informational Efficiency", in The Elgar Companion to Law and Economics, edited by Jurgen G. Backhaus, II ed., Edwar Elgar, 2005, pp.350-363.
25. Posner R. (2004). "Catastrophe", Oxford University Press.
26. Schwartze R. (2007). "Liability for Climate Change: the Benefits, the Costs, and the Transaction Costs", *University of Pennsylvania Law Review*, Vol. 155, pp. 1947-1952.
27. Segerson K. (1996). "Issues in the Choice of Environmental Instruments", in J.B. Braden, H. Folmer, T.S. Ulen (eds.), "Environmental Policy with Political and Economic Integration", Brookfield: Edward Elgar.
28. Shavell S. (1984). "Liability for Harms versus Regulation of Safety", *Journal of Legal Studies*, 13, pp. 357-374.
29. Shavell S. (1986). "The Judgement Proof Problem", *International Review of Law and Economics*, 6, June, pp. 45-58
30. Shavell S. (1987). "Economic Analysis of Accident Law", Harvard University Press, Cambridge.
31. N. Stern (2007). "The Economics of Climate Change – The Stern Review", Cambridge University Press.
32. Swiss Re (2007). "Natural catastrophes and man-made disasters in 2006: low insured losses", Sigma, 2.
33. Swiss Re (2010). "Natural catastrophes and man-made disasters in 2009: catastrophes claim fewer victims, insured losses", Sigma, 1.