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Reflections on U.S. Disaster Insurance Policy for the 21st Century

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Executive Summary

This paper proposes that we examine the feasibility of including earthquake and water damage as part of a global homeowners policy for dealing with the catastrophic risk problem from natural disasters. By undertaking such an analysis one is forced to address the question as to who should pay for disasters and how can we encourage individuals to undertake protective measures in advance of the event.

Two key principles underlying any disaster insurance program is that the rates reflect the risk and that coverage is affordable. For lower income individuals it will be impossible to satisfy the first principle without some type of subsidy from the public sector. There are also a set of questions as to whether the private sector has the ability to cover losses from catastrophic disasters on their own or will need some type of public sector involvement.

There are a set of related issues that have to be considered when developing any type of disaster insurance program. These include the ability to assess the risk and the uncertainty of the models, the appropriate role of regulation, balancing the concerns of the different stakeholders concerned with this issue and the types of subsidies and back-up provision that can be offered by the public sector. Finally we need a clear understanding of the political and social landscape as well as how choices are actually made so as to develop a disaster insurance program as part of a hazard management strategy that achieve its desired impacts. The challenges in this regard are quite different today than they were in the 20th century because of the magnitude of losses from these disasters in the past few years.

Reflections on U.S. Disaster Insurance Policy for the 21st Century

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1. Introduction

The devastation caused by hurricanes during the 2004 and 2005 seasons has been unprecedented and is forcing the insurance industry to reevaluate the role that it can play in dealing with future natural disasters in the United States. As shown in Table 1 the four hurricanes that hit Florida in the fall of 2004 -- Charley, Frances, Ivan and Jeanne---and Hurricanes Katrina and Rita in 2005 comprised half of the top 12 disasters with respect to insured losses between 1970 and 2005. On a related note, 18 of the 20 most costly disasters occurred between 1990 and 2005 and 10 occurred in the 21st Century. This context is totally different than the scale of economic loss the country has suffered from natural disasters and other extreme events in the 20th century.

INSERT TABLE 1

Hurricane Katrina is the most costly event the insurance industry has ever experienced with estimated losses likely to be more than double that of Hurricane Andrew. It is difficult to believe that prior to Hurricane Hugo in 1989 there was not a single natural disaster in the United States that cost the insurance industry $1 billion. (Kunreuther and Roth Jr. 1998 Chap. 1)

The cause of these large losses is a product of several different forces. For one thing, there has been increased development of structures in hazard-prone areas. Data from the 2000 U.S. Census reveals that 53% of the U.S. population now resides along one of the oceans or inland coastlines. From 1970 to 2000 the southeastern Atlantic coast areas had an increase in population density of 66% far exceeding the national average of 38%. In Florida the population has increased by 535% between 1950 and 2005, up from 2.8 million to an estimated 17.8 million in 2005.[1] The total value of insured coastal exposure in the State of Florida was nearly $2 trillion at the end of 2004. Since financial institutions normally require homeowners to purchase insurance coverage as a condition for a mortgage, the amount of insurance in force has ballooned, leading to a greater potential for catastrophic insured losses today than in previous years.

[1] My thanks to Paul Amos for providing these data from the U.S. Census

There has also been an increase in hurricane activity in the North Atlantic basis. During the past ten years the number of hurricanes has increased by more than 60% relative to the low activity period between 1970-1994 and the number of category 3-5 storms have increased by more than 150% when compared with the previous 25 year period. (Risk Management Solutions 2006). The cause of this increased hurricane activity has been actively debated by scientists, especially in the past couple of years. MIT's Kerry Emanuel, a leader in the field, has concluded that the changing pattern is partially due to global warming and that future warming may lead to an upward trend in the destructive potential of future hurricanes. (Emanuel 2005).

An appropriately designed disaster insurance program is vital for stemming the tide of increasing losses from natural disasters while at the same time providing funds to those suffering losses. This paper addresses the following three questions that are likely to determine the shape of a disaster insurance program in the United States:

- What principles should be adhered to in developing a disaster insurance program?
- What is the appropriate balance between private and public sector participation in a disaster insurance program?
- Can an insurance policy that provides coverage against all natural perils attractive to homeowners and insurers as well as policymakers at the local, state and federal levels?

The next section of the paper addresses the first question by outlining two principles on which a disaster insurance program should be based. Section 3 then focuses on the second question by analyzing the insurability of a risk and examining the challenges facing the private sector in providing coverage against natural disasters. Section 4 turns to the third question and delineates the opportunities and challenges of a comprehensive disaster insurance program. Section 5 poses a set of open issues that are currently being addressed by a research project on disaster insurance undertaken by the Wharton Risk Center in conjunction with the Insurance Information Institute and Georgia State University. The concluding section summarizes the key issues associated with providing disaster insurance in the 21st century.

2. Principles of a Disaster Insurance Program

The principles on which to base a disaster insurance program can be highlighted by focusing on a hypothetical homeowner residing in a Gulf Coast community subject to damaging hurricanes:

> The Baylors have a 20 year mortgage on a home along the Gulf Coast that is currently valued at $200,000. The bank that issued the mortgage requires them to purchase a homeowners insurance policy. The best estimate of the annual chance of a severe hurricane that will cause damage to the Baylors house is p =1 in 100. If the hurricane occurs it will totally destroy the Baylor home so that the loss will be *L=$200,000*.

Principle 1: Risk-based premiums

Insurance premiums should reflect the underlying risk associated with the events against which coverage is provided. To illustrate this principle in the context of the Baylors home, the expected loss to their property from hurricanes is estimated to be *pL=$2,000.* A risk-based premium would be $2000(1+λ), where λ is a loading factor reflecting the costs to the insurer of marketing a policy, assessing the risk, settling the claim if any, and making normal profits. If λ = .5, then a risk-based premium for the Baylors home would be $3000.

Risk-based premiums provide a clear signal to individuals and businesses of the dangers they face when locating in hazard-prone areas and provide economic incentives to invest in cost-effective mitigation measures. To highlight these points suppose that a state insurance regulator restricted rates in hurricane-prone areas so that the maximum premium that an insurer could charge the Baylors would be $1500. Assume the Baylors knew that the loading factor on an insurance policy was λ =.5, and that if a hurricane occurred in their area it would destroy their home. Based on the $1500 premium, the Baylors would then conclude that the chances of such a disaster occurring would be 1/200 rather than 1/100. More generally, highly subsidized premiums due to rate regulation, without clear communication on the actual risk facing the homeowner, will encourage development of hazard-prone areas in ways that are costly to both the individuals who locate there as well as the rest of society who are likely to incur the costs of bailing out victims following the next disaster.

There is an additional reason why insurance premiums can make individuals aware of the relative risks associated with locating in different areas. Empirical studies have revealed that

individuals rarely seek out probability estimates in making their decisions, and that low probabilities are inherently difficult to comprehend. When explicit probabilities are given to decision makers they often do not use the information. [Magat, Viscusi and Huber (1987) and Camerer and Kunreuther (1989)]. In one study, researchers found that only 22 percent of subjects sought out probability information when evaluating several risky managerial decisions. When another group of respondents was given precise probability information, less than 20 percent mentioned the probability in their verbal protocols. [Huber, Wider and Huber (1997)]. In other words, people do not deal with uncertainty in ways that would be predicted by normative models of choice.

People are much more likely to pay attention to dollar expenditures when making location decisions. If they have comparative data on insurance premiums in different regions and know that these are risk-based rates, they will be able to determine the relative safety of different areas. In a controlled experimental study on whether individuals can distinguish between probabilities or insurance premiums for low probability events, Kunreuther, Novemsky and Kahneman (2000) found that it was necessary to present comparative information on high and low risk situations for people to judge how safe an area would be with respect to its risk.

Risk-based rates also encourage investment in risk mitigation measures that are cost-effective. Suppose that the Baylors could reduce property damage caused by a hurricane by bracing their roof trusses and installing straps or clips at a cost of $1500. If the annual probability of a hurricane causing damage to their house is 1/100 and the reduction in loss due to strengthening the roof in this manner is $50,000, then the expected annual benefit from roof mitigation to the Baylors is $500 and a risk-based insurance premium with λ =.5 should be reduced by $750 [i.e. $500(1.5)]. If the Baylors were offered a 20 year home improvement loan of $1500 at a 10% annual rate of interest to make their roof more hurricane resistant, their annual loan payment would be $145. The annual savings to the Baylors from investing in this mitigation measures would thus be $605. The bank will also feel that it is now better protected against a catastrophic loss to the property and the insurer knows that its potential loss from a major disaster is reduced. The general public will now be less likely to have large amounts of their tax dollars going for disaster relief. This represents a win-win-win-win situation for these concerned stakeholders.

Now suppose that an insurer would only be allowed to charge the Baylors $1500 for an insurance policy due to state regulations. Then the insurer would have **no** economic incentive to provide a premium discount for undertaking a mitigation measure. In fact, no insurer would want to market coverage to the Baylors or any homeowner in the hurricane-prone area with similar risks because in the long-run the insurer would lose money on each of these policies. More specifically, an insurer's annual expected loss on the Baylors home would be greater than the $1500 they would be receiving in premiums.[2]

Principle 2: Affordable Insurance

In developing an insurance program that stands any chance of being implemented it is necessary to recognize the tension between setting premiums that reflect risk and the financial ability of residents in hazard-prone areas to buy coverage. This was a major issue in the development of the National Flood Insurance Program (NFIP) in 1968. There was great concern that if flood insurance rates were risk-based, then many residents in hazard-prone areas would be charged extremely high premiums for flood coverage and would not want to purchase it. Hence the program was developed with two layers---a subsidized rate for residents currently residing in hazard-prone areas and an actuarially based rate for those who built or substantially improved their structures after the federal government provided complete risk information in the area through flood insurance rate maps (Pasterick 1998). The subsidized rate was also designed to maintain the property values of structures in flood prone areas.[3]

There are some lessons to be learned from the experience of the NFIP that should guide the development of a future disaster insurance program. With subsidized rates there are no economic incentives for residents in hazard-prone areas to invest in mitigation measures because they will not be given premium discounts. Property owners that have repeatedly suffered damage from floods have rebuilt their property in the same location and continue to receive subsidized insurance rates. A recent U.S General Accountability Office (GA0) (2006) study revealed that structures receiving flood insurance payments of $1000 or more over a 10 year period constitute

[2] If the insurer were forced to provide coverage to the Baylors at a premium of $1500 then they would want to offer a premium discount to encourage them to invest in roof mitigation since it would lower their claims payments following a disaster.

[3] The distribution of flood insurance business written in 2005 is anticipated to be 26% at subsidized rates and 74% at risk-based rates. Those being charged a subsidized rate are estimated to pay between 35% and 40% of the risk-based premium. (Hayes and Sabada 2004).

less then 1 percent of the properties covered under the NFIP but involve approximately 25-30 percent of all claims under the program. To address this problem the Flood Insurance Reform Act of 2004 provides states and local communities with an additional $40 million a year for mitigating severe repetitive loss properties such as buyouts, elevation or moving the house (King 2006).

Based on the experience of the NFIP, one should **not** provide subsidized premiums to those residing in hazard-prone areas. Rather either the State or Federal government should offer some type of subsidy or grant that enables low income residents to purchase insurance at a risk-based premium. Suppose that the Baylors had inherited their home and that the family's annual income was $50,000 so that they could not afford to pay $3000 for coverage against damage from hurricanes. Rather than having state regulators set a maximum premium of $1,500 for insuring homes like the Baylors, the family could be given an *insurance voucher* that must be used to buy homeowners coverage. The program could be similar in spirit to the food stamp program. The magnitude of the voucher would be based on the income and assets of the resident. Homeowners could also be provided with subsidies or loans to invest in cost-effective mitigation measures and in return be charged a lower insurance premium reflecting the reduced damage to their structure from a future disaster.

3. Providing Protection by the Private Sector: Insurability Issues

Consider an insurer who would like to provide protection to individuals residing in hazard-prone areas of the United States. What factors will be important to the insurer in determining whether to offer coverage and if so, how much should it charge for this protection? These questions relate to the insurability of a risk. By *insurability* we mean the ability of the insurer to offer coverage to individuals at a price that generates sufficient demand for them to cover the fixed costs of developing and offering the product.

A set of papers from researchers associated with the Wharton Risk Center have examined the conditions for insurability.[4] Cummins (2006) and Litan (2006) have recently examined this issue in the context of catastrophic risks. The discussion that follows utilizes concepts from these papers by focusing on a hypothetical insurer, *Naturesway*, who is deciding whether or not it

[4] See Freeman and Kunreuther (1997) Kunreuther and Roth Chapter 2 (1998) and Wharton Risk Center (2005)

wants to provide coverage to protect homeowners like the Baylors against damage to its house and contents from future hurricanes.

Law of large numbers

Naturesway and other insurers are likely to be concerned about the variability of profits from the risks they insure. The ideal risk is one where the potential loss from each insured individual is relatively small and independent of the losses from other policyholders. As the insurer increases the number of policies it issues in a year, the variance in its annual losses decreases. In other words, the law of large numbers makes it highly unlikely that the insurer will suffer an extremely large loss relative to the premiums collected.

Fire is an example of a risk that satisfies the law of large numbers since losses are normally independent of one another. To illustrate the application of this law, suppose that an insurer wants to determine the accuracy of the estimated fire loss for a group of identical homes valued at $100,000, each of which has a 1/1,000 annual chance of being completely destroyed by fire. If one assumes that only one fire can occur to any structure during the year, the expected annual loss for each home would be $100 (i.e. 1/1000 x $100,000). As the number of fire insurance policies n increases, then the variance of the expected annual loss decreases in proportion to n. Cummins (2006) considers the case where the insurer is willing to accept a low probability of insolvency ε arising out of a catastrophic loss when insuring a book of business. He shows that for risks which are independent and whose losses are characterized by the normal distribution so that the central limit theorem applies, the equity capital per policy approaches zero as the number of insured policies becomes very large.

Conditions for Insurability

The law of large numbers is predicated on the ability of *Naturesway* or other insurers to estimate the likelihood and consequences of a risk and for the risks to be independent of each other. The risks associated with large-scale natural disasters are unlikely to satisfy the law of large numbers. The following three conditions can then determine the degree to which such a risk is insurable:

Condition 1 is the ability to identify and quantify, or estimate, the chances of the event occurring, and the extent of losses likely to be incurred when providing different levels of coverage.

Condition 2 is the ability to set premiums for each potential customer or class of customers. This requires some knowledge of the customer's risk in relation to others in the population of potential policyholders.

Condition 3 is the generation of sufficient demand and revenue from insuring this risk to cover the development, marketing and claims costs incurred by the insurer and still yield the firm a positive expected profit.

I will now examine each condition and raise some questions related to the ability of private insurers to provide coverage in the 21st century.

Condition 1: Identifying the Risk

To satisfy this condition, estimates must be made of the frequency at which specific events occur and the magnitude of the loss. The fire risk is relatively easy in this regard since there are considerable past data available to determine the likelihood of damage of different magnitudes to different type structures in certain locations (e.g. distance from a fire hydrant).

Due to the infrequency of natural disasters insurers have turned to scientific studies by scientists and structural engineers to estimate the frequency of hurricanes, earthquakes and floods of different magnitudes, as well as the damage that is likely to occur to different structures from these disasters. New advances in information technology have led to the development of catastrophe models (CMs) which have proven very useful for quantifying the likelihood of disasters of different magnitudes and the resulting damage to properties as a function of the type of construction, location and other variables.

A CM combines scientific risk assessments of the hazard with historical records to estimate these probabilities and resulting damage. The information can be presented in the form of expected annual losses and/or through exceedance probability (EP) curves such as the probability that in a given year *Naturesway's* damage claims from hurricanes will exceed a certain dollar amount. CMs can also be used to calculate estimated insured losses from specific

hypothesized events (e.g. a severe hurricane hitting downtown Miami and Miami Beach in 2006).

The occurrence of Hurricane Andrew in Florida in 1992 and the Northridge earthquake in California in 1994 stimulated the insurance industry to pay more attention to output from these CMs. Today these models are utilized by individual insurers and reinsurers to determine how much coverage they should provide, what premiums to charge, and where coverage should be offered and restricted to increase the firm's profitability while reducing the probability of severe financial losses.[5]

During the first half of 2006 the three leading modeling firms [AIR Worldwide, EQECAT and Risk Management Solutions (RMS)] reevaluated their hurricane models based on the losses from the recent hurricanes in Florida and the Gulf Coast and new scientific studies. All three firms have revised their near-term models to incorporate an increased likelihood of hurricanes in the next five years and hence higher expected annual losses than they had predicted in 2005.

Condition 2: Setting Premiums for Specific Risks

Once the risk has been identified, *Naturesway* and other insurers need to determine what premium it can charge to make a profit while not subjecting itself to an unacceptably high chance of insolvency or severe loss of surplus due to a catastrophic loss. There are several factors that determine what premiums insurers would like to charge if they are unregulated.

Ambiguity of Risk

The greater the ambiguity the probability of a specific loss and the uncertainty of the claims payments, the higher the premium will be. In a mail survey of professional actuaries conducted by the Casualty Actuarial Society, 463 respondents indicated how much they would charge to cover losses against a defective product where the probabilities of a loss was well specified at p=.001 and where they experienced considerable uncertainty about the likelihood of a loss. The median premium values were five times higher for the uncertain risk than for the well-specified probability when the losses from each insurance policy were independent. This

[5] For a detailed analysis of the use of catastrophe models in the context of natural disasters see Grossi and Kunreuther (2005).

ratio increased to ten times when the losses were perfectly correlated. (Hogarth and Kunreuther 1989).

In another study a questionnaire was mailed to 190 randomly chosen insurance companies of different sizes asking underwriters to specify the prices which they would like to charge to insure a factory against property damage from a severe earthquake, to insure an underground storage tank and to provide coverage for a neutral situation (i.e. a risk without any context). Probabilities and losses were varied. The probability of loss and the size of the claim were either well-specified or there was ambiguity regarding the likelihood of the loss and/or the claim size. The underwriters wanted to charge considerably more for the same amount of coverage when either the probability was ambiguous and/or the claim size was uncertain. (Kunreuther et al. 1993).

Adverse Selection

If the insurer sets a premium based on the average probability of a loss, using the entire population as a basis for this estimate, those at the highest risk for a certain hazard will be the most likely to purchase coverage for that hazard. In an extreme case, the poor risks will be the only purchasers of coverage, and the insurer will lose money on each policy sold. This situation, referred to as *adverse selection*, occurs when the insurer cannot distinguish between the probabilities of a loss for good- and poor-risk categories, but the insured can. Given the development of catastrophe models and better scientific data on the nature of the risks facing different parts of the country it is unlikely that adverse selection present a major problem today for insurers providing coverage against damage from natural disasters.[6]

Moral Hazard

Moral hazard refers to an increase in the probability of loss caused by the behavior of the policyholder. For example, providing insurance protection to an individual may lead that person to behave more carelessly than before he or she had coverage. One way to avoid the problem of moral hazard is to introduce *deductibles* and *coinsurance* as part of the insurance contract. A sufficiently large deductible can act as an incentive for the insureds to continue to behave carefully after purchasing coverage because they will be forced to cover a significant portion of their loss themselves. With coinsurance the insurer and the insured share the loss together. As

[6] The absence of adverse selection has been empirically demonstrated in several other insurance markets. In these markets the data show that there is no positive correlation between the level of risk and the quantity of insurance

with a deductible, this type of risk-sharing arrangement encourages safer behavior because those insured want to avoid having to pay for some of the losses.[7]

Even with these clauses in an insurance contract, individuals may still behave more carelessly with coverage simply because they are protected against a large portion of the loss. For example, they may decide not to take precautionary measures that they would have adopted had they been uninsured. The cost of adopting mitigation may now be viewed by policyholders as too high relative to the dollar benefits that the insured perceives it would receive from this investment.

The other type of moral hazard problem that could exist with respect to natural hazards is illustrated by a decision to move unwanted furniture to the basement a day or two in advance of a predicted flood or hurricane to increase the likelihood that they will be damaged or destroyed than had they remained in their normal spots. Similarly a homeowner may claim cracks and other damage that existed prior to the earthquake from the disaster itself (*ex post* moral hazard)). A sufficiently large deductible might prevent individuals from putting contents in harms way or providing false information about the cause of damage from a disaster.

Correlated Risk

Earthquakes, floods, hurricanes and other large-scale natural disasters produce highly correlated losses since many homes in the affected area are damaged and destroyed by a single event. Insurers who cover the risks from such disasters may have to pay potentially large claims to policyholders before they are able to collect sufficient premiums to cover their costs. This *timing risk* is an important element associated with highly correlated risks and catastrophic losses. [Litan (2006)].

To illustrate the nature of timing risk consider the decision by *Naturesway* as to how much coverage it will want to offer and what premium it will want to charge for damage to homes in one region of the Gulf Coast from future hurricanes. To keep the analysis simple assume that all the structures are identical to the Baylor home. Each home is valued at $200,000 and will be destroyed by a hurricane that has a probability of 1/100 of occurring next year. Suppose *Naturesway* insured 100 such homes in the area at a risk-based premium of $3000 [i.e.

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coverage. For a survey of these studies during the past ten years see Henriet and Michel-Kerjan (2006).

[7] For more details on deductibles and coinsurance in relation to moral hazard, see Pauly, 1968.

$(1+\lambda)pL = 1.5$ ($2000)] and the hurricane would destroy all the homes (i.e. perfect correlation). Then *Naturesway* would collect $300,000 in premiums each year but would be forced to pay out $20 million in claims should a damaging hurricane hit the area where the Baylors and others live. Unless *Naturesway* had considerable surplus it could become insolvent from this event. Should that be the case, and depending on which state it operates, part of the claims *Naturesway* is unable to pay would be reassessed against all other insurers operating in this state, as we have seen after the 2004 and 2005 hurricanes when several catastrophe state funds became technically bankrupt.

More generally, this has been also a critical issue facing countries when they set up any type of insurance pool for covering losses from catastrophic events such as natural disasters or terrorism. Several countries have responded by providing the pool with some type of temporary federal backstop to cover losses should the pool not have enough reserves to pay claims from a major disaster. When this occurs the pool is responsible for reimbursing the central government after it gets back on its feet again (e.g., Pool Re in the UK for terrorism insurance).

Actuaries and underwriters both utilize heuristics that reflect this concern with insolvency in determining how much coverage to offer in hazard-prone areas and what premium to charge. Actuaries at *Naturesway* will first use their best estimates of the likelihood of hurricanes of different intensities to determine an expected annual loss to the property and contents of a particular residence such as the Baylor home. Underwriters utilize the actuary's recommended premium as a reference point and then focus first on the impact of a major disaster on the probability of insolvency or some prespecified loss of surplus to determine an appropriate premium to charge and the number of policies to market. (Kunreuther 1989).

Roy (1952) first proposed a safety-first model to characterize this type of firm behavior. In the context of insurance, such a model explicitly concerns itself with insolvency when determining the maximum amount of coverage the insurer should offer and the premiums to charge. Stone (1973) formalized these concepts by suggesting that an underwriter who wants to determine the conditions for a specific risk to be insurable will first focus on keeping the probability of insolvency below some threshold level (q^*). Let A = the insurer's total assets. The underwriter is considering whether to provide coverage for a risk at a premium z^* for each policy it sells. The likelihood of a loss occurring is p and the magnitude of the loss is L. Then a

safety first model implies that the underwriter will determine the maximum number of policies *m* it is willing to sell so that

$$\sum_{j=1}^{m} \{\text{Probability } [jL > (A+mz^*)]\} < q^* \qquad (1).$$

where q^* is a preassigned probability that reflects the insolvency probability that the firm is willing to tolerate (i.e. its acceptable risk of insolvency).[8]

To illustrate the nature of a safety-first model for underwriters, suppose that *Naturesway* had a surplus of A= \$15 million and wanted to determine how many policies to write in the hazard-prone area where the Baylors locate. Suppose the risks were perfectly correlated and there is a probability $p=1/100$ of a loss of $L= \$200{,}000$ to each house that *Naturesway* insured against damage from hurricanes. If *Naturesway* charged a risk-based premium of \$3,000 per policy and $q^* < 1/100$, then the underwriter would not want to write more than 76 policies in order to meet the solvency constraint given by equation (1).[9] *Naturesway* would only want to maintain its current book of business of 100 insured homes in the area if it could transfer some of the risk of a catastrophic loss to others through reinsurance or financial instruments such as catastrophe bonds.

Rating agencies may also play a role in influencing how many policies an insurer will want to write on risks with respect to catastrophic losses. A recent report by AM Best focuses on the importance of the ratio of annual insured catastrophic losses as percentage of policyholder surplus (PHS). In general, the report notes that the higher the level of loss relative to surplus, the greater has been the financial damage to the insurance industry (Williams and King 2006).

The AM Best report points out that insured catastrophic losses of less than 5% of PHS has been the norm during the 88 of the past 100 years and that the damage to the industry's financial stability has been minimal. On the other hand, when insured catastrophic losses are between 10% and 20% of PHS, as was the case in 1938 with the Great New England hurricane

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[8] The use of a safety-first model implies that underwriters are risk averse. Greenwald and Stiglitz (1990) contend that managers suffer damage to their personal career prospects if their companies become insolvent and that they cannot diversify their risk as owners of the firm can. By this logic, underwriters would focus on the insolvency constraint where the owners of the firm would be less likely to do so.

[9] Since the risks are perfectly correlated for this example and $q^* < 1/100$, the maximum number of policies (m^*) is determined by finding the largest value of m where $mL < A+mz^*$. If L=\$200,000, A= \$15 million and z^*= \$3,000 then $m^* = 76$.

and in 1992 with Hurricanes Andrew and Iniki, then there was considerable financial stress placed on the industry.

It is unclear how rating agencies treat the ratio of catastrophic losses/policyholder surplus for individual firms. In the case of the terrorism risk, insurers are concerned with maintaining an aggregate exposure to any terrorist attack at no more than 10 percent of its surplus based on concerns that they might be downgraded by rating agencies if their exposure/surplus ratio exceeded this percentage (Wharton Risk Center 2005). If one applies the same criterion to natural disasters, then insurers would want to limit its coverage against catastrophic risk by reducing the number of policies that it insures unless it could lay off a portion of its risk through reinsurance or other risk transfer instruments. In the above example, if *Naturesway* had a surplus of $15 million it would only want to write 7 homeowners policies, each for coverage of $200,000, should the insurer believe that the losses were perfectly correlated and it wanted to keep its cat risk potential less than 10% of its surplus (i.e. below $1.5 million).

Condition 3 Sufficient Demand for Coverage

After examining the coverage that *Naturesway* believes it can offer at risk-based rates, the company may be convinced that it cannot offer enough policies to cover the fixed costs associated with developing a program for marketing coverage. One alternative is to raise premiums to cover some of these costs but this would adversely affect demand. If there are regulatory restrictions that limit the price insurers can charge for certain types of coverage, then *Naturesway* may not want to provide protection against these risks. In addition, if *Naturesway's* portfolio leaves them vulnerable to the possibility of extremely large losses from a given disaster due to adverse selection, moral hazard, and/or high correlation of risks, then it will want to reduce the number of policies in force for these hazards.

To illustrate the challenges that insurers face in this regard, suppose *Naturesway* is considering marketing a new policy where the fixed costs are D dollars to develop and administer in addition to the marginal costs associated with marketing a policy and processing claims that comprise the loading factor λ. The fixed cost D can be spread across the number of policies that the insurer is able to sell. To the extent that *Naturesway* is restricted in selling large numbers of policies because of the impact that a loss will have on its surplus, a higher premium will have to be charged per policy sold in order to cover these fixed costs D. However, the

higher the premium will lower the demand for coverage. In other words high values of D coupled with a concern with insolvency may make a risk uninsurable even if there are no rate regulations. It is thus not surprising that some insurers are reluctant to offer coverage against risks that have catastrophic potential particularly after suffering losses from a major disaster that causes a large loss of surplus. Any restrictions on the rates that insurers can charge for coverage will exacerbate the problem.

In fact, recent experience with losses from large-scale disasters suggests that the insurance industry will turn to the public sector for assistance. Following Hurricane Andrew, which caused $21.5 billion in insured losses (in 2002 prices) to property in the southern coast of Florida, some insurers felt that they could not continue to provide coverage against wind damage in hurricane-prone areas within the State, especially since insurance rate regulation would prevent them from charging the high rates required to continue writing coverage. This led to the formation of the Florida Hurricane Catastrophe Fund that reimburses a portion of insurers' losses following major hurricanes (Lecomte and Gahagan 1998).

In the case of earthquakes, the Northridge, CA earthquake of January 1994 caused $12.5 billion in private insured losses while stimulating considerable demand for coverage by residents in earthquake-prone areas of California. Insurers in the state stopped selling new homeowners policies because they were required to offer earthquake coverage to those who demanded it and were concerned with the possibility of suffering large losses from the next severe earthquake in California. This led to the formation of the California Earthquake Authority (CEA) in 1996 which limited the losses that insurers can suffer from a future earthquake (Roth, Jr. 1998).

Given rate and coverage restrictions imposed on them, some insurers claim that coverage for wind damage from hurricanes and earthquake losses **cannot** be profitably marketed today in Florida and California.[10] Insurers reached a similar conclusion a number of years ago with respect to the flood hazard, which led to the development of the National Flood Insurance Program in 1968.

[10] It should be noted that most insurance companies made large profits prior to the early 1990s by marketing hurricane insurance in Florida and earthquake coverage in California. However, all of these disappeared, and more, with the occurrence of Hurricane Andrew and the Northridge earthquake.

4. Comprehensive Disaster Insurance---Advantages and Disadvantages[11]

One way to deal with issues of insurability discussed above is to have insurers provide coverage against all hazards in a single policy. Current insurance programs for residents in hazard prone areas are segmented across perils. Standard homeowners and commercial insurance policies, normally required as a condition for a mortgage, cover damage from fire, wind, hail, lightning, winter storms and volcanic eruption. Earthquake insurance can be purchased for an additional premium. As noted in the introduction, flood insurance for residents and businesses is offered through the National Flood Insurance program, a public-private partnership created by Congress in 1968.

If one is to develop a comprehensive disaster insurance policy it should adhere to the two principles of risk-based rates and affordability discussed in Section 2. A comprehensive insurance policy with risk-based premiums is likely to come closer to meeting the conditions of insurability discussed in the previous section than the current program. However, it also presents challenges for small insurers that market policies in only a single state subject to catastrophic losses from natural disasters. All insurers face the challenge of having to convince a policyholder living far away from any water that he is not being charged a premium to cover the losses from those at risk from flood damage.

The idea of a comprehensive disaster insurance program where all natural disasters are covered by a single policy is not a new one. I proposed such a program for the United States many years ago in one of my first papers on the disaster insurance (Kunreuther 1968). In 1954 Spain formed a public corporation, the Consorcio de Compensation de Seguros (CCS) that today provides mandatory insurance for so-called "extraordinary risks" that include natural disasters and political and social events such as terrorism, riots and civil commotion. Such coverage is an add-on to property insurance policies that are marketed by the private sector. CCS pays claims only if the loss is not covered by private insurance, if low income families did not buy insurance and/or the insurance company fails to pay because it becomes insolvent. The government collects the premiums and private insurers market the policies and handle claims settlements (Freeman and Scott 2005).

[11] This section is based on Kunreuther (2006) and Kunreuther and Pauly (in press).

In France, a mandatory homeowners policy also covers number of different natural disasters along with terrorism. The main difference comes at the reinsurance level which is partially provided by a publicly owned reinsurer, the Caisse Centrale de Reassurance, for flood, earthquakes, and droughts, and by an insurance pool, Gareat, with unlimited government guarantee for terrorism. There is no public reinsurance for storms (Michel-Kerjan and de Marcellis, 2006).

Advantages of Comprehensive Disaster Insurance

Consider an insurer marketing homeowners coverage in different parts of the country. With risk-based rates it will collect premiums that reflect the earthquake risk in California, hurricane risk on the Gulf Coast, tornado damage in the Great Plains states and a flood risk in the Mississippi Valley. Each of these disaster risks is independent of the others. Using the law of large numbers discussed above, this higher premium base and the diversification of risk across many hazards reduces the likelihood that such an insurer will suffer a loss that exceeds its surplus in any given year for a given book of business.

An all-hazards homeowners policy should also be attractive to both insurers and policyholders in hurricane-prone areas because it avoids the costly process of having an adjuster determine whether the damage was caused by wind or water. This problem of separating wind damage from water damage was a particularly challenging one following Hurricane Katrina. Across large portions of the coast, the only remains of buildings were foundations and steps where it is difficult to determine the cause of damage. In these cases insurers may decide to pay the coverage limits rather than incurring litigation costs to determine whether the damage came from water or wind. For a house still standing, this process is somewhat easier since one knows, for example, that roof destruction is likely to be caused by the wind and water marks in the living room are signs of flooding (Towers Perrin 2005).

An all hazards policy would also deal with the problem that insurers currently face with respect to fire damage caused by earthquakes. Even if a homeowner has not purchased an earthquake insurance policy it will be able to collect any damages from an earthquake due to fire. In the case of the 1906 San Francisco earthquake most of the damage was caused by fire and insurers were on the hook to cover these losses. In this sense homeowners insurance actually covers a portion of earthquake losses even though this coverage is excluded from the policy

Another reason for having an insurance policy that covers all hazards is that there will be no ambiguity by the homeowner as to whether or not she has coverage. Many residing in the Gulf Coast believed they were covered for water damage from hurricanes when purchasing their homeowners policies. In fact, lawsuits were filed in Mississippi and Louisiana following Katrina claiming that homeowners policies should provide protection against water damage even though there are explicit clauses in the contract that excludes these losses (Hood 2005).

The attractiveness of insurance that guarantees that the policyholder will have coverage against all losses from disasters independent of cause has also been demonstrated experimentally by Kahneman and Tversky (1979). They showed that 80 percent of their subjects preferred such coverage to what they termed probabilistic insurance where there was some chance that a loss was not covered. What matters to an individual is the knowledge that she will be covered if her property is damaged or destroyed, not the cause of the loss. Such a policy has added benefits to the extent that individuals are unaware that they are not covered against rising water or earthquake damage in their current homeowners policy.

Another advantage of a comprehensive homeowners program is that it may address some of the issues that currently plague the National Flood Insurance Program. As noted in a recent GAO report (2006) only half of the properties eligible for flood insurance are covered by it. Furthermore there were a number of properties suffering water damage from Hurricane Katrina that were not eligible to purchase flood insurance under the NFIP. Those who did have flood insurance and suffered large losses from the rising waters were only able to cover a portion of their losses because the maximum coverage limit for flood insurance under the NFIP is $250,000 on building property and $100,000 on personal property (Hartwig and Wilkinson 2005).

Naturally, an all-hazards insurance policy will be more expensive than the standard homeowners policy because it is more comprehensive. If premiums are based on risk then policyholders would only be charged for hazards that they face. Thus a homeowner in the Gulf Coast would theoretically be covered for earthquake damage but would not be charged anything for this additional protection if the area in which they reside is not a seismically active area. In promoting this all-risk coverage one needs to highlight this point to the general public who may otherwise feel that they are paying for risks that they do not face.

Disadvantages of Comprehensive Disaster Insurance

The major disadvantage of a comprehensive disaster insurance program with risk-based rates is that it will force state regulators to raise their rates considerably to cover the potential damage in hazard-prone areas. For example, in Florida insurance rates along the coast subject to hurricanes are currently well below the actuarially fair premium.(Grace, Klein and Kleindorfer 2004). If insurance commissioners allow companies to charge a rate that reflects the risk many individuals will be forced to pay premiums that are considerably higher than what they are currently charged. Many are likely to complain that this is highly unfair and unanticipated.

A large increase in premium will be viewed by homeowners as unjustified and there will be significant resistance to paying for this coverage. For high income residents who have second homes on the coast there is an economic rationale for them to pay the cost of their insurance. A step in this direction was recently discussed by the Florida legislature indicating that homes valued at over $2 million would have to be turned down by three surplus lines carriers (whose rates are not regulated) before they could turn to the state fund for coverage. For lower income residents there needs to be an insurance subsidy from the state or federal government (as discussed in Section 2) so that these homeowners can afford to purchase coverage.

Many insurers are likely to resist a comprehensive disaster insurance program because they may fear the possibility of even larger losses than they have suffered to date. Some note that if both wind and water damage were to be included in a homeowners policies the losses from Hurricane Katrina to private insurers would be considerably higher. In order for insurers to feel comfortable with such a program they would have to be able to protect themselves against catastrophic losses either through private risk transfer instruments (e.g. reinsurance, catastrophe bonds), State funds or federal reinsurance.

There will also be special needs facing small companies operating in a single state who have smaller surplus than larger firms and are limited in their ability to diversify their risk. These insurers may find that the variance in their losses increases by incorporating the flood and earthquake risks as part of a homeowners policy. For example, a Louisiana insurance company providing protection against hurricane damage might find the variance in losses to be higher than it is today if both wind and water damage were covered under a homeowners policy. For these companies to compete with larger firms they would have to be able to protect themselves against

catastrophic losses through either private or public-based risk transfer instruments that would not price them out of the market.

These smaller firms need to be differentiated from single-state subsidiaries established by some national insurer groups to help the parent company maintain or establish a high financial rating. The parent company has the option to disown itself from this single state subsidiary should it suffer a catastrophic loss (Grace, Klein and Liu 2006). There needs to be some protection given to the policyholders in this case should the single-state subsidiary declare itself to be insolvent.

Insurers who market a comprehensive disaster insurance policy face an additional challenge in trying to convince homeowners that they are only paying for risks that they actually face. One way for them to do this is to itemize the cost of different types of coverage on the policy itself in much the way current homeowners or automobile insurance breaks up the cost for different types of protection. If the Baylor family knew that it would be paying $3,000 for wind coverage, $1500 for water coverage. $500 for fire coverage and $0 for earthquake coverage, it would not complain about covering damage from seismic risk facing California homeowners. Such an itemized list of coverage would also highlight the magnitude of risks that the Baylors faced by living in their home, another role that insurance can play----a signal as to how hazardous a particular place is likely to be.

5. Open Issues for Future Research

There are a number of issues that need to be examined in order to determine whether a comprehensive disaster insurance program has a chance of being implemented, whether an alternative disaster insurance program is more appropriate or whether one should maintain the status quo. A program of research is now being undertaken by the Wharton Risk Management and Decision Processes Center in conjunction with the Insurance Information Institute and Georgia State University that will be exploring these issues.

Mandatory vs. Voluntary Insurance

Should all property owners be required by the federal or state government to have insurance coverage against natural disasters? Today banks normally require homeowners and commercial insurance as a condition for a mortgage. There will be some individuals who either

own their house outright or are not required by their bank to purchase insurance. One of the open questions where we need better data are the number of uninsured homes in hazard prone areas and the income distribution of those individuals who reside in them. If there are a significant number of uninsured individuals, many of whom are in the middle and low income brackets, the federal government is likely to provide financial [12]assistance following the next large-scale disaster. If the disaster occurs at a critical time in the political process it is almost certainty that liberal relief will be forthcoming. One only has to look back at earlier disasters, such as the Alaskan earthquake of March 1964 and Tropical Storm Agnes of June 1972 that occurred during a Presidential election year, to remind oneself of the type of aid the Federal government is capable of giving. In both disasters there were low interest loans and forgiveness grants that actually resulted in individuals being financial better off after the disaster than before the event. Moss (2002) documents the nature of government assistance for both natural disasters and other risks.

If the prevailing view is that those residing in hazard-prone areas should be responsible for covering their own losses then a mandatory insurance program would be appropriate. Many states require automobile insurance as a condition for obtaining a license. Disaster insurance could be treated in a similar fashion by including the premium as part of a person's property tax assessment. To the extent that individuals misperceive the amount of assistance they will receive following a disaster, requiring insurance may be viewed by them as a blessing should these individuals suffer losses from a disaster. Following Hurricane Katrina uninsured victims complained about not receiving more disaster assistance. They may not have known that under the Stafford Act, the maximum amount of assistance to any individual or household for repairing damaged property is $25,000 (FEMA 2006). Although the Small Business Administration (SBA) offers loans of up to $200,000 for repairs to damaged primary residences, low income residents may not eligible for them because of their inability to repay the loan.

Tax Write-offs for Uninsured Losses

One factor that needs to be considered when examining whether or not to make insurance mandatory are the income tax provisions with respect to uninsured losses. At the federal level homeowners who have losses from a disaster that exceed 10% of their income can deduct this

[12] For more details on the disaster assistance program following these two disasters see Kunreuther (1973).

loss when filing their taxes.[13] Homeowners in a high tax bracket who are not required to purchase insurance because they don't have a mortgage may determine that it makes economic sense to be uninsured and use the tax write-off provision to cover a significant portion of their losses following a major disaster (Kaplow 1992). Some states may also have similar provisions in their tax codes which would provide additional savings to these uninsured victims by reduced state income tax payments.

Mitigating Losses from Natural Disasters

To reduce losses from future disasters property owners need to protect themselves by investing in cost-effective mitigation measures. The importance of well-enforced building codes coupled with appropriate land use regulations cannot be overemphasized in this regard. These measures are likely to be controversial since they limit economic development and growth in hazard-prone areas and thus reduce the tax base for the State.

The construction and real estate sectors have traditionally opposed measures that increase the price of a structure so that one needs to provide appropriate economic incentives for undertaking these measures. Long-term loans tied to a mortgage for mitigating a structure coupled with reduced insurance premiums are one way to make these measures financially attractive. The example provided in Section 2 where the Baylors were far better off financially by investing in roof shutters illustrates this point.

Providing Affordable Coverage

One of the principles guiding any disaster insurance program is that insurance premiums reflect the risk. State insurance departments need to give insurers freedom to charge these rates subject to solvency regulations that prevent undercapitalized insurers from charging unduly low premiums with the intent of declaring bankruptcy should a catastrophic disaster occur. A key challenge facing the states and federal government would be how to provide affordable coverage and deal with the political fallout that will undoubtedly occur when insurance rates are increased from their current levels. This is a major political problem and needs to be discussed openly with the concerned stakeholders. When presenting this issue one needs to highlight the importance of

[13] More details on write-off provisions on federal income tax can be found at http://www.irs.gov/taxtopics/tc515.html

risk-based rates for encouraging property owners to invest in cost-effective mitigation measures and the savings that will emerge from a reduced disaster assistance program following a catastrophic event.

Protecting Insurers against Catastrophic Losses

One of the reasons that some insurers are now withdrawing coverage from areas that are subject to large-scale losses is because they are concerned with the impact that a disaster will have on their surplus should it occur in the next few years. As shown with the illustrative example of the *Naturesway* insurance company, the premiums that an insurer collects in any given year on its homeowners policy will only pay a fraction of the claims should a large number of their insured properties suffer severe damage from a disaster.

An important issue that needs to be examined carefully is whether the private sector has the ability to provide sufficient coverage against catastrophic losses or whether one needs to rely on some type of public sector involvement at the State and/or federal level for financial protection should a large-scale hurricane or earthquake occur. There have been a number of recent papers that have addressed this issue in the context of natural disasters that suggest a variety of different ways to address the problem.[14] There is general agreement that one should do everything one can to rely on the private sector to provide insurance protection but that there may be capacity limitations which require public sector involvement.

In order to address this issue one needs to have a clearer understanding of the availability of risk transfer mechanisms, such as reinsurance and catastrophe bonds, and their costs to insurers relative to public sector options such as state catastrophe funds and federal reinsurance. Given the need for short-term funds to help replenish surplus following a disaster there may be a role that federal loans can play as noted by Jaffee and Russell (2006) or some type of reinsurance contracts auctioned by the federal government as proposed by Lewis and Murdock (1997). The federal government does have an easier time raising money in times of disaster than does the private sector and has a comparative advantage in this sense. On the other hand, the private insurance industry has had long-term experience in marketing coverage and paying claims needs to be taken into account when evaluating alternative disaster insurance programs.

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[14] See Cummins (2006), Grace, Klein and Liu (2006), Harrington (2006), Jaffee and Russell (2006), and

6. Summary and Conclusions

This paper proposes that we examine the feasibility of including earthquake and water damage as part of a global homeowners policy for dealing with the catastrophic risk problem from natural disasters. By undertaking such an analysis one is forced to address the question as to who should pay for disasters and how can we encourage individuals to undertake protective measures in advance of the event.

Two key principles underlying any disaster insurance program is that the rates reflect the risk and that coverage is affordable. For lower income individuals it will be impossible to satisfy the first principle without some type of subsidy from the public sector. There are also a set of questions as to whether the private sector has the ability to cover losses from catastrophic disasters on their own or will need some type of public sector involvement.

There are a set of related issues that have to be considered when developing any type of disaster insurance program. These include the ability to assess the risk and the uncertainty of the models, the appropriate role of regulation, balancing the concerns of the different stakeholders concerned with this issue and the types of subsidies and back-up provision that can be offered by the public sector. Finally we need a clear understanding of the political and social landscape as well as how choices are actually made so as to develop a disaster insurance program as part of a hazard management strategy that achieve its desired impacts. The challenges in this regard are quite different today than they were in the 20th century because of the magnitude of losses from these disasters in the past few years.

Kunreuther (2006).

The 20 Most Costly Catastrophe Insurance Losses, 1970-2005

(18 of them occurred between 1990 and 2005; 10 of them occurred in the last 5 years)

Rank	*U.S.$ Billion* *(indexed to 2004)*	*Event*	*Victims* *(Dead and missing)*	*Year*	*Country*
1	40-55	Hurricane Katrina	1,281*	2005	USA
2	32.4	9/11 Attacks	3,025	2001	USA
3	21.50	Hurricane Andrew	43	1992	USA, Bahamas
4	17.80	Northridge Quake	61	1994	USA
5	11.00	Hurricane Ivan	124	2004	USA, Caribbean et al
6	8.00	Hurricane Charley	24	2004	USA, Caribbean et all
7	7.80	Typhoon Mireille	51	1991	Japan
8	6.7	Winterstorm Daria	95	1990	France, UK et al
9	6.6	Winterstorm Lothar	110	1999	France, Switzerland et al
10	6.4	Hurricane Hugo	71	1989	Puerto Rico, USA et al
11	4-7*	Hurricane Rita	119	2005	USA
12	5.0	Hurricane Frances	38	2004	USA, Bahamas
13	5.0	Seaquake, Tsunami	280,000	2004	Indonesia, Thailand et al
14	5.0	Storms and floods	22	1987	France, UK et al
15	4.6	Winterstorm Vivian	64	1990	Western/Central Europe
16	4.6	Typhoon Bart	26	1999	Japan
17	4.1	Hurricane Georges	600	1998	USA, Caribbean
18	4.0	Hurricane Jeanne	3,034	2004	USA, Caribbean et al
19	3.6	Typhon Songda	45	2004	Japan, South Korea
20	3.4	Tropical Storm Alison	41	2001	USA

*Sources: Wharton Risk Center with data from Swiss Re, Insurance Information Institute and press releases (*estimations)*

References

Camerer, Colin and Kunreuther, Howard (1989). Decision Processes for Low Probability Events: Policy Implications. *Journal of Policy Analysis and Management* 8: 565-592.

Cummins, David (2006) "Should the Government Provide Insurance for Catastrophe?" Paper presented at 30th Annual Economic Policy Conference Federal Credit and Insurance Programs Federal Reserve Bank of St. Louis, Oct. 20-21, 2005.

Emanuel, Kerry (2005) "Increasing destructiveness of tropical cyclones over the past 30 years" *Nature* 436:686-88.

Freeman, Paul and Kunreuther, Howard (1997) *Managing Environmental Risk through Insurance*. AEI Press (softback), Kluwer Academic Publishers (hardback).

Freeman, Paul and Scott, Kathryn (2005) "Comparative Analysis of Large Scale Catastrophe Compensation Schemes' in *Catastrophic Risks and Insurance* Paris: Organization for Economic Cooperation and Development (OECD) July.

Grace, Martin F.,. Klein, Robert and Kleindorfer, Paul (2004). "Homeowners Insurance with Bundled Catastrophe Coverage", *Journal of Risk and Insurance*, Vol. 7:3 September.

Grace, Martin, Klein, Robert and Liu, Zhiyong (2006) "Mother Nature on the Rampage: Implications for Insurance Markets" Paper presented at the NBER Insurance Workshop Cambridge, MA February 2006.

Greenwald, Bruce and Stiglitz, Joseph (1990) "Asymmetric Information and the New Theory of the Firm; Financial Constraints and Risk Behavior," *American Economic Review: Papers and Proceedings* 80:160-65.

Grossi, Patricia and Howard Kunreuther (2005), *Catastrophe Modeling: A New Approach to Managing Risk*. New York: Springer.

Harrington, Scott (2006) "Rethinking Disaster Policy After Hurricane Katrina" *This Volume*

Hartwig, Robert and Claire Wilkinson, (2005), *Public/Private Mechanisms Handling Catastrophic Risk in the United States*, Insurance Information Institute, New York, N.Y. October.

Hayes, Thomas and Sabada, Shama (2004) *National Flood Insurance Program: Actuarial Rate Review* Washington, DC: Federal Emergency Management Agency (FEMA) November 30.

Henriet, Dominique and Michel-Kerjan, Erwann (2006) "Optimal Risk-Sharing under Dual Asymmetry of Information and Market Power: A Unifying Approach", Wharton Risk Center Working Paper, June.

Hogarth, Robin and Kunreuther, Howard (1989) "Risk, Ambiguity and Insurance" *Journal of Risk andUncertainty* 2:5-35.

Hood, Jim (2005) "A Policy of Deceit" *New York Times* November 19 p. A27.

Huber, O., Wider, R. and Huber, O. (1997) "Active Information Search and Complete Information Presentation in Naturalistic Risky Decision Tasks" *Acta Psychologica* 95:15-29.

Jaffee, Dwight and Russell, Thomas (2006) "Should Governments Provide Catastrophe Insurance?" *Economists' Voice* pp. 1-8 April.

Kahneman, Daniel and Tversky, Amos (1979), "Prospect theory: An analysis of decision under risk." *Econometrica* 47(2):263-291.

Kaplow, Louis. (1992) "Income Tax Deductions for Losses as Insurance," *American Economic Review* 82: 1013-17

King, Rawle (2006) "Hurricanes and Disaster Risk Financing Through Insurance: Challenges and Policy Options" Washington, DC: Congressional Research Service January 27.

Kunreuther (1968) "The Case for Comprehensive Disaster Insurance" *Journal of Law and Economics* April.

Kunreuther, Howard. (1973). *Recovery from Natural Disasters: Insurance or Federal Aid?.* Washington, D.C.: American Enterprise Institute for Public Policy Research.

Kunreuther, Howard (1989) "The Role of Actuaries and Underwriters in Insuring Ambiguous Risks" *Risk Analysis*, 9:319-28.

Kunreuther, Howard Hogarth, Robin, Meszaros, Jacqueline (1993), "Insurer Ambiguity and Market Failure," *Journal of Risk and Uncertainty* 7: 71-87.

Kunreuther, Howard and Richard Roth, Sr. (1998), *Paying the Price: The Status and Role of Insurance Against Natural Disasters in the United States*, Washington, D.C: Joseph Henry Press.

Kunreuther, Howard, Novemsky, Nathan, and Kahneman, Daniel (2001). "Making Low Probabilities Useful", *Journal of Risk and Uncertainty*, 23:2, pp. 103-120.

Kunreuther, Howard (2006), "Comprehensive Disaster Insurance: Has its Time Come?" in *Risk and Disaster: Lessons from Hurricane Katrina*. University of Pennsylvania Press, Philadelphia, PA.

Kunreuther, Howard and Mark Pauly (in press) "Rules rather than Discretion: Lessons from Hurricane Katrina *Journal of Risk and Uncertainty*

Lecomte, Eugene and Karen Gahagan, (1998), "Hurricane Insurance Protection in Florida" in Howard Kunreuther and Richard Roth, Sr., eds., *Paying the Price: The Status and Role of Insurance Against Natural Disasters in the United States,* Washington, D.C.: Joseph Henry Press: 97-124.

Lewis, Christopher and Kevin C. Murdock (1996) "The Role of Government Contracts in Discretionary Reinsurance Markets for Natural Disasters" , *Journal of Risk and Insurance* 63: 567-597.

Litan, Robert (2006). "Sharing and Reducing the Financial Risks of Future "Mega-Catastrophes", *Issues in Economic Policy No.4,* Brookings Institute Washington, DC March.

Magat, Wes. Viscusi, W. Kip and Huber, Joel (1987). "Risk-dollar Tradeoffs, Risk Perceptions, and Consumer Behavior," In W. Viscusi & W. Magat (eds.), *Learning about Risk* (p. 83-97). Cambridge, MA: Harvard University Press

Michel-Kerjan, Erwann and Nathalie de Marcellis (2006) "Public-Private Programs for Covering against Extreme Events: The Impact of Information Distribution on Risk-Sharing" *Asia-Pacific Journal of Risk and Insurance*, 1: 21-49.

Moss, David (2002) *When All Else Fails: Government as the Ultimate Risk Manager* Cambridge: Harvard.

Pasterick, Edward T. (1998), "The National Flood Insurance Program." in Howard Kunreuther and Richard J. Roth, Sr. (eds.), *Paying the Price: The Status and Role of Insurance Against Natural Disasters in the United States*. Washington, DC: Joseph Henry Press.

Pauly, Mark (1968), 'The economics of moral hazard: Comment'. American Economic Review 58, 531–536.

Risk Management Solutions (2006) *U.S. and Caribbean Hurricane Activity Rates* March.

Roth, Richard Jr. (1998) "Earthquake Insurance in the United States" in Howard Kunreuther and Richard J. Roth, Sr. (eds.), *Paying the Price: The Status and Role of Insurance Against Natural Disasters in the United States*. Washington, DC: Joseph Henry Press.

Roy, A.D. (1952). Safety-first and the holding of assets. *Econometrica* 20:431—449.

Stone, James (1973). A theory of capacity and the insurance of catastrophe risks: Part I and Part II. *Journal of Risk and Insurance* 40:231-243 (Part I) and 40:339-355 (Part II).

Towers Perrin (2005) "Hurricane Katrina: Analysis of the Impact on the Insurance Industry." Available online at http://www.towersperrin.com/tillinghast/publications/reports/Hurricane_Katrina/katrina.pdf

U.S. Government Accountability Office (2006) *Federal Emergency Management Agency: Challenges Facing the National Flood Insurance Program* Washington, DC: GAO-06-174T

Wharton Risk Center (2005), *TRIA and Beyond: Terrorism Risk Financing in the U.S.* Philadelphia, Pa: Wharton Risk Management and Decision Processes Center

Williams, John and King, Carole Ann (2006) "2006 Annual Hurricane Study: Shake, Rattle and Roar" Oldwick, NJ; A.M Best Company, Inc. June.