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Climate Change and Insurance:
Integrative Principles and Regulatory
Risks

Climate Change and Insurance: Integrative Principles and Regulatory Risks

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ABSTRACT

In medicine, an iatrogenic risk is a risk that arises from the medical treatment itself, such as side effects of surgery or drugs. The same phenomenon arises in the process of regulatory and legislative actions intended to facilitate mitigating and financing of catastrophic risks. Unanticipated regulatory or legislative fiats can have fundamental effects on insured risks. Moreover, economic disruptions in the much more densely interdependent global economy can also have systemic effects well beyond their direct locus of impact. These systemic risks are likely to become more evident in the catastrophe risk area in the years ahead, as the effects of climate change become more apparent. One can expect as a result increasing demands on regulators and parliamentarians who, in turn, are likely to look to the insurance and reinsurance industries for solutions. This paper describes the challenges likely to arise in this process, with a particular focus on catastrophe risks that may result from climate change (of course, weather-related events will continue to occur whether or not discernible climate change the culprit). These challenges include the magnitude of the hazards themselves, the complex interactions of mitigation with the Kyoto-driven carbon economy and the uncertainties associated with climate change itself. I review some principles that derive from the economics of insurance regulation and from the decision sciences. Some of these have been recently put forward as policy recommendations at the World Economic Forum and in the OECD Advisory Board on Financial Management of Large-scale Disasters. These recommendations on the role of insurance in mitigation and financing of catastrophe risks must be seen as part of a larger international debate on these issues. They are set against the background of increasing losses from catastrophes due to increased assets and population in vulnerable areas, the increased scale of weather-related events, possibly related to climate change, and increased interdependencies in the global economy. Given the magnitude of these risks, there is growing recognition on the importance of greater collaboration between the public and private sectors in identifying and quantifying risks from large-scale catastrophes and in the design of mitigation and residual risk financing mechanisms to cope with them. I argue here that it is essential that the insurance industry take a leadership role in developing principles and actions to address these risks.

INTRODUCTION

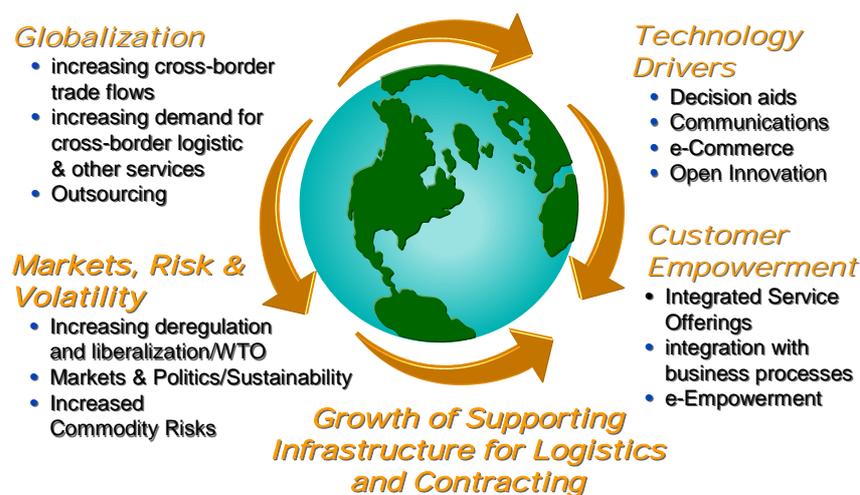
Human activity is putting the future of the planet at risk. The increasingly visible signs of this are everywhere (see Munasinghe, 2009). The most visible of all is population growth, with global population predicted to top 7 billion souls by May of 2010. The resulting strain from this population and increasing consumption per capita are also visible. Depletion of cheap resources, including forests and fish populations, are in clear evidence as extraction has exceeded new discoveries or replenishment. Water pollution and droughts are complicating already scarce clean water supplies, with major consequences for households and the agriculture sector. The list of anthropogenic impacts is a long one, and not a very cheery one to contemplate. At the top of this list one must place Greenhouse Gas (GHG) emissions and the threat of global climate change associated with them.

These events arrive at a time when global economic integration is at a new peak. In the past two decades, the forces and institutions that govern global economic activity have undergone immense changes (see Kleindorfer & Wind, 2009). As shown in Figure 1, these include the ongoing development of the European Union, and the changes in liberalization and governance initiated by the World Trade Organization (WTO). Cross-border acquisitions and alliances, together with new markets and new forms of contracting, are supporting outsourcing, unbundling, contract manufacturing, and a variety of other forms of extended-value, network-based constellations. On the market side, the Internet has empowered consumers, giving rise to peer-to-peer networks, and transformed whole industries. These Internet-related changes include the impact of Skype on the telecommunications industry, search engines such as Google, and the growth of e-retailing with companies such as Amazon and eBay. In tandem, developments in transportation and integrated logistics providers such as FedEx, UPS, and DHL have revolutionized global fulfillment architectures for business-to-business (B2B) and business-to-consumer (B2C) markets. These changes together have resulted in large increases in international trade from 2000 to 2008 (as shown in Figure 1 in terms of total exports in merchandise and services--M&S in the Figure). All of this spells increasing interdependency and increasing risks from disruptions in the resulting much more integrated global economy.

Continuing Growth in International Trade*

Total Exports (M & S) 2000 = \$7.94 Trillion

Total Exports (M & S) 2008 = \$19.86 Trillion



*Figures are in current \$'s. Source: WTO--<http://stat.wto.org/Home/WSDBHome.aspx>

Figure 1: Global Trends Driving Increasing Economic Interdependence

Increased global economic integration is itself a first-order effect driving the increase in systemic risks from sea-level rise, increasing storm frequency or virulence and other weather-related risks.

Just as increased population movements to coastal areas increases economic value at risk from storm activity, so too the increased integration of the economic order exposes many global supply chains to a greater scope of hazards. For insurers, there will be both increased risks and increased opportunities. Indeed, helping business clients to assess, mitigate and insure the risks from their increased global exposures is going to be a significant business opportunity for risk management services arising from the threat of climate change. These increased vulnerabilities will require new services and competencies to assist business clients to improve Enterprise Risk Management Systems to manage increased supply chain and facility disruption risks and political risks. Other opportunities will come in insurance innovations for the new carbon economy, green technologies and in hybrid adaptation projects, which link risk management with major infrastructure investments responding to changing water or energy needs. However, climate change is potentially a very large and unpredictable phenomenon and harvesting these opportunities will require the insurance industry to do something it has been reluctant to do in the past—take a leadership position in developing a framework for global management of these risks. Since climate change necessarily also involves the public sector, this leadership must be in partnership with regulators, legislators and the general public. This is not the time for a “go it alone” strategy.

The call to action to address climate change was first muted and uncertain. That has changed. Around the world, companies and countries are now deeply engaged in developing strategies to cope with what are now viewed as very likely adverse consequences of significant climate change, with some of these on the near-term horizon of the next decade. First, and most visibly, there have been international and national laws stemming from the Kyoto protocol to motivate companies in the energy sector (electric power, oil and gas) and in allied energy-intensive industries (steel, pulp & paper, glass, aluminum, transportation and cement) to reduce emissions of GHGs (see Mansanet-Bataller and Pardo, 2008). Second, and near and dear to the hearts of the insurance industry, is the increased use of modeling by regulators and insurers to measure and price insurance coverage of catastrophe risks, for companies, households and public infrastructure. Third, are growing initiatives related to adaptation strategies (Munasinghe, 2009), which are focused on coupling project development activity to combat the damages of climate change with insurance and risk management services. Among the very visible signs of the carbon economy is the wave of new laws and regulatory incentives associated with renewable energy. For example, the Climate Change Package approved by the European Union in April of this year will have immense implications for how energy-intensive businesses function in Europe. It will affect everything from plant location decisions to technology choices, and ultimately the profitability and risk, of these industries.

The insurance industry has clearly understood the increased risks involved with climate change. This conference itself indicates the commitment of Aon Benfield to business innovation in catastrophe risk management. Major position statements and research reports have been issued by the World Economic Forum (WEF, 2008) and the Geneva Association (2009). Munich Re and Swiss Re have been in the forefront in promoting research on the effects of climate change. The effects are expected to include in the near term potential increases in flooding and surge damage, increased tropical cyclone activity, and increased impacts of droughts and temperature rise on agriculture and water supply. Going out another decade or so, we could see irreversible climate change, potentially large migrations from countries at or below sea level to other less affected regions, a possible flip in climate in Northern Europe if the Gulf Stream shuts down, large and uncertain impacts from decreases in biodiversity in plant and animal populations—in other words the potential changes could be huge.

Against this turbulent background of new systemic risks unleashed by climate change, the insurance industry faces some important challenges in defining its proper role, in convincing external stakeholders, including regulators, of the legitimacy of this role, and in developing the needed products and services to play its role effectively. Let me note right at the outset that many of the catastrophe risks attributed to climate change are not new per se to the insurance industry.

Certainly the general issue of catastrophe cover for large correlated risks, be they from earthquakes or terrorism, are now fairly well understood. Indeed, special designation of some weather-related risks as climate change risks has its own perils, as a common approach to catastrophe risks should be based on the character of the underlying hazard, and correlations across insured losses affected by this hazard, and not what the hazard is called. Nonetheless, I believe there is a real opportunity, and a real urgency, in the current growing awareness of the threat of climate change, to address catastrophe risks under the heading of climate change. This must be done with care, however, without neglecting other major catastrophe risks that are for some regions more important than weather-related risks from floods and tropical cyclones that could reasonably be associated with climate change.

The paper proceeds as follows. In the next section, we consider the elements of regulatory and political activity related to climate change, and the threats arising from climate change for the economy as a whole and for the insurance industry. We then consider the theory of regulatory risk and discuss the particular areas of insurance activity (from traditional insurance to securitization and adaptation strategies) where regulatory risk could have important impacts. In the process, we note the special features of climate change that make it particularly subject to regulatory and legislative errors/risks and unanticipated consequences. We then consider some principles that have been advanced related to private and public responsibilities in risk bearing and risk transfer for catastrophe risks. This leads to a conclusion of the opportunities and challenges for the insurance industry in the climate change area. I argue that the insurance industry must build on its recognized competencies in the catastrophe risk area to assume a position of leadership, based on innovation and vision, in addressing the challenges associated with climate change.

NATURE AND IMPLICATIONS OF POTENTIAL CLIMATE CHANGE

The Nature and Scope of Climate Change

As explained in Munasinghe (2009), the 4th Assessment of the Intergovernmental Panel on Climate Change (IPCC), issued in 2007, was unequivocal in its finding that total radiative forcing of the climate now is unprecedented when judged against the evidence of global temperatures during the past several thousand years, and is due to rising concentrations of Greenhouse Gases or GHGs (CO₂, CH₄ & NO₂). Moreover, it is very likely human activities since the 18th century that have caused net warming of the Earth's climate, dominating over the last 50 years. More temperature and sea level rise is inevitable, even with existing GHG concentrations. Although this is the "consensus opinion", the uncertainty bounds on the magnitude of sea level rise and other effects are very large, and there are many scientific links in the chain of reasoning leading to these effects that are still in dispute. For example, based on very large simulation models of the earth's climate, the predicted rise in sea level in this century is between 20 and 60 centimeters with a median prediction of 40 centimeters if ppm concentrations of GHGs can be limited to 450 ppm (which will take vigorous and immediate actions to achieve). The difference between 20 and 60 centimeters is obviously very large in itself. When one couples this with the uncertainties in the carbon cycle and our general lack of knowledge about the causal features leading to climate change, there is plenty of room for skeptics to argue that we don't understand enough about this to know a) what to do and b) when to start doing it. Nonetheless, based on the imperfect evidence available, appeals to the precautionary principle, to the sustainability paradigm and intergenerational equity and to other notions of prudence have led to a flurry of activity in the past decade in attempting to respond to the threat of climate change. This includes, foremost, efforts to mitigate GHG emissions through the Kyoto Protocol and its associated implementing laws and regulations around the world, as well as the beginning stirrings of international concern about eventual adaptation and migration plans.

The Figure below shows some of the predicted consequences of climate change based on the findings of the IPCC's 4th Assessment. These are effects at the median scenario associated with achieving significant reductions in GHGs by 2050. There are also beneficial effects, for some regions, with increased agricultural output in some mid-level latitude regions, and increased forestry yields. However, most of the news is bad, and especially for the developing world. The main negative consequences expected are based on predictions of higher maximum temperatures and heat waves over nearly all land areas, higher minimum temperatures and fewer cold spells over nearly all land areas; more intense precipitation events over many areas; increased summer drying over most mid-latitude continental interiors and associated risks of drought; and increased tropical cyclone mean and peak wind intensity.

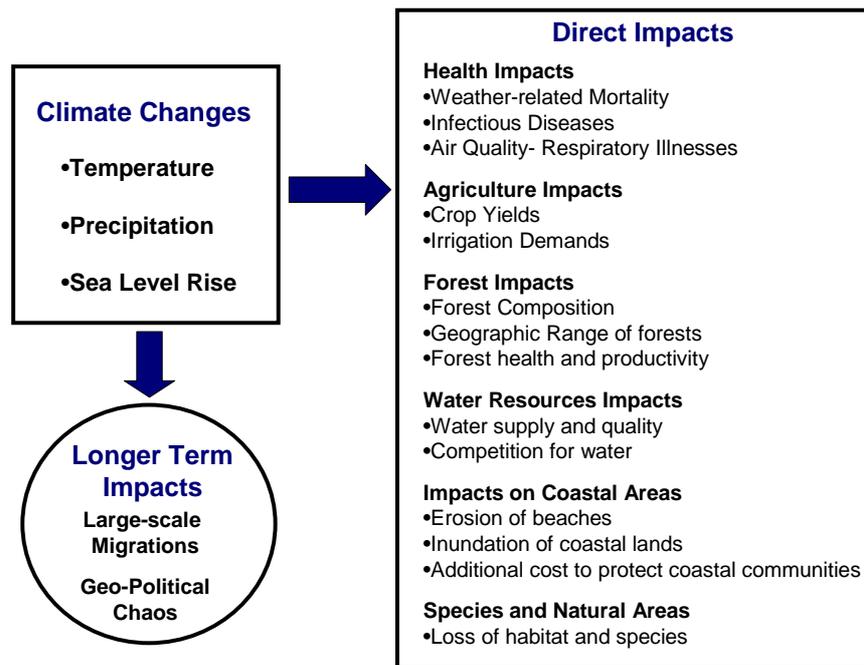


Figure 2: Predicted Consequences of Climate Change through 2100

What is at Stake for the Insurance Industry?

To begin with, it is important to note the key role that insurance can and should play in signaling to households and businesses the magnitude of the risks they face from natural hazards and what they can do to mitigate the consequences. This signaling is accomplished through risk-based rates, supported by reliable information provided to property owners, financial intermediaries and communities. Major studies such as Kunreuther and Michel-Kerjan (2009) have verified the key role of insurance as a fundamental policy instrument in providing information before the fact on the value of mitigation and after the fact in providing immediate cash injections to aid in recovery.

In theory, appropriate geographical diversification and risk-based pricing should allow the insurance and reinsurance industry to cope with even large changes in frequency or severity of events. The reason I say this is because, while severe and uncertain, the likely speed of change of climate change effects will almost certainly be more gradual and over sufficiently long time spans, say 5-year periods, for insurance to adjust policy conditions and reinsurance treaties to track changes in the overall exceedance probability curves. If this assumption is true, then the central problem is whether this process of necessary adaptation will be acceptable in the market, and whether regulators and legislators will work in partnership with the insurance industry on these problems. Besides solvency and price regulation that are subject to strong regulatory

controls in many jurisdictions, other governmental actions will also strongly affect the ultimate magnitude of economic value at risk from climate change. Certainly changing insurance law or liability laws could have an instant and major effect on casualty and liability insurance (see Leimbacher et al. (2009) for the potential implications of such changes in the context of climate change). Other policy areas in which the government will play a key role include providing information on risks, data gathering on both storm activities and asset locations, as well as in zoning, building regulations and strengthening of public infrastructure. The government should also play a central role in establishing and reinforcing the cultural pre-conditions of personal responsibility for locating assets in vulnerable areas, and in gaining agreement on the “social risk contract” regarding the structure of risk-bearing for climate change events borne by the government and by individuals. In the best of all possible worlds, the latter arrangements (the terms of governmental participation in risk bearing) will be determined in advance. Given the necessary involvement of the state in mitigation and in risk bearing for catastrophic events, a central issue in all of this is the proper, respective domains of private insurance and of the public hand. There is at present an unfortunate schizophrenia on this score in many countries, whereby private insurers are opposed to government involvement in catastrophe risk bearing and yet it is understood by everyone that there are clear limits to the ability of the private insurance industry to cover the far tail of catastrophic events. Sorting this out to find a workable balance between the benefits of private insurance and the limits of insurability remains an essential element of catastrophe insurance, and is likely to become even more salient as the effects of climate change become more pronounced.

One broad categorization of the stakes for the insurance industry is to consider those associated with the developing world and those of the industrialized countries.

In the developing world, where more than 3 billion people live on less than \$2 per day (Munasinghe, 2009), the impacts of climate change are potentially disastrous. Here insurance can play an important role in mitigating the effects of major disasters, through modeling and information services, and through Alternative Risk Transfer instruments with parametric triggers or other indexed and securitization instruments that are contracted for with the government (see Brahin et al., 2009; Linnerooth-Bayer et al., 2009). Micro-insurance in the mid-level developing countries will also be feasible in the future to provide immediate cash infusions to small business owners after an event (Warner and Spiegel, 2009). Increasingly, catastrophe modeling capabilities, coupled with GIS, will be needed to predict and support responses to the major humanitarian disasters and migrations that will follow climate change impacts for developing countries that are especially vulnerable. I hesitate to refer to the benefits derived from these services as an opportunity, but considering the likely scenarios in their absence, the payoff from using insurance industry capabilities to predict and cope with climate change in the developing world is obviously huge. A problem will be how to fund the research needed to support data and model development. There is minimal financial incentive for the major commercial modeling firms to self-fund the research needed to create data systems and relevant model refinements, given the low insurance penetration in these regions. For this reason, initial funding will need to come from governments and organizations with economic and humanitarian interests in the affected areas. Moving ahead in this area will require a real push from the insurance industry to move public-private partnerships ahead in the developing world.

For the developed world, where there is high penetration of cat coverage and excellent modeling capabilities in place for risk assessment (see, e.g. Clark, 2007), the stakes are two-fold. First are the potential increases in the magnitude and uncertainty of the changes induced by climate change, including (for the corporate sector) the interdependencies and network effects of these across multiple lines of business; and second is the regulatory and legislative inertia that may prevent insurers and reinsurers from adjusting their policies and rates to the changing environment. Concerning the first, failing to respond to these changes in a timely fashion could be fatal for both insurers and reinsurers. For the second, it will undoubtedly take a concerted effort to work effectively with regulatory, governmental and inter-governmental representatives to

define evolving risk-bearing structures that make sense in individual country markets and globally. In terms of the very basic issue of the magnitude of increased risks from climate change, long-term estimates in Stern (2007), Garnaut (2008) and IMF (2008) suggest a range of scenarios from 2050 onwards that are expressed in % of GDP reduction relative to a no-climate-change scenario of 1 to 3%, but with much larger losses within the range of the possible.

Considering recent data, Miller et al. (2008) considered loss data from weather-related disasters since 1970, and normalized this data to remove the effects of demographics and increase of economic assets in vulnerable areas. Their results show a 2% upward trend in economic losses from weather-related disasters since 1970. However, this result is sensitive to the currency based used for loss evaluations and to various other idiosyncratic features of the post-1970 period—e.g. leaving out the effects of Hurricane Katrina significantly affects results. The authors conclude that while there is “limited statistical evidence of an upward trend in normalized losses from 1970 through 2005”, there is “insufficient evidence to claim a firm link between global warming and disaster losses.” (Miller et al., p.240) Knutson (2008) draws a similar conclusion in his summary of the conflicting scientific evidence concerning the relationship between climate change and tropical cyclone activity. He concludes that while it is too early to determine if climate change or greenhouse gases have affected intensity or frequency of storms to date, it is nonetheless likely that increasing concentrations of greenhouse gases will in the coming century cause hurricanes to be more intense, with associated increases in rainfall, floods and surge damage in coastal areas. The effects for Australia, in particular, have been laid out in great detail by Garnaut (2008), with severe adverse effects from climate change projected for agriculture and the environment. Fact sheets and studies from the major reinsurers provide additional information on current storm activity and insurance losses (e.g., Heck et al., 2006; Munich Re, 2009; Swiss Re/ProClim, 2009). Given the increased property and populations at risk on the coast lines in economically important regions in the Americas, Asia and Oceania, all of this points to a major threat to global economic activity and a major challenge for the insurance industry. Indeed, given the evidence of sea level rise and global temperatures increases, Rauch and Menhart (2009) echo the general consensus of recent studies on the likely consequences of climate change in their conclusion that the citizens of planet Earth are indeed very likely already in a pickle: “Globally, the impacts of climate change are expected to become increasingly negative (perhaps exponentially) with rising global temperatures.” (Rauch and Menhart, p. 46).

POLITICAL AND REGULATORY RISK ASSOCIATED WITH CLIMATE CHANGE

Let me begin by noting why the area of climate change is so prone to regulatory and political risks. In a nutshell, the reason is that these risks are complex and provide very few observable cues to regulators and legislators, as surrogates of the public, on whether they are doing a good job or not. Moreover, as these risks are global and systemic in nature, regulatory changes in one country can have large effects on other parts of the world (e.g., if China and India do not levy carbon taxes on certain sectors while the rest of the world does, there will be potentially large economic dislocations from the rest of the world to China and India for carbon-intensive industries). When such cues are not observable within a reasonable time frame of decision making, or when a regulator has no reason to pay attention to the cues that are available, the normal legitimization process for assessing and improving national or regional regulation is difficult to apply. We then enter naturally into the realm of political process and international negotiations, unanchored by indisputable evidence on the performance of past regulatory decisions or the causal connections between present regulatory decisions and future outcomes. In insurance, the economic rationale for regulation is to protect consumers and investors from risks they cannot reasonably be expected to understand or control. Many books and research papers have been written on descriptive and prescriptive theories of such regulation (for catastrophe insurance, see von Ungern-Sternberg, 2004; CCS, 2008; Kunreuther and Michel-Kerjan, 2009). In comparative assessments of regulation, one often sees words like “transparency”, “independence” and “openness” touted as important elements of credibility of a regulatory agency or governmental

approach. The underlying theme is that openness to experts from all sides of an argument will eventually produce better data, better models and better decisions than closed proceedings, especially if these are embedded within a broader bureaucracy or ministry of government that buffers accountability. However, the conditions under which such openness can be expected to lead to improved decision making interact with other elements of the regulatory context (such as problem complexity, availability of feedback, direct relevance to the regulator's mandate, and level of knowledge of stakeholders). I will argue that many of the natural reinforcement mechanisms for good regulation and legislation are absent in the climate change area, and especially when it comes to insurance. The result is like a religious war—high stakes and no clear benchmark of what is right while the war is being fought.

Political and Regulatory Risk in Insurance Markets

Perhaps the most central aspect of political and regulatory risk in insurance markets relates to the concept of insurability (Berliner, 1982; Skogh, 1998). Among other requirements, insurability of a risk requires that it be a chance event (not pre-ordained or the result of legislative fiat), quantifiable (so that it can be priced), and not subject to restrictions on the transfer of the risk that would preclude pricing geared to the cost of the risk (both in expected loss terms as well as in the liquidity costs of reserving for the risk). Major regulatory risks for insurance typically involve a violation of one of these three basic requirements. For example, changes in liability laws can have fundamental effects on insurability, and insurance lawyers spend many hours attempting to craft policy language that precludes imposing additional liability costs *ex post facto* (as was done, for example, for environmental liability in the USA in the 1980s—e.g., Kleindorfer & Kunreuther, 1987). Similarly, unquantifiable risks may be sharable through mutualization (e.g., Skogh, 1998), but they cannot be covered through the traditional market-based insurance mechanism. Finally, if regulators impose price ceilings that prevent recovery of expected loss costs and necessary administrative fees for supporting insurance, then this cannot be offered through private insurance (although it naturally could still be offered as a subsidized cover backed by the government). The insurance mechanism is a very robust mechanism, but it cannot survive regulatory or environmental changes that undermine the basic criteria for insurability. It is usually through violation of insurability criteria that regulatory and political interventions cross the line and interfere with or completely undermine the ability of insurance to operate efficiently.

Regulatory risk (I will use the term here also to mean political risk) enjoys a rich literature in economics, where it has generally come to mean those risks that arise from a regulator undertaking actions that are within its legal mandate that lead either to increased uncertainty, and resulting increases in capital costs for private investors in the market in question, or simply unanticipated behavior that leads to a loss for either investors or for society as a whole. Principal contributions include those of the Chicago School (Stigler, 1971; Becker, 1983; Peltzman, 1989) and the Rent-seeking literature identified with James Buchanan and Gordon Tullock (e.g., Buchanan & Tullock, 1999; and Tullock, 2003). The Chicago School emphasizes the interaction of interest groups seeking to “capture” regulatory agencies and bend them to their own purposes. The Rent-seeking literature emphasizes that public agents may engage, just as private agents do, in rent-seeking behavior and echoes similar notes from the theory of bureaucracy (e.g., Niskanen, 1968). The interaction between regulators and legislators in restricting regulatory behavior by restricting their mandates is explored in Knieps and Weiss (2007). For on-going insurance markets, these considerations are obviously important in discussions of both solvency regulations as well as risk-based pricing in individual country markets.

In Kleindorfer and Klein (2003), Bob Klein and I analyzed the interactions of various regulatory policies governing catastrophe insurance that were implemented in Florida following Hurricane Andrew. These included solvency criteria, but also a number of other regulations, including restrictions on pricing. We based our analysis on the structure of optimal insurance portfolios for private insurers, including the tradeoffs between the structure of regulated prices across geographical zones and marketing cost functions. The analysis shows a complex interaction

between underwriting criteria, the frequency and severity distributions characterizing catastrophe hazards and insurer approaches to risk retention, underwriting, marketing and pricing. These results would not be surprising to anyone familiar with catastrophe insurance; they underline the integrated nature of traditional insurance functions, from actuarial science to underwriting and pricing. It is perhaps more surprising that regulators in some jurisdictions have attempted micro-management of prices and entry restrictions, notwithstanding the complexity of these matters for individual insurers, with some rather dubious consequences.

In particular, as Grace et al. (2004) and Kunreuther and Michel-Kerjan (2009) note for the case of Florida, the combination of price and entry restrictions there have led to underpricing of the risks. This has led to distorted entry decisions, continuing frictions with insurers and the announced exit in January of this year of one of the largest insurers (State Farm) from the State altogether. In addition to these directly observable results, the underpricing of catastrophe risks leads further to inefficient mitigation choices (see Kleindorfer & Kunreuther, 1999; Kunreuther & Michel-Kerjan, 2009), including location and type of new construction. Finally, the use of guarantee funds such as the Florida Hurricane Catastrophe Fund (FHCF) to attempt to provide catastrophe coverage where, at regulated prices, none would be otherwise available, has distorted the market and may be altogether unsustainable (Kunreuther and Michel-Kerjan (2009). Without making too much of the Florida story, my point here is that the regulatory risks apparent in this description could increase significantly under the added weight of climate change.

What is driving this? My answer is more or less the traditional one: the complexities of the insurance process, together with the lack of sophistication and predisposition of the public towards myopia come together in a particularly precarious manner in the catastrophe risk arena. Together with the all too human tendency to try to have others pay for the risks we face, these factors contribute to the adoption of solutions by regulators and legislators that tend towards underestimating the price of risk, and reserving for these risks from a general and vague pot of gold whose source is never quite specified. These factors interact to provide an environment in which citizens prefer to repress the dangers of where they locate their homes and businesses, representative governments at all levels prefer to let the citizens enjoy their blissful ignorance until a disaster occurs, and they then extend the hand of good Samaritan relief when disaster strikes, further undermining incentives to make reasonable choices about mitigation and insurance before the fact. Legislative and regulatory programs that hide or obfuscate the magnitude of the risk, coupled with guarantee funds and pools that mortgage the future, are (for the logically inclined) frustrating accompaniments to this very non-virtuous cycle. For reasons I now discuss, I think this cycle will be particularly difficult to break in the area of catastrophe risks linked to climate change.

Legitimation and Accountability

Legitimation theory in its modern form derives from the German philosopher Jürgen Habermas (1973). A short summary of the descriptive theory of legitimation could be stated as follows (Kleindorfer, 2009b): if a decision maker knows s/he is being observed while making a decision, this will have predictable effects on the process and outcomes of decision making. The parallel prescriptive theory of legitimation supports the notion that it is both sensible and desirable to subject some aspects of decision making to *ex post* review, both to justify the process and outcomes of choice and to provide affected stakeholders with assurance that their interests have been considered. Legitimacy of institutions is central in an open society, for both reasons of accountability of these institutions as well as to attempt to improve regulation (e.g., in terms of efficiency or fairness).

This line of thinking has been subject to experimental and empirical work over the years, both for individual choices and for regulatory choices. For example, Simonson and Nye (1992) designed several studies to determine whether accountability ('anticipation of required justification') would affect decision making, and they found this to be so. Their studies also show that decision biases may not be reduced by accountability alone, because it is not performance that subjects seek

under conditions of accountability but rather the favorable opinion of those able to observe and/or sanction their behavior. The extensive antecedent work of Cottrell (1968) underscores the findings that anticipation of evaluation has rather different effects on behavior than passive observability per se. This research suggests that observability of behavior, together with expected valuation and defined norms, act together to alter reasoning processes and decision outcomes in ways that align process and outcomes with accepted norms of making such choices. While this may be intuitively obvious, it has immense implications for regulation and legislative actions in the climate change area as I now explore.

Climate Change and Legitimation

The basic problem with assuring reasonable and reasoned outcomes in the area of catastrophe insurance and climate change is the lack of an agreed framework and principles (or norms if the reader prefers that term) for judging what is a good process and outcome. This is true for nearly any group of stakeholders one wishes to consider in this debate. The recent exchange of views among economists triggered by the Stern Report (see Stern, 2008 for some of the arguments) suggests some of the recognized characteristics of the problems associated with this issue. These include huge uncertainty, large time lags between actions and effects, and massive complexities and knowledge gaps in the underlying science. For legitimation, these characteristics imply heavy weather for both validation of policy actions as well as individual choice related to mitigation and insurance. Let me note a few of these.

Aggregate valuation of alternative options: As the problems here are very long term in nature, and beyond the temporal reach of market-based instruments, political choices are fundamental in determining policies. The lack of a clear market-based definition of efficiency in political choices gives rise to any number of problems in arguing for an appropriate course of action. Notwithstanding the predilection of economists, it is not helpful to insist to the public or to regulators and legislators, as surrogates of the public, that the only principles that matter are economic principles. This is even truer in the international arena where calls to the developing world to commit to GHG reduction targets have by and large been met with a cold shoulder. The Stern Report itself concludes that economic principles alone do not suffice to come to a conclusion about what to do concerning climate change; one needs to apply additional principles from the realm of ethics to make the case for immediate costly mitigation versus more gradual approaches.

Individual valuation of alternative options: In participating in the democratic processes underlying political choices, or in the international political arena, how should the views of citizens be shaped, informed and represented in the political process? In terms of representing values and preferences of citizens in the political process, survey methods such as contingent valuation are likely to be of limited use because of the characteristics (uncertainty, complexity and intertemporal) of the climate change problem (Fischhoff, 1991). How to shape, inform and represent individual preferences about approaches to climate change, and the role of advanced preparation including insurance, remains a largely open question.

International and intergenerational equity, irreversibility and intertemporal choice: Legitimation problems are particularly difficult in this context because it is impossible to consult all the affected parties at the time policy choices are made. I have noted already above the problem of developing vs. developed countries and the problem of determining equitable burden sharing. The special problems of intergenerational equity and irreversibility have been at the heart of the climate change debate, just as they were for radioactive waste (Easterling & Kunreuther, 1995). More generally, the “precautionary principle” and the whole sustainability debate itself has been focused on the central question of what it actually means for present generations to live in such a manner so as not to disadvantage future generations. Coupled with great uncertainty, irreversibility of some damages and very long time frames for effects, these characteristics together bring climate change to the very limits of what human decision makers are able to cope

with in terms of models of rational choice (Brekke and Johansson-Stenman, 2008; Kleindorfer, 2009a). The result is an unsettling cloud of normative uncertainty as to who should be responsible for the costs of GHG mitigation or for realized losses from catastrophe events that may be related to climate change.

Low-probability, High-consequence events: Added to the above are the continuing perplexities of risk management and mitigation associated with the low-probability, very high-consequence outcomes of climate change. Howard Kunreuther's contributions over the years have highlighted the huge difficulty that human decision makers have in coming to grips with these problems. The lack of easily interpretable feedback on climate change policies contributes to the ease of misinterpretation and denial of the noisy signals that arise from climate change and to the ability of third parties to obfuscate matters in their interest. Results in the climate change arena need to be interpreted by panels of scientists, run through complicated models and qualified in ways that make the results nearly incomprehensible to all but a limited number of affected parties. In this context, individual choices, e.g. about location or retrofitting of homes, are prone to basic biases of threshold decision making and myopia (see Part III of Kunreuther and Michel-Kerjan, 2009). By extension, public reactions to regulatory practices regarding zoning and other community or societal mitigation practices are often muted, distorted or confused.

What guidance can research on legitimation theory provide us to guide our discussion of understanding political and regulatory risks to the insurance industry from climate change? According to Habermas, we should engage in open discourse and attempt to promote communicative rationality, rather than holing up in our disciplines and attempting to legitimize the goodness of one or another policy by decorating our ideas with the plumage of intellectual certifications or professional consensus within the industry. This would call for a proactive approach by the industry to engage both the general public and their regulatory surrogates, as articulated, for example, in the inspiring conclusions to the Report on Climate Change by the Geneva Association (2009). At first glance, Habermas' call for a more democratic approach would appear to be an impossible recipe to follow, given the complexities and international scope of this problem. However, on reflection, are the ideas so difficult that individual citizens and non-insurance experts and policy makers cannot be brought into the discussion? Can they not be made aware of the stakes in meaningful terms? Of the trade-offs for themselves and their grandchildren? Rather than speaking in terms of \$800 billion of NPV of the global GDP versus \$4 trillion (the types of economic numbers attached to the Stern report for various alternatives), could not the consequences of alternatives be expressed in terms that are meaningful to an individual in various parts of the world? I think the answer to these questions is most definitely yes. Moreover, given the magnitude of the stakes in this problem, it seems to me critical to bring in the citizens of the planet into a meaningful and urgent debate of these policies, which have the potential to significantly affect their lives and those of many generations to come. As Hiroyuki Hata (2009) notes in his recent summary of insurance industry responses to the climate change debate, this process of engagement has definitely begun. A central question here is what principles might be put forward to position the insurance industry's response to regulatory and legislative action regarding climate change and to make this communication process real and compelling.

PRINCIPLES UNDERLYING CATASTROPHE RISK UNDER CLIMATE CHANGE

When in doubt and uncertainty is all about, then values and principles must lead the way. This seems an appropriate adage in the context of climate change. In this spirit, this section reviews of principles that have been advanced recently in the area of climate change and insurance for catastrophe risks. Specifically, I consider the principles advanced in the World Economic Forum CEO document (WEF, 2008), in the draft Kleindorfer et al. (2008) formulated for discussion at the OECD, and the principles articulated in Kunreuther and Michel-Kerjan (2009). I also take note of the significant research project and recommendations on climate change from the Geneva

Association (2009) and the detailed reports on the economics of climate change by Stern (2007) and Garnaut (2008).

As relates to insurance, these various position statements and research studies all agree on two basic propositions:

1. In matters that intersect with the economy, it is desirable to rely on markets to implement choices, even when the choices involved derive from ethical principles or are the outcomes of a political process. Generally, markets promote transparency and innovation. Reliance on markets allows those affected to adapt, flexibly and autonomously, to local conditions. These claims are made both for insurance as well as for the carbon economy and other elements of the economic response to climate change.
2. With respect to insurance, in particular, risk-based pricing based on sound science to quantify the risks is a central pillar of insurability and of sustainable approaches to catastrophe risks arising from climate change. This principle is important not only as a critical underpinning of insurance markets, but also in providing proper signals for households and firms to adopt cost-effective mitigation choices and adaptation strategies related to climate change. It has immense implications for public-private partnerships for collecting reliable data and on acceptance of actuarial and model-based approaches to quantify catastrophe risks.

Beyond the above two principles, three others are advanced in Kleindorfer et al. (2008) and Kunreuther and Kerjan (2009).

3. Perceived fairness and affordability are critical determinants of acceptability of any approach to catastrophe risk. This means that the costs of mitigation measures and insurance should be commensurate with the means and abilities of individuals, companies and countries to undertake or pay them. If costs of insurance reflect risks, one might need to consider providing financial assistance to individuals in hazard-prone areas needing special treatment (e.g., low-income uninsured or inadequately insured residents and businesses). In poor countries, this effort might require financial support from the international community and international organizations, e.g., Climate Adaptation Funds administered by the Global Environmental Facility of the World Bank (see Hellmuth et al., 2009, for details).
4. Options for protecting against catastrophic losses should be widely discussed and clearly understood before a major disaster. Risk management strategies should help inform the affected public of the risks they face and the available cost-effective mitigation and recovery options. Each country/national government should articulate a clear social contract identifying the expected behavior of their citizens and the role of the private and public sectors in reducing losses and in paying for the losses from natural and man-made disasters.
5. A general principle apparent in Geneva Association (2009) and WEF (2008) is that for both companies and countries a workable framework must be comprehensive in nature. For the WEF, this was intended to convey the sense that all nations and all sectors must participate in moving to the low-carbon economy. From the perspective of the Geneva Association research project on Climate Change, the recommendation implies that prevention/mitigation, preparedness/adaptation and risk transfer are a trio and none of these stands on its own in an efficient approach to catastrophe risk management. (See also Brahin et al., 2009 on the need for integrated risk management at the country level.)

To date, catastrophe modeling and insurance pricing has focused resolutely on the short term. This reflects the general belief that policy terms of policies and contracts can be renegotiated

annually or for catastrophe bonds in 2-3 years. As argued by Kunreuther (2009a), there is a real need to expand the temporal reach of both modeling and policy terms to include multi-year arrangements. This would promote greater sensitivity to the intertemporal and growing hazards associated with climate change. It would also broaden the scope of awareness and effective mitigation to the multi-year horizon that is going to be essential to address the value of mitigation of the consequences of rising sea levels and increased storm activity associated with climate change. To the extent that frequency of natural hazard events is also affected by climate change, it is clear that modeling and contracting for multi-event reinstatement reinsurance contracts and other multi-period aggregate loss coverage instruments will become more important for reinsurance pricing. Thus, and especially in respect to risks associated with climate change, to the above principles we should add:

6. There is a pressing need to understand and encompass in insurance products the intertemporal effects of catastrophe risks, and in particular those related to weather-related hazards. Directly connected to this principle is the need for precaution and foresight, as we cannot predict the exact impact of climate change. Moreover, it is easier to gradually phase in the impact of expected changes than waiting for a signal disaster to indicate that they are upon us.

The above principles have a number of corollaries and implications. First and foremost is the importance of establishing these as accepted foundations within the regulatory and policy community dealing with climate change and insurance. Failing to do so will leave the insurance industry isolated in its beliefs and subject to continued regulatory and political risks. No matter how valid these beliefs and principles may be, this will be a recipe for continued tension and regulatory risk for the industry rather than the resonant public-private partnership that will be necessary to cope with the effects of climate change.

As evident as these principles may be to the insurance community, they are not so evident at this point to the general public or to policy makers. Partly this has to do with the magnitude of the changes likely to be required in the near future and the natural reluctance of most of us to commit to costly change unless there is no other apparent course of action. Moreover, these principles interact and are in tension with one another. For example, consider the position of a homeowner or business located in a very vulnerable zone that would see its potential insurance costs go up by a factor of 5 or 10 under risk-based pricing—affordability in this case is in tension with risk-based pricing. (An extended discussion of this particular tension is provided by Kunreuther and Michel-Kerjan (2009) for the US context.)

A second reason for the lack of movement in the direction of implementing these principles is the centrality of the political process in addressing climate change issues. Politics is about process and rarely about long-term outcomes. There is an increasing intertwining (some would say entanglement) of the public and private sectors in both the carbon economy and in the weather-related insurance. The reasons are several. First, for climate change, the public sector is going to own the far tail of the loss distribution in any case, given the magnitude of the potential risks and the problem of reserving for such large losses. In countries with private insurance involved in catastrophe cover (e.g., Australia, USA, and Germany), insurance regulation in terms of rates, underwriting and coverage restrictions as well as solvency represent direct governmental interventions in catastrophe insurance. In other countries (e.g., France, New Zealand, Turkey), the government or its direct agent is a primary risk-bearer for catastrophe risks (see CCS, 2008; von Ungern-Sternberg, 2004). Governments at various levels are also involved in building codes and zoning. Data gathering and warehousing is often a primary government responsibility. In short, the government has a direct hand in many of the issues that are central to catastrophe risks and, in particular, to those that may be exacerbated by climate change. They also have an indirect hand these risks through regulations and laws that will affect location and operating practices of energy-intensive sectors that interact strongly with the carbon economy. Naturally, then, the actions of regulators and legislators will have important consequences for risk

management in this era of climate change. However, the nature of politics, together with the inherent complexities of climate change and catastrophe risk, have thus far led mostly to debate but not to resolution of appropriate national and regional approaches to catastrophe risk and climate change. This matter is undoubtedly further complicated by the diversity of country-specific approaches to managing and insuring catastrophe risks (CCS, 2008).

A further complexity, recognized in insurance circles, is the issue of multiple perils and their correlations. The issue of correlations across major categories of risk has been fundamental to the ERM approach of the past decade, following stunning examples from the World Trade Center attacks of 9/11/01 of the problem of missed correlations across lines of business. While this is now a generally recognized issue in the insurance industry, climate change may exacerbate this matter further. Similar to the contagion effects we have witnessed in the current financial crisis, deep blows from increased storm activity to one part of the world in, say, a manufacturing region in China could have strong ripple effects around the world. The systemic effects of climate change could be very serious for the current tightly coupled global economic order.

What are the implications of this increase in global interdependency for our topic here? First, for climate change risks, lagging indicators based on normal data-driven science and falsification methods will not, on their own, provide a sufficient basis for timely action in responding to climate change. Globalization, together with its technological underpinnings in new communication technologies, has fundamentally changed the level of interdependency of financial and market activities, with many more actors involved in these activities directly or indirectly, and in real time. Per the arguments in Kleindorfer (2009a) and Kunreuther (2009), this increased interdependency and speed of responses means that organizational decision making and action confront a considerably expanded set of states of the world conditioning outcomes. The resulting increase in complexity currently exceeds organizational abilities to incorporate these increased states into decisions at the time they are made. What can be done about this from a management perspective is suggested by the anthropomorphic metaphor of an explorer entering uncharted terrain. That individual would do well to prepare mentally for surprises, to be agile and unencumbered by heavy baggage, to have increased acuity and perhaps communication capabilities to home base, and in general to have developed the ability to react to unforeseen and unforeseeable exigencies as they arise. This anthropomorphic metaphor of the prepared, agile explorer is helpful in thinking how and why insurance must be a leading partner in responding to the threat of climate change. More than any other industry, insurance has developed the integrated framework of prevention, preparation and risk transfer to help individuals and businesses analyze major threats to their well being, where possible avoid those that are too large to survive, mitigate others to an acceptable level and provide the resources in advance to recover from events. This framework and the principles articulated above must be the starting point for coping with climate change risks. Most importantly, working with regulators, legislators and political leaders, these should also be the starting point for aligning their interests with workable insurance markets and decreasing the risk of political and regulatory risk to the insurance industry.

CONCLUSION

Several points emerge from this discussion. First, climate change is systemic and global and any effective framework to manage the associated risks of climate change must therefore recognize the interdependencies on the current global economic order. Different companies and countries will draw different conclusions from this perspective, but failing to recognize climate change as systemic could have potentially disastrous consequences. Given the stakes and the competencies required, and echoing Hata (2009), the insurance industry should take a leadership role in the global debate on how to confront these risks. This leadership role should encompass the following:

- Leadership in terms of establishing the insurance industry as a critical partner in this arena. It should do so by providing convincing examples of where and how insurance is adding value in terms of risk management services, in terms of generating knowledge to support company and country decision making, and in terms of facilitating needed change and adaptation where it would otherwise not occur.
- Leadership in terms of establishing the validity of the principles noted above and their implications for designing national and global social contracts that address the risks of climate change, and with a horizon long enough to properly value the magnitude of impacts we are likely to face under climate change and the nature of mitigation and adaptation measures necessary to cope with these impacts.
- Leadership in integrating insurance and risk management approaches relevant to climate change to other major catastrophe perils (such as earthquakes, terrorism). While each of these major perils has its own important idiosyncrasies, the issue of climate change must be used as an opportunity to address broader catastrophe risk issues, and not only those that are perceived to be directly connected to climate change.
- Leadership in working with regulators and legislators to develop a viable vision of risk bearing between public and private sectors, coupled with mitigation and response to climate change risks, and developing a joint strategy for communicating with the public about this vision.

Undertaking this leadership role will also necessarily require innovations in products and risk management services, which the insurance industry has already begun to develop:

- Innovation in terms of the developing world where the largest impacts of climate change will occur. These innovations must encompass acquisition of better data on hazards and property/lives at risk, as well as the means for financing mitigation and adaptation that make sense for the developing world and simultaneously also contribute to achieving global targets for GHG emissions.
- Innovation in terms of national planning that assists country planners and emergency response organizations to understand in an integrated fashion the full landscape of correlated risks they will see as climate change impacts begin to take traction.
- Innovation in terms of integrated risk management services for companies, especially those with tighter ties to areas likely to be more strongly affected by climate change (e.g., the global retail industry) that allow companies to understand climate change, to integrate this with sustainability strategies and to prevent, prepare and reserve for risks they will confront.

A fundamental question raised by the above is unanswered here. How will or should the insurance industry come together to accomplish these formidable tasks? One-by-one with their clients? Through international organizations like the UNEP, UNDP and the international meetings of the parties related to the Kyoto Agreement (e.g., the Copenhagen meeting in December of this year)? Perhaps the right forum would be the OECD or the GEF of the World Bank and other multilateral financial organizations? Perhaps the efforts already underway at the World Economic Forum will be the right platform? Perhaps all of the above. To date, the Chief Risk Officers Roundtable and the Geneva Association have served as important meeting points to foster dialog in the insurance industry. However, a broader podium is now required with a much higher profile to address the above urgent matters and to establish the leadership role for the insurance industry that will surely be required in the climate change arena.

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REFERENCES

- Becker, G. S. 1983. "A Theory of Competition among Pressure Groups for Political Influence", Quarterly Journal of Economics, Vol. 98, N° 3, 371-400.
- Berliner, B. 1982. Limits of Insurability of Risks. Englewood Cliffs, NJ, Prentice-Hall.
- Brahin, P., D. Bresch, R. Schnarwiler and R. Tanner. 2009. Country Risk Management: Making Societies More Resilient. Zurich: Swiss Reinsurance Company.
- Brekke, K. A. and O. Johansson-Stenman 2008. "The Behavioral Economics of Climate Change", Working Paper, University of Gothenburg, May.
- Buchanan, J. M. and G. Tullock 1999. The Calculus of Consent: Logical Foundations of Constitutional Democracy, Liberty Fund, Inc., Library of Economics and Liberty.
- CCS (Consortio de Compensación de Seguros). 2008. Natural Catastrophe Insurance Cover: A Diversity of Systems. CCS, Madrid.
- Clark, K. 2007. Managing Changing Catastrophe Models. Managing the Changing Landscape of Catastrophe Risk (Proceedings of the 10th Aon Re Australia Biennial Hazards Conference). Sydney: Aon Re Australia Ltd.
- Cottrell, N. B. 1968. "Performance in the Presence of Other Human Beings." In E. C. Simmel, R. A. Hoppe and G. A. Milton (eds), Social Facilitation and Imitative Behavior. Boston: Allyn & Bacon, 91-110.
- Easterling, D. and H. C. Kunreuther 1995. The Dilemma of Siting a High-Level Nuclear Waste Repository, Boston: Kluwer Academic Publishers.
- Fischhoff, B. 1991. Value elicitation: Is there anything in there? American Psychologist, 46(8), 835-847.
- Garnaut, R. 2008. The Garnaut Climate Change Review. Cambridge: Cambridge University Press.
- Geneva Association. 2009. The Insurance Industry and Climate Change, Geneva: The Geneva Association (July).

Grace, M. F., R. W. Klein and P. R. Kleindorfer 2004. The Demand for Catastrophic Insurance, J. of Risk and Insurance, Vol. 71, pp. 351-379.

Habermas, J. 1973. The Legitimation Crisis. Boston: Beacon Press.

Hata, H. 2009. Leadership by Insurance: How the Insurance Industry Can Establish Best Practices in Its Business Models Related to Climate Change. Chapter 8 in Geneva Association (2009).

Heck, P., D. Bresch and S. Troeber. 2006. The Effect of Climate Change: Storm Damage in Europe on the Rise. Zurich: Swiss Reinsurance Company.

Hellmuth M.E., D. E. Osgood, U. Hess, A. Moorhead and H. Bhojwani (eds) 2009. Index Insurance and Climate Risk: Prospects for Development and Disaster Management: Climate and Society No. 2. International Research Institute for Climate and Society (IRI), Columbia University, New York, USA.

IMF (International Monetary Fund). 2008. Climate Change and the Global Economy, in World Economic Outlook April 2008. Washington DC: IMF.

Kleindorfer, P. R. 2009a. Reflections on Decision Making under Uncertainty, forthcoming in F. Diebold, N. Doherty and R. Herring (eds), The Known, the Unknown and the Unknowable in Financial Risk Management. Princeton: Princeton University Press.

Kleindorfer, P. R. 2009b. Legitimation in Decision Making, forthcoming in Erwann Michel-Kerjan and Paul Slovic (eds), The Irrational Economist: Making Decisions in a Dangerous World, New York: Public Affairs Books.

Kleindorfer, P. R. and R. W. Klein. 2003. "Regulation and Markets for Catastrophe Insurance", in Murat R. Sertel and Semih Koray (eds), Advances in Economic Design, Heidelberg: Springer Verlag.

Kleindorfer, P. R. and Kunreuther H. C. 1987. Insuring and Managing Hazardous Risks: From Seveso to Bhopal and Beyond. Heidelberg: Springer-Verlag,

Kleindorfer, P. R. and H. C. Kunreuther. 1999. The Complementary Roles of Mitigation and Insurance in Managing Catastrophic Risks. Risk Analysis, 19(4), 727-738.

Kleindorfer, P. R., H. C. Kunreuther, E. Michel-Kerjan and R. Zeckhauser. 2008. Mitigating and Financing Catastrophic Risks: Principles and Action Framework; Discussion Document, International Network on Financial Management of Large-Scale Catastrophes, Paris: OECD.

Kleindorfer, P. R. and J. Wind 2009. The Network Challenge: Strategy, Profit and Risk in an Interlinked World. Wharton Publishing Company, Upper Saddle Creek, NJ.

Knieps, G. and H. J. Weiss 2007. Regulatory Agencies and Regulatory Risk. Discussion Paper 118, Institut für Verkehrswissenschaft und Regionalpolitik, Universität Freiburg.

Knutson, T. R. 2008. Global Warming and Hurricanes: An Overview of Current Research Results. Geophysical Fluid Dynamics Laboratory/NOAA . At <http://www.gfdl.noaa.gov/global-warming-and-hurricanes>

Kunreuther, H. C. 2009. Long-Term Insurance and Climate Change. Working Paper # 2009-03-13, Wharton Risk Management and Decision Processes Center, University of Pennsylvania. At http://opim.wharton.upenn.edu/risk/library/WP2009-03-13_HK_LTI.pdf.

Kunreuther, H. C. 2009. The Weakest Link: Risk Management Strategies for Dealing with Interdependencies. Chapter 22 in Kleindorfer and Wind (2009).

Kunreuther, H. C. and E. Michel-Kerjan. 2009. At War with the Weather. Cambridge: MIT Press.

Leimbacher, U., R. Murray, D. Bassi and A. Spiegel. 2009. The Globalization of Collective Redress: Consequences for the Insurance Industry. Zurich: Swiss Reinsurance Company.

Linnerooth-Bayer, J., K. Warner, C. Bals, P. Höpfe, I. Burton, T. Loster and A. Haas. 2009. "Insurance, Developing Countries and Climate Change." The Geneva Papers, **34**, 381–400.

Munasinghe, M. 2009. Sustainable Development in Practice. Cambridge: Cambridge University Press.

Mansanet-Bataller, M. and A. Pardo 2008. What You Need to Know to Trade in CO2 Markets. Mission Climat de la Caisse des Dépôts, Paris. At <http://ssrn.com/abstract=1156973>.

Miller, S., R. Muir-Wood and A. Boissonnade. 2008. An Exploration of Trends in Normalized Weather-related Catastrophe Losses. In H. F. Diaz and R. J. Murnane (eds), Climate Extremes and Society. Cambridge: Cambridge University Press.

Mills, Evan. 2009. A Global Review of Insurance Industry Responses to Climate Change. The Geneva Papers **34**, 323–359.

Munich Re 2009. Natural catastrophes 2008: Analyses, Assessments, Positions. Munich : Munich Re Group.

Niskanen, W. A. 1968. Nonmarket Decision Making - The Peculiar Economics of Bureaucracy, American Economic Review, Vol. 58, No. 2, 293-305.

Peltzman, S. 1989. The Economic Theory of Regulation after a Decade of Deregulation, Brookings Papers on Economic Activity, Microeconomics, Vol. 1989, pp. 1-59.

Rauch, B. and M. Menhart. 2009. Impacts on the World Economy in a „Business as Usual“ Scenario. Chapter 3 in Geneva Association (2009).

Simonson, I. and P. Nye. 1992. The Effect of Accountability and Susceptibility on Decision Errors. Organizational Behavior and Human Decision Processes. 51, 416-446.

Skogh, G. 1998. Development Risks, Strict Liability and the Insurability of Industrial Hazards, Geneva Papers on Risk and Insurance—Issues and Practice. 23, 247-264.

Stern, N. 2007. The Economics of Climate Change: The Stern Review. Cambridge: Cambridge University Press.

Stern, N. 2008. "The Economics of Climate Change", American Economic Review, May, 98(2), 1-37.

Stigler, G. J. 1971. The Theory of Economic Regulation, The Bell Journal of Economics and Management Science, Volume 2, N° 1, pp. 3-21.

Swiss Re/ProClim 2009. SwissRe/ProClim Climate Fact Sheets (No. 1) (2nd ed.): Influence of global warming on tropical cyclones (Hurricanes, Typhoons). Zurich: Swiss Reinsurance Company.

Tullock, G. 2003, The Origin of the Rent-seeking Concept. International Journal of Business and Economics, Volume 2, N° 1, pp 1-8.

von Ungern-Sternberg, T. 2004. Efficient Monopolies: The Limits of Competition in the European Property Insurance Market,. Oxford: Oxford University Press.

Warner, K. and A. Spiegel. 2009. Climate Change and Emerging Markets: The Role of the Insurance Industry in Climate Risk Management. Chapter 7 in Geneva Association (2009).

WEF (World Economic Forum) 2008. CEO Climate Policy Recommendations to G8 Leaders. Geneva: World Economic Forum.

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