The Development of Long Term Insurance (LTI) To Address Catastrophe Insurance Market Failure

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Preliminary Version – Comments Welcome[1]

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Abstract

This paper proposes long-term insurance (LTI) as an alternative to the standard annual policies for homeowners coverage. We underscore the need for such a contractual arrangement by focusing on the challenges facing homeowners living in high-risk areas and insurers today, given the significant increase and variability in losses from natural disasters in recent years. Lessons from the mortgage market provide a benchmark for the development of LTI. More specifically, we propose fixed and adjustable rate insurance contracts that have features similar to those in the mortgage market with penalties for canceling a long-term (LT) contract before it expires. For insurers to want to offer LTI, premiums have to reflect the risk including the cost of capital. Consumers are likely to prefer LTI to annual policies if there is considerable uncertainty as to whether their insurance will be cancelled unexpectedly or premiums are increased significantly following the next disasters. A two-period model illustrates when an LT contract would be attractive to both insurers and consumers under competitive market conditions. We show that insurers will be willing to offer such a policy if they can charge a high enough penalty for cancellation. The concluding section raises a set of questions related to the feasibility of LTI for insurers, consumers, rating agencies and public sector organizations.

1. INTRODUCTION

A. Nature of the Problem: Increasing Variability in the Impacts of Extreme Events

There has been a significant increase in the economic and insured losses from natural catastrophes worldwide in recent years as shown in Figure 1. A comparison of these economic losses over time reveals a huge increase: $53.6 billion (1950-59), $93.3 billion (1960-69), $161.7 billion (1970-79), $262.9 billion (1980-89) and $778.3 billion (1990-99). The current decade has already seen $420.6 billion in losses, principally due to the 2004 and 2005 hurricane seasons, which produced historic records.

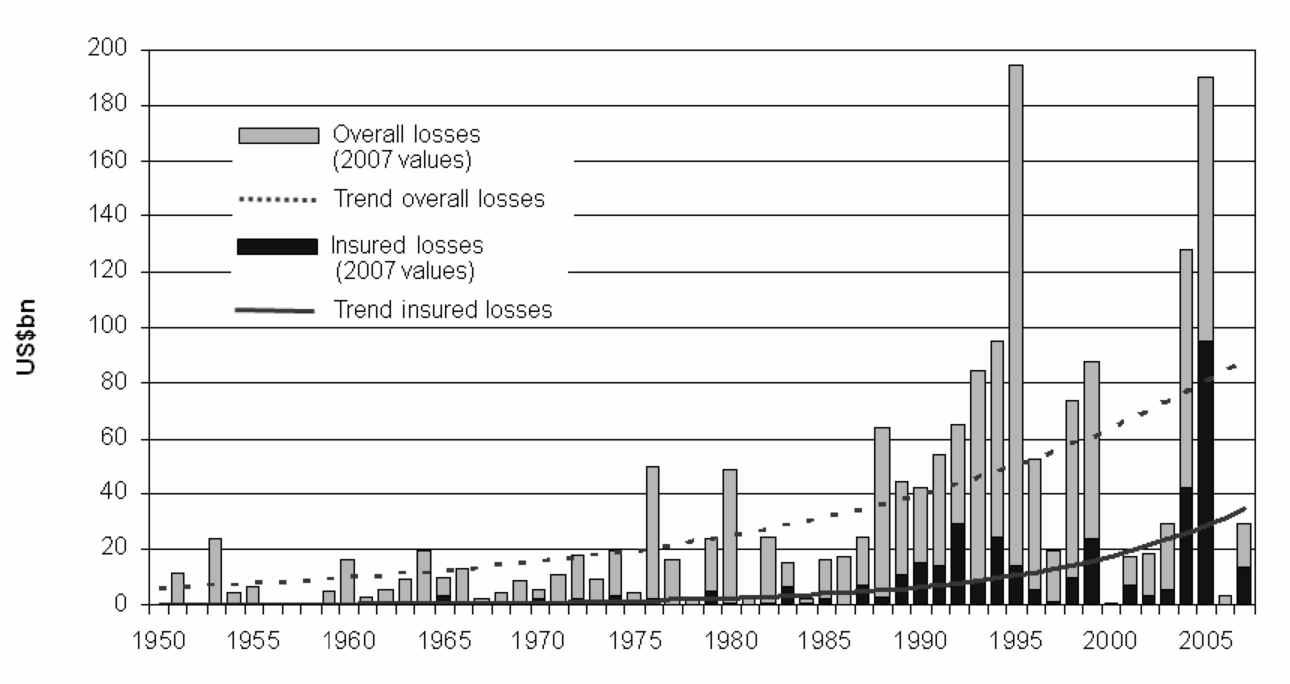

FIGURE 1. EVOLUTION OF "GREAT NATURAL CATASTROPHES" WORLDWIDE, 1950-2007
ECONOMIC VERSUS INSURED IMPACT
Sources: Data from Munich Re, 2008 Geo Risks Research – in U.S. $ billon indexed to 2007

Catastrophes have had a more devastating impact on insurers over the past 15 years than in the entire history of insurance. Between 1970 and the mid-1980s, annual insured losses from natural disasters (including forest fires) were in the $3 to $4 billion range. The insured losses from Hurricane Hugo, which made landfall in Charleston, South Carolina on September 22, 1989, exceeded $4 billion (1989 prices). It was the first natural disaster to inflict more than one billion dollars of insured losses in the U.S. A radical increase in insured losses occurred in the early 1990s, with Hurricane Andrew in Florida ($23.7 billion in 2007 dollars) and the Northridge earthquake in California ($19.6 billion in 2007 dollars). The four hurricanes in Florida in 2004 (Charley, Frances, Ivan and Jeanne) taken together cost insurers almost $33 billion. Insured and reinsured losses from Hurricane Katrina, which made landfall in the U.S. in August 2005, are now estimated at $46 billion; total losses paid by private insurers due to major natural catastrophes were $87 billion in 2005.[2] Figure 2 depicts the upward trend in worldwide *insured*

[2] This figure excludes payment by the U.S. National Flood Insurance Program (NFIP), a federal entity, for damage due to 2005 flooding (over $20 billion in claims).

losses from catastrophes between 1970 and 2007 (in 2007 indexed prices; corrected for inflation).[3]

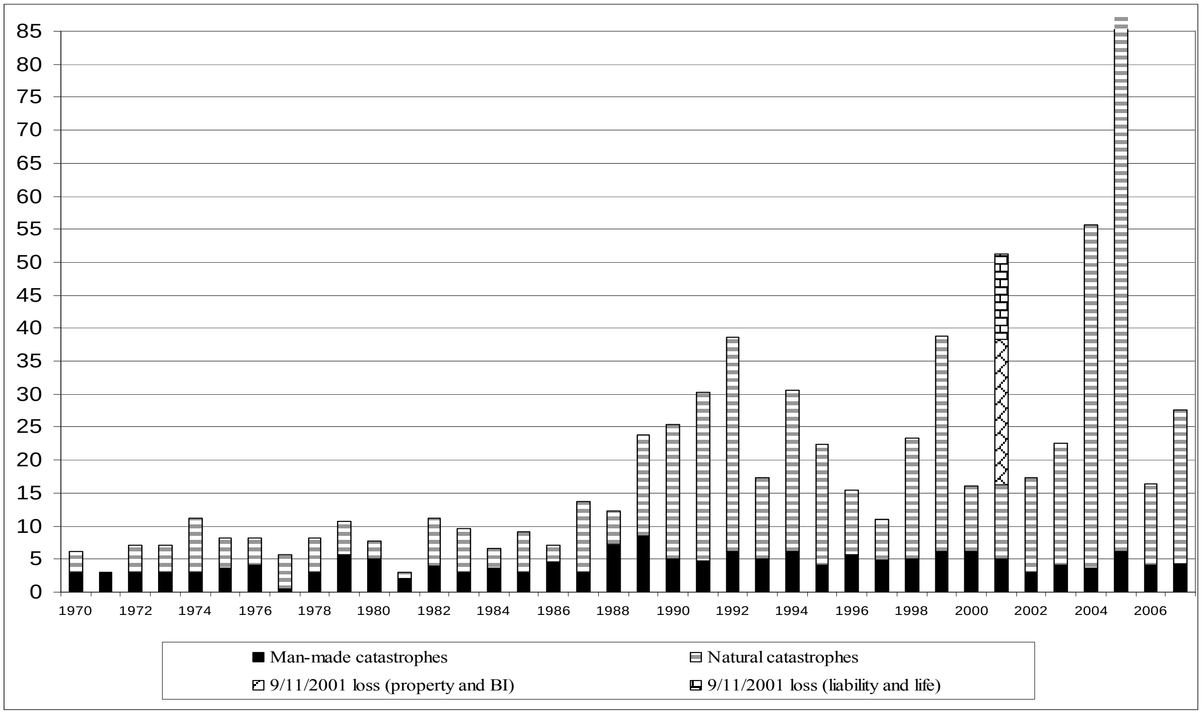

FIGURE 2. WORLDWIDE EVOLUTION OF CATASTROPHE INSURED LOSSES, 1970-2007
(9/11: All lines, including property and business interruption (BI); in U.S. $ billon indexed to 2007)
Source: Wharton Risk Center with data from Swiss Re and Insurance Information Institute

Figures 1 and 2 highlight another pattern of change: there has been a dramatic increase in the *variability* of losses due to major catastrophes from one year to the other. Hurricane Katrina is estimated to have caused over $120 billion in economic losses and federal relief, more than four times than the most costly hurricane in the United States between 1950 and 2000. On the other hand, despite forecasts of higher-than-normal hurricane activity during the 2006 and 2007 seasons, the only hurricane to make landfall in the U.S. since 2005 was a Category 1 hurricane.

B. Increasing Variability in Insurance Price and Earnings

The combination of historical losses and increasing variability has important consequences for the insurance industry. The amount of coverage an insurer is willing to provide against risks in different hazard-prone areas partly depends on how much of its exposure can be transferred to reinsurers and at what cost. Reinsurers typically cover a significant portion of

[3] Munich Re and Swiss Re, the two leading reinsurers in the world, do not use the same definition of catastrophic losses. Natural disasters inflicting insured losses above $38.7 million or total losses above $77.5 million are considered a major catastrophes by Swiss Re (we use this threshold in Figure 2); Munich Re considers a higher threshold, which explains the difference between Figures 1 and 2. For example, when Munich Re estimated insured loss from natural disasters at about $42 billion in 2004, Swiss Re's estimate was over $52 billion. As a result, most figures used in the literature regarding the evolution of catastrophe loss actually underestimate the real effect on insurers. We appreciate Swiss Re's and Munich Re's willingness to share their 2007 estimates prior to their publication.

insurance from catastrophic risks through *pro rata* (co-insurance or quota-share) or *excess of loss* contracts. Reinsurers estimated their losses for 2005 to be $40 billion, approximately half of which were due to Hurricane Katrina. Further, reinsurers are unregulated with respect to the premiums they charge.[4] As a result of the 2004 and 2005 hurricane seasons, the price of catastrophe reinsurance in the U.S. increased significantly, rising 76 percent between July 1, 2005 and June 30, 2006 and 150 percent for Florida-only insurers over the same period of time.[5]

Insurers responded to this hard reinsurance market by filing for significant rate increases to insurance regulators in states subject to hurricanes, only a portion of which was granted. As part of a large study undertaken by the Wharton Risk Center, in conjunction with Georgia State University and the Insurance Information Institute, we found that the average homeowner premium in Florida more than doubled in the past six years, increasing from $723 at the start of 2002, to $1,465 in the first quarter of 2007. In coastal areas, premiums have tripled or even quadrupled for some homeowners. While the market price of insurance has significantly increased in coastal areas (especially in Florida), insurers are still concerned about earnings volatility and the possibility that their long-term earnings will be negative in high-risk areas. Some insurers simply refused to renew policies in coastal areas subject to hurricanes. In February 2007 State Farm, the largest insurer in Mississippi, stopped selling new policies on homes and small businesses there. Allstate, another giant residential insurance provider, announced it would restrict new homeowners' policies in New Jersey, Connecticut, Delaware and New York City, refusing to write policies in areas subject to hurricanes.

This volatility in catastrophe losses and the market and regulatory reactions after the 2004 and 2005 hurricane seasons in the U.S. raises the following question for insuring catastrophe risks in the future: How can one smooth the cost of coverage over time to avoid the radical changes in the market environment from year to year that have recently been occurring? To address this question, one needs to find ways to reduce insurers' earnings volatility while assuring people living in high-risk areas that their insurers will not cancel their policies or double or triple their rates from one year to the next.

There are also issues on the demand side. Indeed, it is important to recognize that prior to a disaster, many individuals perceive its likelihood to be sufficiently low that they believe, "It will not happen to me" and are reluctant to incur upfront cash expenditures to reduce future losses. As a result, they do not voluntarily invest in protective measures, such as strengthening their houses or buying insurance. It is only after the disaster occurs that these same individuals claim they would like to have undertaken these actions (Kunreuther, 2006).[6] To illustrate, the Department of Housing and Urban Development (HUD) reported that 41 percent of damaged homes from the 2005 hurricanes were uninsured or underinsured. Of the 60,196 owner-occupied

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[4] For a more detailed discussion of the role of private reinsurance in supplying coverage against natural disasters see Wharton Risk Center (2008), *Managing Large-Scale Risks in a New Era of Catastrophes,* Chapter 8. See also Froot, K. and P. O'Connell (1999), "The Pricing of U.S. Catastrophe Reinsurance," in *The Financing of Catastrophe Risk*, K. Froot (ed.), University of Chicago Press, pp. 195-232.

[5] Between July 1, 2006 and June 30, 2007, prices fell slightly but were still considerably higher than during 2005. Prices continued to fall at the January 2008 renewal, but are still considerably higher than they were at the beginning of 2005. See Guy Carpenter (2008), "2008 Reinsurance Market Review: Near Misses Call for Caution" and Guy Carpenter (2007), "The World Catastrophe Reinsurance Market: New Capital Stabilizes Market," Sept. 2007.

[6] Kunreuther, H. (2006), "Disaster Mitigation and Insurance: Learning from Katrina," *The Annals of the American Academy of Political and Social Science,* 604: 208-227.

homes with severe wind damage from these hurricanes, 23,000 (38 percent) did not have insurance against wind loss. (GAO, 2007)[7]

To address the problem of volatility of insurance and lack of interest in protecting against disaster, we propose in this paper a new approach to providing homeowners coverage: long-term insurance contracts (LTI) rather than annual policies on residential property. The paper is organized as follows. **Section 2** discusses the reasons for the radical change in both the scale and frequency of weather-related catastrophes in recent years. We then turn in **Section 3** to the need for LTI and the reasons why a market for this type of coverage does not exist today. **Section 4** provides lessons from the mortgage market that can serve as a benchmark for LTI. Indeed, this market used to be made of short-term mortgages, not the 20- or 30-year mortgages we know today. **Section 5** apply concepts from long-term mortgages to insurance and describes how fixed rates and adjustable insurance contracts would function. **Section 6** introduces a simple two-period model to capture some of the features in designing an LTI contract. **Section 7** raises questions for future research and implementation of this concept in the real world.

2. THE QUESTION OF ATTRIBUTION[8]

During the period between 1970 and 2004, storms and floods have been responsible for over **90 percent** of the total economic costs of extreme weather-related events worldwide. Storms (*hurricanes* in the U.S. region, *typhoons* in Asia and *windstorms* in Europe) contributed to over 75 percent of insured losses. In constant prices (2004), insured losses from weather-related events averaged $3 billion annually between 1970 and 1990 and then increased significantly to $16 billion annually between 1990 and 2004 (ABI, 2005).[9] In 2005, 99.7 percent of all catastrophic losses worldwide were due to weather-related events (Mills and Lecomte, 2006).[10]

What are the key drivers of the increase in the level and variability of these losses? More specifically, what role have socio-economic factors played? How is a change in climate likely to affect the number and severity of catastrophes in the future?

Increased Development in Hazard-Prone Areas

There are at least two principal socio-economic factors that directly influence the level of economic losses due to catastrophic events: *degree of urbanization* and *value at risk*. In 1950, approximately 30 percent of the world's population lived in cities. In 2000, about 50 percent of the world's population (6 billion) resided in urban areas. Projections by the United Nations show that by 2025, that figure will have increased to 60 percent based on a world population estimate of 8.3 billion people.

In the U.S., in 2003, 53 percent of the nation's population, or 153 million people, lived in the 673 U.S. coastal counties, an increase of 33 million people since 1980, according to the National Oceanic Atmospheric Administration—yet coastal counties, excluding Alaska, account

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[7] U.S. Government Accountability Office (2007), Natural Disasters: Public Policy Options for Changing the Federal Role in Natural Catastrophe Insurance, Washington, DC: GAO, November, p. 25.

[8] This section is based on Kunreuther, H. and E. Michel-Kerjan (2007), "Climate Change, Insurability of Large-Scale Risks and the Emerging Liability Challenge," *Penn Law Review*, 155 (6): 1795-1842.

[9] Association of British Insurers (ABI) (2005), "Financial Risks of Climate Change," June 2005.

[10] Mills, E. and E. Lecomte (2006), "From Risk To Opportunity: How Insurers Can Proactively and Profitably Manage Climate Change," *Ceres*, August 2006.

for only 17 percent of U.S. land area. And the nation's coastal population is expected to increase by more than 7 million by 2008, and 12 million by 2015 (NOAA, 2004).[11]

In hazard-prone areas, this urbanization and increase of population also translates into increased concentration of exposure. The development of Florida as a home for retirees is an example. According to the U.S. Bureau of the Census, the population of Florida has increased significantly over the past 50 years: 2.8 million inhabitants in 1950, 6.8 million in 1970, 13 million in 1990, and a projected 19.3 million population in 2010 (almost a 700 percent increase since 1950), increasing the likelihood of severe economic and insured losses, unless cost-effective mitigation measures are implemented. Florida also has a high density of insurance coverage, with most houses covered against windstorm losses and about one-third insured against floods under the U.S. National Flood Insurance Program (NFIP),[12] according to a study undertaken by Munich Re (2000).[13] In 2004, (the most recent available data) the modeling firm AIR Worldwide estimated that nearly 80 percent of insured assets in Florida are located near the coasts, the high-risk area in the state (Figure 3).

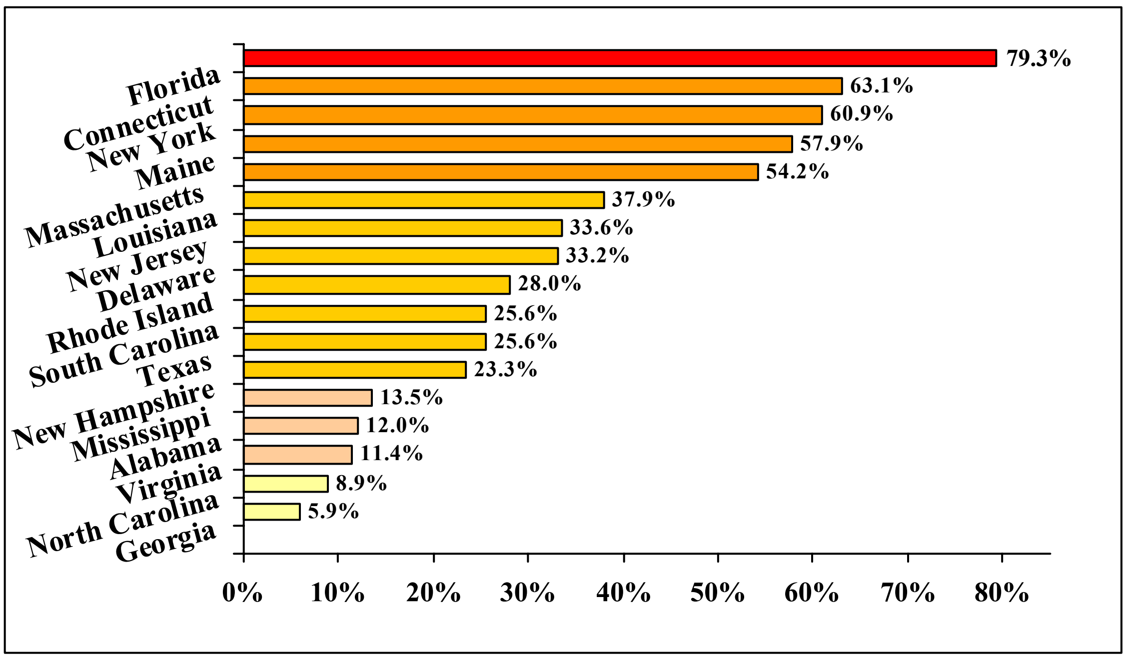

FIGURE 3. INSURED COASTAL EXPOSURE AS A PERCENTAGE OF STATEWIDE INSURED EXPOSURE AS OF DECEMBER 2004 (RESIDENTIAL AND COMMERCIAL PROPERTIES)
Source: Data from AIR Worldwide Corporation

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[11] Crossett, K.M., T.J. Culliton, P.C. Wiley, and T.R. Goodspeed (2004), "*Population Trends Along the Coastal United States: 1980-2008,*" National Oceanic and Atmospheric Administration, NOAA's National Ocean Service, Special Projects: Silver Spring, MD.

[12] The NFIP is a public insurance program created in 1968. Insurers play the role of intermediaries between the policyholders and the federal government. Following Hurricane Katrina, the program had to borrow $20 billion from the federal government in 2006 to meet its claims. Congress is considering modifying the program substantially. For a more detailed discussion of the NFIP, see Michel-Kerjan, E. and C. Kousky. (2008) "Come Rain or Shine: Evidence on Flood Insurance Purchases in Florida", Working paper, The Wharton School of the University of Pennsylvania and Kennedy School of Government, Harvard University, February 2008.

[13] Munich Re (2000), "Topics 2000. Natural Catastrophes – The Current Position," Special millennium issue.

This represents $1.9 trillion of insured exposure located in coastal areas (commercial and residential exposure) (Figure 4). Insurance density is thus another critical socio-economic factor to consider when evaluating the evolution of insured loss due to weather-related catastrophes. These factors will continue to have a major impact on the level of insured losses from natural catastrophes. Given the growing concentration of exposure on the Gulf Coast, another hurricane like Katrina hitting the Gulf Coast is likely to inflict significant direct losses (property damage) and indirect losses (business interruption) unless strong mitigation measures are put in place.[14]

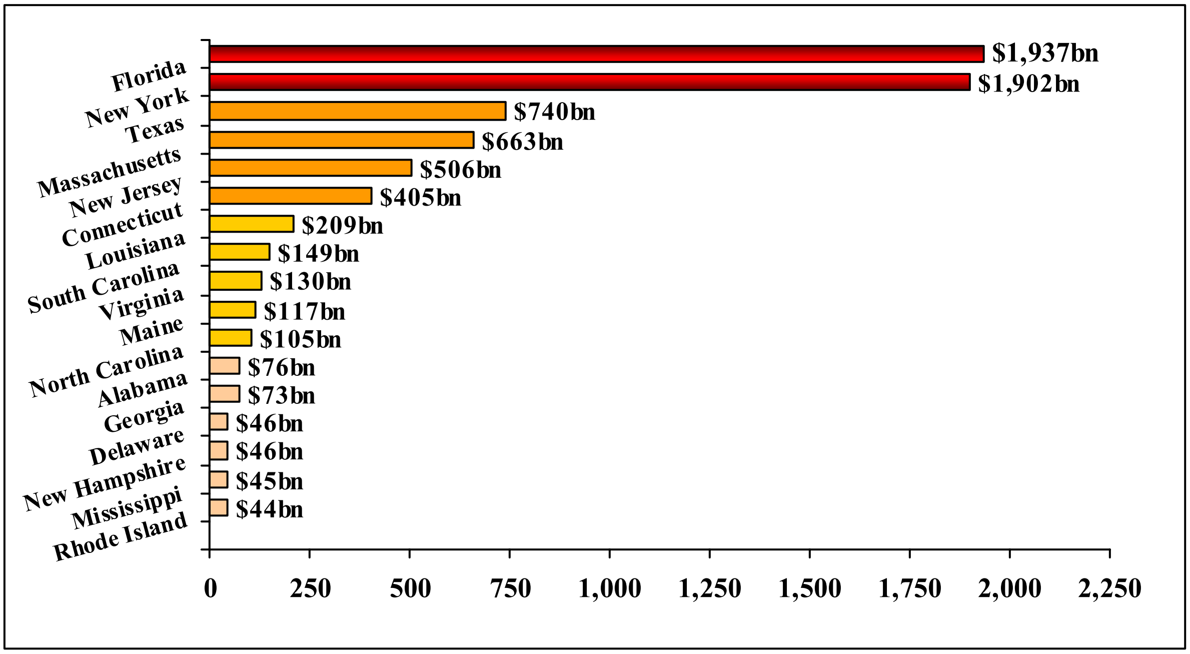

FIGURE 4. TOTAL VALUE OF INSURED COASTAL EXPOSURE AS OF DECEMBER 2004 (IN $ BILLION; RESIDENTIAL AND COMMERCIAL PROPERTIES)
Source: Data from AIR Worldwide Corporation

In order to better understand our new vulnerability, it is possible to calculate the cost of major hurricanes that occurred in the U.S. in the past century, adjusted for inflation, population and wealth normalization, that is, an estimate of what each of these hurricanes would have cost had they hit in 2005 (total direct cost).[15] This exercise has been done in several studies, the most recent one by Pielke et al. (2008) which normalizes mainland U.S. hurricane damage from 1900–2005 to 2005.[16] Table 1 provides estimates for the top 20 most costly hurricanes assuming they had occurred in 2005. The authors propose two ways to normalize these losses, each of which gives a cost estimate. In Table 1 we provide the range of costs between these two estimates,

[14] For additional data on the economic impact of future catastrophic hurricanes, see The Financial Services Roundtable, *Blue Ribbon Commission on Mega-Catastrophes Comprehensive Report*, Chapter 2 (2007).

[15] These estimates might vary, depending on underlying assumptions over such a long period of time, such as inflation, population growth, and wealth normalization in the studied area; moreover, mitigation and building codes will have an important impact on total losses.

[16] R. Pielke Jr, J. Gratz, C. Landsea, D. Collins, M. Saunders, and R. Musulin (2008), "Normalized Hurricane Damage in the United States: 1900–2005", *Natural Hazard Review*, February 2008.

along with the year when the hurricane originally occurred, the states that were the most hit as well as the hurricane category on the Saffir-Simpson scale.

TABLE 1. TOP 20 HURRICANE SCENARIOS (1900-2005)
RANKED USING 2005 INFLATION, POPULATION, AND WEALTH NORMALIZATION

Rank	Hurricane	Year	Category	Cost range ($ billion) in 2005
1	Miami (Southeast FL/MS/AL)	1926	4	140-157
2	Katrina (LA, MS)	2005	3	81
3	North Texas (Galveston)	1900	4	72-78
4	North Texas (Galveston)	1915	4	57-62
5	Andrew (Southeast FL and LA)	1992	5-3	54-60
6	New England (CT,MA,NY,RI)	1938	3	37-39
7	Southwest Florida	1944	3	35-39
8	Lake Okeechobee (Southeast Florida)	1928	4	32-34
9	Donna (FL-NC,NY)	1960	4-3	29-32
10	Camille (MS/Southeast LA/VA)	1969	5	21-24
11	Betsy (Southeast FL and LA)	1965	3	21-23
12	Wilma	2005	3	21
13	Agnes (FL/CT/NY)	1972	1	17-18
14	Diane (NC)	1955	1	17
15	4 (Southeast FL/LA/AL/MS)	1947	4-3	15-17
16	Hazel (SC/NC)	1954	4	16-23
17	Charley(Southwest FL)	2004	4	16
18	Carol (CT,NY,RI)	1954	3	15-16
19	Hugo (SC)	1989	4	15-16
20	Ivan (Northwest FL/AL)	2004	3	15

Sources: Data from Pielke et a. (2008)

Climate Change and Hurricanes: Likelihood Versus Intensity

There have been numerous discussions and scientific debates as to whether the series of major hurricanes that occurred in 2004 and 2005 might be partially attributable to the impact of a change in climate.[17] One of the expected effects of global warming will be an increase in hurricane intensity. This has been predicted by theory and modeling, and substantiated by empirical data on climate change. Higher ocean temperatures lead to an exponentially higher evaporation rate in the atmosphere which increases the intensity of cyclones and precipitation.

Emanuel (2005)[18] introduces an index of potential destructiveness of hurricanes based on the total dissipation power over the lifetime of the storm. He shows a large increase in power dissipation over the past 30 years and concludes that this increase may be due to the fact that storms have become more intense, on average, and/or have survived longer at high intensity. His

[17] For more details on the scientific evidence regarding climate change and its impact see Stern Review (2006), *The Economics of Climate Change*, H.M. Treasury, December, and Intergovernmental Panel on Climate Change (2007), *Climate Change 2007*, January.
[18] Emanuel, K., (2005), "Increasing destructiveness of tropical cyclones over the past 30 years," *Nature,* 436(4): 686-688, August.

study also shows that the annual average storm peak wind speed over the North Atlantic and eastern and western North Pacific has increased by 50 percent over the past 30 years.

A paper by Webster et al. (2005)[19] published a few weeks later, indicates that the number of Category 4 and 5 hurricanes worldwide has nearly doubled over the past 35 years.[20] In the 1970s, there were an average of about ten Category 4 and 5 hurricanes per year globally. Since 1990, the number of Category 4 and 5 hurricanes has averaged 18 per year. Focusing only on the North Atlantic (Atlantic-Caribbean-Gulf of Mexico), Category 4 and 5 hurricanes have increased from 16 in the period of 1975-1989, to 25 in the period of 1990-2004 (a 56 percent increase). The Webster, et al. (2005) study concludes that "global data indicate a 30-year trend toward more frequent and intense hurricanes." This significant increase in observed tropical cyclone intensities, linked to warming sea surface temperatures that may be associated with global warming, has been shown in another study published recently (Hoyos et al., 2006).[21]

But this is not to say that there is consensus by scientists on the relationship between hurricane activity and global warming.[22] In a perspective article published in *Science*, Landsea et al. (2006)[23] point out that subjective measurements and variable procedures make existing tropical cyclone databases insufficiently reliable to detect trends in the frequency of extreme cyclones. This conclusion is reinforced in a recent summary of articles on global climate change by Patrick Michaels, past president of the American Association of State Climatologists, who notes that all studies of hurricane activity that claim a link between human causation and the recent spate of hurricanes must also account for the equally active period around the middle of the 20th century. Studies using data from 1970 onward begin at a cool point in the hemisphere's temperature history, and hence may draw erroneous conclusions regarding global climate change and hurricane activity (Michaels, 2006).[24]

A reanalysis of global tropical cyclone data since 1980 that addressed inaccuracies related to the interpretation of satellite recordings was published last year (Kossin et al., 2007).[25] The reanalyzed data shows a lack of global trend in the number and percentage of Category 4 and 5 hurricanes and power dissipation index (PDI) globally, thus contradicting the results of Webster, et al., (2005). An increase in PDI and in the number and proportion of Category 4 and

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[19] Webster, P., G.J. Holland, J. Curry and H.R. Chang (2005), "Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment," *Science,* 309: 1844-1846, September 16, 2005.

[20] Category 4 hurricanes have sustained winds from 131 to 155 miles per hour; Category 5 systems, such as Hurricane Katrina at its peak over the Gulf of Mexico, have sustained winds of 156 mph or more.

[21] Hoyos, C., P.A. Agudelo, P.J. Webster, and J.A. Curry (2006), "Deconvolution of the Factors Contributing to the Increase in Global Hurricane Intensity," *Science,* 312: 94-97, April 7, 2006.

[22] See for instance the exchange between Pielke R., Jr., C.W. Landsea and K. Emanuel (2005) in *Nature*, 438, 22/29 and Chan, J. (2006), Comment on "Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment," *Science,* 311: 5768, 1713, March 24, 2006 and Webster P.J., J.A. Curry, J. Liu, G.J. Holland (2006), Response to Comment on ''Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment," *Science,* 311, 1713c, 24 March, 2006.

[23] Landsea, C.W., B.A. Harper, K. Hoarau, J.A. Knaff (2006), "Can We Detect Trends in Extreme Tropical Cyclones?" *Science,* 313: 452-454, July 28, 2006.

[24] Michaels, P. (2006), "Is the Sky Really Falling? A Review of Recent Global Warming Scare Stories," *Policy Analysis*, 576, August 23, 2006, Washington, DC: The Cato Institute.

[25] Kossin, J.P., J.R. Knapp, D.L. Vimont, R.J. Murnane, B.A. Harper (2007), "A globally consistent reanalysis of hurricane variability and trends." *GRL* 34.

5 hurricanes was still found for the Atlantic. While this supports the results of Emanuel (2005)[26] for the Atlantic, the lack of a global increase in tropical cyclone activity despite the increase in tropical sea-surface temperatures in all basins "poses a challenge to hypotheses that directly relate globally increasing tropical sea surface temperatures to an increase in long-term mean global hurricane intensity" (Kossin et al., 2007).[27] The Atlantic also appears to be characterized by large natural variability on the multi-decadal scale with a shift to a more active phase around 1995 (World Meteorological Organization, 2006; Goldenberg et al., 2001).[28]

The current debate in the scientific community regarding changes in the frequency and intensity of hurricanes and their relationship to global climate change is likely to be with us for a long time to come. The results to date do raise issues for the insurance industry to the extent that an increase in the number of major hurricanes over a shorter period of time is likely to translate into a greater number hitting the coasts, with a greater likelihood of damage to a much larger number of residences and commercial buildings today than in the 1940s.[29]

The combination of the three factors we discussed here –increasing urbanization, concentration of value in high-risk areas, and the potential impact of a change in weather-patterns – raises questions for the insurance industry as to how they will provide protection against catastrophic risks in the future. Traditional insurance relies on geographical *and* time diversification, which are both somewhat compromised by these recent developments.

3. Developing Long-Term Insurance (LTI)

Our discussion on LTI is directed to homeowners insurance for residential properties with reference to insurance against natural disasters, including earthquakes, wind damage, and floods. This coverage has always been provided in the form of an annual contract renewable at the option of the insurer. In some cases legislation has been passed to restrict insurers from canceling policies or charging premiums that reflect risk. For example, following the Northridge quake of 1994, California, in effect, imposed an exit fee on insurers that no longer wished to offer earthquake coverage, by requiring these firms to provide the initial capitalization for the newly created California Earthquake Authority. Similarly, Florida established a state-operated assigned risk pool—Citizens Property Insurance Corporation—as a stop-gap measure for those hurricane risks that the private insurers are unwilling to accept.[30] As pointed out above, some

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[26] Emanuel, K. (2005), "Increasing destructiveness of tropical cyclones over the past 30 years." *Nature* 436(4): 686-688, August.

[27] Op. Cit.

[28] World Meteorological Organization (2006), Statement on Tropical Cyclones and Climate Change. WMO 6th International Workshop on Tropical Cyclones, San Jose, Nov. 2006; Goldenberg, S.B., C.W. Landsea, A.M. Mestas-Nunez, W.M. Gray (2001), "The recent increase in Atlantic hurricane activity: causes and implications," *Science,* 293, p. 474.

[29] For more discussion on this issue see Mills, E. (2005), "Insurance in a Climate of Change" *Science* 308: 1040-44, August 12, 2005, and Höppe, P. and R. Pielke (eds.) (2006), *Report of the Workshop on Climate Change and Disaster Losses*, May 25-26, Hohenkammer, Germany, October.

[30] Citizens, which used to be the insurer of last resort in Florida, has actually become the largest insurance providers for homeowners coverage in the state in 2007. However, Citizens clearly does not have enough financial reserve to meet its liability in case of a major hurricane. Further Citizens' deficit can be recouped against all other homeowner

insurers have recently restricted the sale of new homeowners policies in hurricane prone areas. Policyholders cannot help but worry that their existing coverage might be subject to unexpected cancellation or very significant premium increases, particularly if there is severe hurricane damage in the near future.

3-A. Need for Long-Term Insurance

We propose to develop a market for a new kind of homeowners policy, one that would last as long as a mortgage, that is, up to 30 years. Assuming that the premium variations reflect changes in the underlying expected loss, consumers would benefit from a long-term contract rather than being subject to the uncertainties associated with annual policies, the standard contract for property coverage.

The absence of LTI constitutes a true puzzle for economists who study the insurance market and is an important example of market failure.[31] Here we concentrate on the market for homeowners policies in areas subject to catastrophic risks. Short-term insurance policies create significant social costs. Evidence from recent catastrophes reveals that many consumers fail to adequately protect their home or even insure at all, creating a welfare cost to themselves and a possible cost to all taxpayers in the form of government disaster assistance. Overall, the number of Presidential disaster declarations has dramatically increased over the past 50 years: there had been 162 over the period 1955-1965, 282 over 1966-1975, 319 over the period 1986-1995 and 545 during 1996-2005 (Michel-Kerjan, in press).[32] Many individuals voluntarily purchase insurance only after a disaster occurs. If they have not collected on their policy for several years, they then cancel it, because they view it as a bad investment.[33] As we discussed in the introduction, more than 40 percent of damaged homes from the 2004-2005 hurricanes were uninsured or underinsured.[34]

The absence of long-term insurance has also a direct private cost to both the insurer and the insured. The private value of the LTI over a period of N years is higher than the sum of N one-year insurance contracts if the risk remains constant over time, for two reasons: (1) LTI reduces the transaction costs associated with purchasing a policy for consumers if their annual insurance contract is not renewed and for insurers if the homeowner cancels their policy and (2) an LTI reduces the uncertainty as to whether insurers will raise their premiums following a severe disaster.

LTI can also encourage individuals to invest in cost-effective mitigation measures if it can be linked to long-term mitigation loans. Many homeowners do not invest in cost-effective

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insurers operating in the state of Florida. See Chapters 2 and 13 in Wharton Risk Center (2008), for a detailed analysis of the market in Florida.

[31] See Culter, D. (1996), "Why Don't Markets Insure Long-Term Risks?", Unpublished manuscript, Department of Economics, Harvard University.

[32] Michel-Kerjan, E. (in press), "Disasters and Public Policy: Can Market Lessons Help Address Government Failures," proceedings of the 99th National Tax Association Conference, Boston, MA, *National Tax Journal.*

[33] Kunreuther, H., W. Sanderson and R. Vetschera (1985), "A Behavioral Model of the Adoption of Protective Activities," *Journal of Economic Behavior and Organization*, 6: 1-15.

[34] General Accountability Office (GAO) (2007), Natural Disasters: Public Policy Options for Changing the Federal Role in Natural Catastrophe Insurance, Washington, DC: GAO November, p. 25.

mitigation measures because they are myopic, underestimate the risk and have budget constraints. They are unwilling to incur the high upfront cost of these measures relative to the small premium discount they would receive the following year that reflects the expected reduction in annual insured losses (Kunreuther, Meyer and Michel-Kerjan, forthcoming).[35] With a long-term loan, the annual payment to the bank will be less than the reduction in insurance premiums, so investing in mitigation will be financially attractive. The social welfare for LTI coupled with long-term mitigation loans over N years can be significant in that there will be less damage to property, reduction in costs of protection against catastrophic losses by insurers, more secure mortgages and lower costs to the government for disaster assistance.

The use of insurance markets to motivate mitigation activities must be structured with care. The worst case arises when complete insurance is provided at a flat premium, independent of whether or not mitigation precautions have been taken. The insuree then has no financial incentive to invest in mitigation measures, since the benefits would only accrue to the insurer in the form of lower claims. In such a case the incentive to mitigate would actually be greater if there were no insurance market at all, since the benefits of mitigation would accrue to the homeowner by reducing the damage potential from future disasters. The most efficient solution, however, is risk-based premiums since it provides an *ex ante* incentive to mitigate to qualify for lower premiums, while maintaining the *ex post* benefit of risk sharing through insurance.

3-B. Why Does a Market for Long-Term Insurance Not Exist Today?

Several factors contribute to the non-existence of LTI for homeowners' property on both the supply and demand side.

Supply Side

Rates are regulated due to political pressure, with premiums frequently required to be artificially low in hazard-prone areas. The result is that the risks most subject to catastrophic losses also become the most unattractive for insurers to market. A second stumbling block, derived from premium regulation, is that insurers are unclear as to what premiums they will be allowed to charge in the future.

Uncertainty regarding costs of capital and changes in risk over time may also deter insurers from providing long-term insurance. In principle, of course, insurers could add a component in their premium quotes to account for the costs created by these factors. The problem is that consumers, or the regulator presumed to be representing their interests, may not allow these costs to be embedded in the approved premiums. In a real sense, the cost of time-varying risks and capital costs is a market failure and may require some form of government intervention to resolve it.

One may ask why banks, which now provide long-term mortgages, have not played an active role in packaging insurance to cover the physical asset (house, building, etc). Two factors contribute to the answer. First, until 1999, banks were prohibited from operating an insurance

[35] Kunreuther, H., R. Meyer and E. Michel-Kerjan (forthcoming), "Strategies for Better Protection against Catastrophic Risks", in E. Shaffir (ed), *Behavioral Foundations of Policy*, Princeton University Press.

business. It was only with the passage of the 1999 Gramm-Leach-Bliley Act, which removed features of the Glass Steagall Act, that insurance activities were allowed. Even then, bank entry has been relatively slow as highlighted by the 2004 spin-off of the Travelers insurance division by Citigroup just six years after they merged.

Lenders may also feel they are protected by the first-loss position of the homeowner given the homeowner's equity in the dwelling. Lenders may also be able to transfer most of their exposure to the capital market investors through securitization. However, regulatory responses to the subprime mortgage crisis may hamper the future securitization of high-risk instruments, with particularly negative consequences for insurance-linked securitization. Earthquake, wind damage, and flood risks may also be quite different in this regard. Homeowner's equity may protect lenders with respect to seismic risks, since most wood-frame homes are relatively resilient to earthquakes. This is not the case for hurricane and flood risks, where a house can be totally destroyed by these disasters. Indeed, most lenders do require homeowners to purchase insurance in such high-risk regions.

Demand Side

Some insurees might worry about the financial solvency of their insurer over a long period, particularly if they have the feeling they would be locked-in if they sign an LTI contract. It is noteworthy that the quasi-public California Earthquake Authority is quite clear in its policies that there will be a range of major events for which it will not be able to pay all claims. Consumers might also fear being overcharged if they have not suffered a loss for 10 years but have a 25-year LTI. It is thus essential that the design of an LTI contract anticipates these concerns, including specific features that allow contract terms to change over time.

4. BENCHMARK FOR LTI: LESSONS FROM MORTGAGE MARKETS

4-A. History of Mortgages in the U.S.[36]

Until the Great Depression, most U.S. mortgage maturities were 1 to 3 years, with the full principal due and payable at maturity. In practice, however, the loans were regularly rolled over at each maturity date. However, banks refused to renew these contracts as the Great Depression took hold. The problem was that most bank depositors had the right to withdraw their funds on demand, and, fearing a bank run, were doing so. In other words, the banks had to recall the mortgage loans in order to raise the funds to pay off their depositors.

House prices were naturally falling under the dire depression conditions, so in most cases the loan balance exceeded the house value, giving the borrower further incentive to default. In addition, a vicious circle ensued as falling house prices begot more mortgage defaults and mortgage defaults begot greater declines in house prices. As a result, the National Housing Act of 1934 established the Federal Housing Administration (FHA) to oversee a program of home

[36] This section is based in part on Jaffee, D.M. and J.M. Quigley (2007), "Housing Policy, Subprime Mortgage Policy, and the Federal Housing Administration", Working Paper No. W07-004, Program on Housing and Urban Policy, University of California, Berkeley, August 2007.

mortgage insurance against default. The default insurance was funded by the proceeds of a fixed premium charged on unpaid loan balances. Insurance was offered on "economically sound" self-amortizing mortgages with terms as long as twenty years and with loan-to-value ratios up to eighty percent. Importantly, the program was required to be self-supporting, with the insurance premiums based on actuarial requirements. The long-term and fully amortizing feature of the FHA mortgage greatly reduced mortgage defaults because it meant borrowers were no longer expected to pay off the full principle on short notice.[37]

The FHA program greatly expanded the use of the fixed payment, fully amortizing, mortgages in the United State, probably reducing the time of adoption by a decade or more than if the private markets had been left to their own devices. The FHA action greatly facilitated the innovation for at least two reasons: The FHA contract provided low cost government insurance, ensuring its immediate and widespread adoption. And as it was adopted, the FHA contract format became a *de facto* "standard" even for loans made by private lenders.

Following World War II, the Veteran's Administration created a parallel program of mortgage guarantees. Figure 5 show the percentage of total 1 to 4 family mortgages outstanding that represented FHA and VA mortgages. As recently as the mid-1980s, these government mortgage insurance programs were supporting over 20 percent of the overall market. A factor contributing to their success was that FHA and VA mortgages became the raw material to create the GNMA (Government National Mortgage Association) certificate, the first organized mortgage backed security (MBS) in the U.S. The GNMA certificates were soon traded in very active security and futures markets, helped in large part because the underlying mortgages were already fully guaranteed by the U.S. Treasury. In other words, the FHA program not only made the fixed payment, fully amortizing, long-term mortgage the standard instrument for the U.S. mortgage market, but it also was origin of the entire U.S. MBS market.

When it started in 1934, the FHA mortgage program had no counterpart in the private market. There had been a private mortgage insurance (PMI) industry in the 1920s, but by the early 1930s, all of these firms had become bankrupt—echoing the concerns created by the current subprime mortgage crisis for security guarantee insurers. A private industry was restarted in the 1950s, and, as shown in Figure 6, by the late 1970s, it had reached a 50 percent share of the overall market for insured mortgages. By 2006, the PMI industry had a market share of over 70 percent of all insured mortgages; see Jaffee (2006) for a discussion of the PMI industry as monoline insurers.[38]

[37] Of course, default would still occur if house price declines created negative owner equity. When default occurred, the FHA took possession of the house and then arranged for its sale, using a variety of alternative channels.
[38] Jaffee, D. (2006) "Monoline Restrictions, with Applications to Mortgage Insurance and Title Insurance," *Review of Industrial Organization*, 28: pp 83-108.

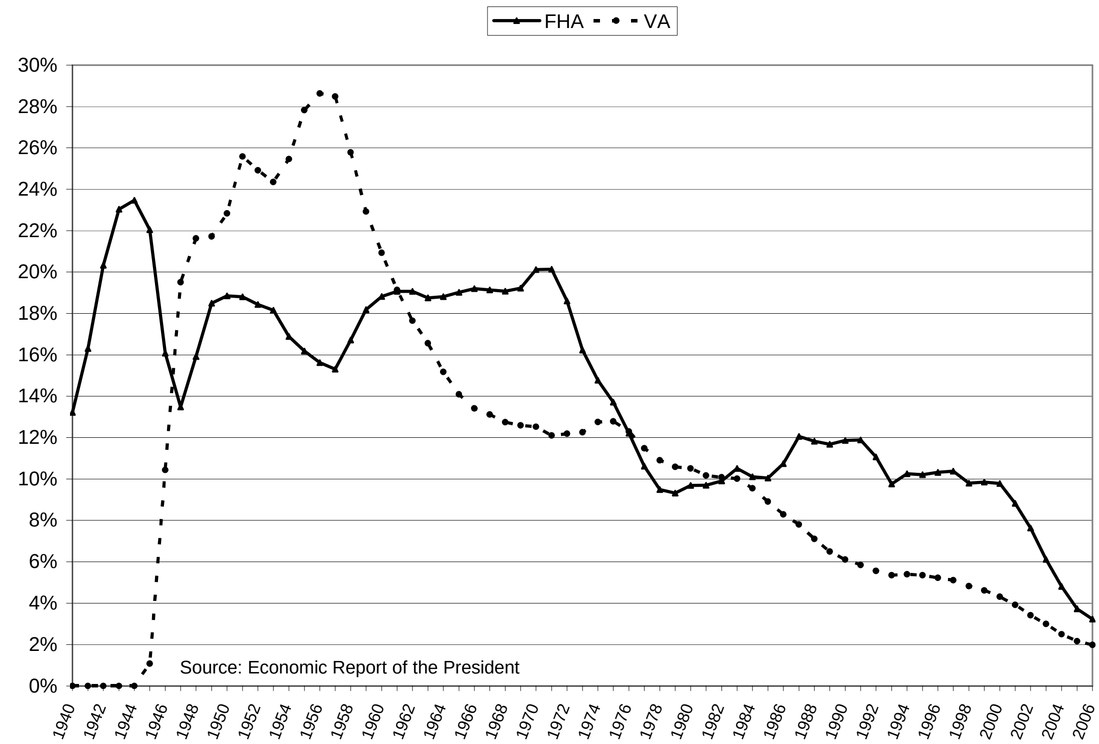

FIGURE 5: INSURED MORTGAGES OUTSTANDING AS PERCENTAGE OF TOTAL 1-4 MORTGAGES OUTSTANDING

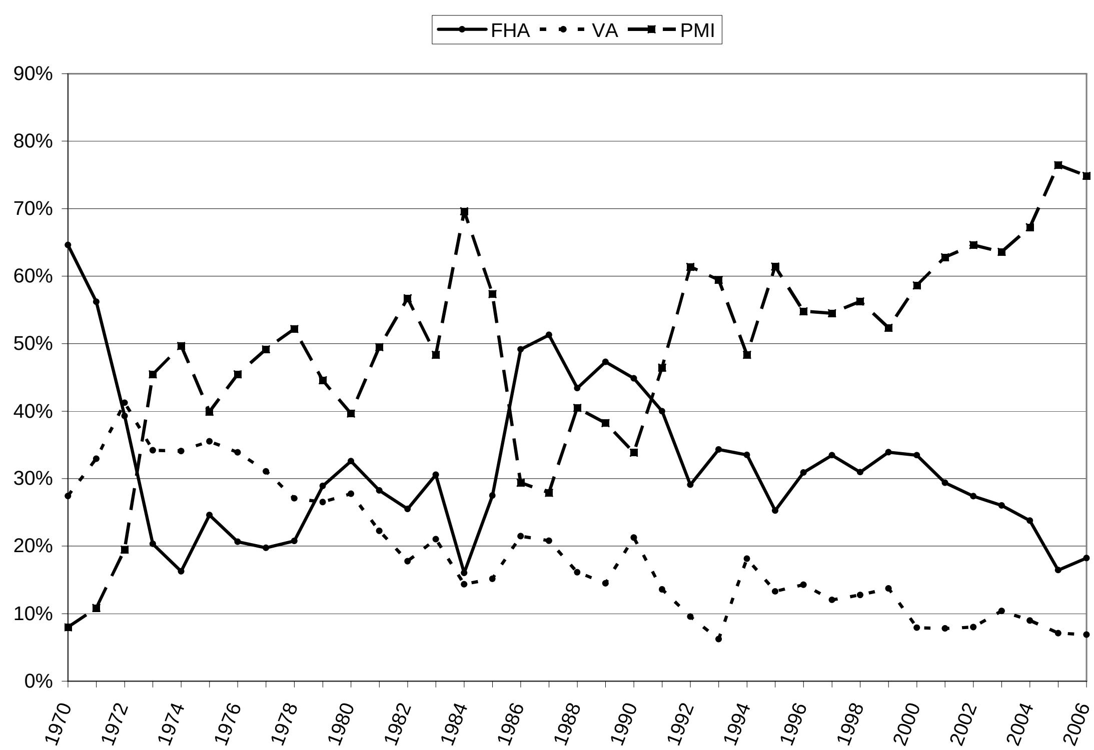

FIGURE 6: INSURED MORTGAGE ORIGINATIONS AS SHARE OF ALL 1 TO 4 FAMILY MORTGAGE ORIGINATIONS

Several factors led to this dramatic and continuing decline in the market share of the government programs:

- Success of the Private Mortgage Industry (PMI). Although the PMI firms traditionally focused on borrowers with higher income and larger mortgages than the FHA program, competition between the two formats became increasingly aggressive. Importantly, the PMI firms quickly adapted to provide coverage on newly design mortgage formats which were not eligible for FHA loans.
- Failure of the FHA to innovate its mortgage contracts. A variety of technological and informational advances took place in the U.S. mortgage starting in about 1990. These provided the opportunity for lenders to make loans to lower-income borrowers and those with more erratic income patterns than had previously been considered possible. The FHA, however, was remarkably slow in adapting to these new conditions, even though the changes were directly relevant to its traditional client base.
- Subprime and predatory lending. While the FHA was slow to respond to the new lending opportunities created by technological and informational advances, the private markets were not. In its most positive aspect, this created a new form of subprime lending, which allowed very large numbers of American families to become homeowners. In its most negative aspect, it also allowed very cruel forms of predatory lending, whereby uninformed families were induced to take on mortgage obligations that were far from their best interest.
- Fannie Mae and Freddie Mac competition. Traditionally, the two government sponsored enterprises were not active in the lower reaches of the mortgage quality spectrum. Increasingly, however, as these firms found little growth opportunity in their traditional markets, they began to compete with the FHA for borrower clients.

The history of the FHA program provides a very useful template for the creation of a new long-term insurance market against natural disaster risks. First, it illustrates that in the absence of coordination, private markets may fail to initiate an important financial innovation. The government intervention was not only of value for its own sake, but it provided a variety of external benefits, such as the FHA-based creation of the mortgage backed security market. Jaffee and Quigley (2007)[39] even suggest that the FHA program was instrumental in allowing the recreation of a private mortgage insurance industry, since the success of the FHA program demonstrated that it was feasible to insure fixed payment, long-term home mortgages. Second, the later development and success of the private mortgage insurance industry indicates that a government program will not necessarily crowd out private competitors. A key factor here, of course, is the requirement that the premiums charged by the government program be actuarially sound. It no doubt also helped that the FHA program has progressively been directed to lower income borrowers, thus providing a natural market niche with middle- and upper-income borrowers for the private mortgage insurance industry.

[39] Jaffee, D. and J. Quigley (2007), "Housing Policy, Mortgage Policy, and the Federal Housing Administration," Program on Housing and Urban Policy Working Paper No. W07-04, at http://urbanpolicy.berkeley.edu/publist.htm#Working%20Papers

4-B. Reasons for Long-Term (LT) mortgages

LT mortgages developed due to the need for liquidity by homeowners given their budget constraints. They also had a desire for stable payments over time -- planning ahead. LT mortgages—either fixed rate or variable rate—have various advantages. Due to its long maturity, the borrower does not face the risk that the full principal may be called on short notice. The loans amortize the principal in a series of steady payments over the life of the loan, so at the maturity date, the loan principal due equals zero. With securitization, both the interest rate and credit risk can also be transferred from the lender to a capital market investor. Intermediation by Fannie Mae and Freddie Mac serves a similar purpose.

Fixed-rate, LT mortgages These normally have higher interest rates than variable-rate loans to reflect the interest rate risk and the normal ascending shape of the yield curve. Interest-only (i.e. no amortization) mortgages will have still higher rates, since the homeowner has less equity at the end of any time period. Most mortgages allow the borrower an option to repay the loan under a variety of circumstances. The standard "due on sale" clause requires the homeowner to repay the loan if the home is sold. There is no fee for this, since it is to protect the lender. (There remain some *assumable* mortgages under which the homeowner can transfer the existing mortgage to a new home buyer under certain conditions).

Most mortgages allow the borrower to refinance the mortgage (which benefits the borrower on a fixed-rate mortgage when market rates fall). In some cases, the borrower pays for this option with a prepayment penalty that is due when the mortgage is refinanced. In other cases, the expected cost of the prepayment option is simply reflected in a higher contractual rate. (This is the case, for example, on most fixed-rate mortgages securitized by Fannie Mae and Freddie Mac).

Adjustable rate LT mortgages The interest rates on adjustable rate mortgages (ARMs) have been systematically lower than comparable rates on fixed-rate mortgages. Figure 7 shows that the spread has been as high as 3.5 percent points while it is currently at the relatively low spread of about 1 percentage point; the spread has averaged 1.8 percentage points from 1985 to 2007. As already noted, the normally ascending yield curve is one explanation for this positive spread. In addition, since ARMs impose the risk of rising interest rates on the borrower, lenders systematically offer discounts on ARM rates that are even greater than the yield curve would warrant.

Figure 7 also shows that the ARM percentage of all originated mortgages has varied significantly over time, reaching almost 60 percent in 1987, but falling to almost 10 percent at times during the last 10 years. There is a substantial and growing literature on the factors that determine the borrower's choice between the two contracts formats.[40] It is apparent that all else the same, borrowers would prefer the price certainty created by fixed-rate mortgages. However, two factors may induce borrowers to choose ARMs. The first factor is that ARM rates are generally lower than FRM rates. The second factor is that borrowers may believe they can predict future movements in interest rates, and therefore have special motive to take out ARMs

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[40] See, for example, Campbell, J. "Household Finance," forthcoming *Journal of Finance*; Van Hemert, O., "Household Interest Rate Management" and Koijen, R., O. Van Hemert, and S. Van Nieuwerburgh, "Mortgage Timing."

when the expect market interest rates will soon be falling. There is evidence that the borrowers are somewhat successful in this regard, as an inspection of Figure 7 reveals.

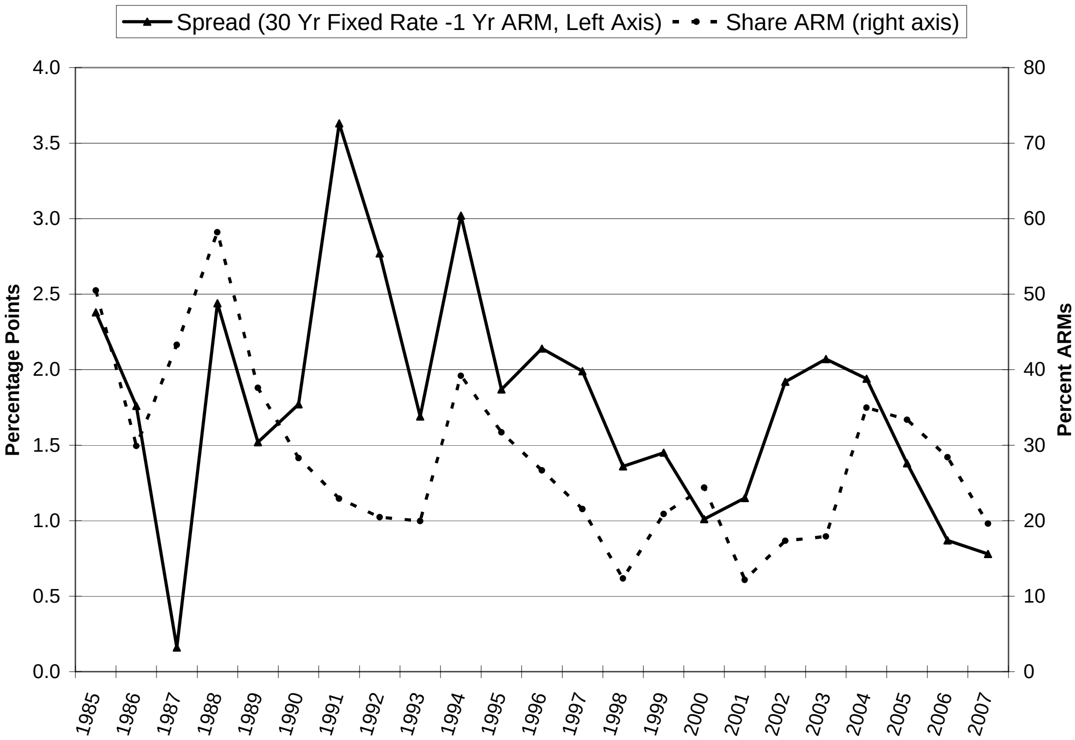

FIGURE 7: INTEREST RATE SPREAD (FIXED-RATE MINUS ADJUSTABLE-RATE) AND ARM SHARE OF TOTAL MORTGAGE ORIGINATIONS

Most states require a series of "caps" that limit the increases in the contractual interest rate and the payment amounts. The interest rate may not change by more than a fixed amount (e.g. 1 percentage point, and payments likewise cannot rise more than given percentage (e.g. 5 percent). The payment caps are usually applied in terms of the annual changes, whereas rate caps may apply to both annual changes and life time changes (measured from the initial conditions on the mortgage). On most prime adjustable mortgages, and reflecting some state laws, homeowners facing a payment increase are allowed a "no penalty window" during which they can prepay without penalty. Interesting, many of the subprime mortgages found a way to avoid these windows, thus forcing the borrowers either to pay the higher premiums or to pay prepayment penalties.[41]

Mortgage lenders benefit when homeowners repay mortgages that have below-market contract rates, but suffer when the repaid mortgage has an above-market rate. Overall, the lenders probably suffer, since more sales occur when market rates are falling. Compensation for

[41] Mortgage rates in the U.S. were also once limited by a variety of state usury laws, many enacted in the late 19th century. Federal legislation in 1980 was passed to preempt these laws, because it was increasingly evident that their major effect was to reduce mortgage lending, especially for higher risk borrowers who would normally be expected to pay higher rates. Interestingly, the federal legislation provided state legislatures the right to reenact their usury legislation, but no states did so.

this expected loss, however, is embedded in the initial mortgage rate. This works tolerably well. Commercial mortgages, in contrast, to residential mortgages, require the borrower repay the lender for any financial loss due to a mortgage repayment (whether due to sale or refinancing). Commercial mortgages have developed a variety of mechanisms for this purpose.

5. APPLYING CONCEPTS FROM LT MORTGAGES TO LT INSURANCE

5-A. Reducing the Uncertainty

The infrequency of major catastrophes in a single location implies that the loss distribution for homeowners insurance in hazard-prone areas of the country is not always well specified. The ambiguities associated both with the probability of an extreme event occurring and with the outcomes of such an event raise a number of challenges for insurers with respect to pricing their policies. Empirical studies reveal that actuaries and underwriters are averse to ambiguity and want to charge much higher premiums when the likelihood and/or consequences of a risk are highly uncertain than if these components of risk are well specified. (Kunreuther et al., 1995).[42]

Insurers often are provided with imprecise estimates of the likelihood of a specific catastrophe event, such as a range of probabilities (i.e., $p \in [p_{low}; p_{high}]$) from the leading modeling firms or in-house modeling capacity.[43] In some cases, experts will strongly disagree on the estimate of this probability, with one group confidently estimating the probability to be p_{low}, and the other confidently estimating it as p_{high}.

Fueled with such estimates, how would insurers react? How do they aggregate the differing probability estimates which different experts have provided them with? Recent research shows that insurers are sensitive to the type of ambiguity associated with the likelihood of an event occurring. In a survey of 78 actuaries in France, Cabantous (2007)[44] showed that actuaries would charge a much higher premium when ambiguity came from conflict and disagreement regarding the probability of a loss than when the ambiguity came from an imprecise forecast.[45] On average, the annual mean premium was 32 percent higher when the ambiguity came from an imprecise forecast that when the risk was well-known and it was 40 percent higher when ambiguity came from conflict. The survey also showed that the source of ambiguity matters (see Table 2 for details of the questions).

In 2007 Wharton Risk Center launched a web-based survey of actuaries and underwriters' decision making under risk, uncertainty without conflict and uncertainty with conflicting information on risk estimates. We invited underwriters and actuaries from several insurance companies working with us to complete a 15-minute survey that had also the support of the Casualty Actuarial Association. We obtained responses from 78 insurers. In this survey,

[42] Kunreuther, H., J. Meszaros, R. Hogarth, and M. Spranca (1995), "Ambiguity and underwriter decision processes," *Journal of Economic Behaviour and Organization*, 26: 337-352.

[43] The three leading modeling firms are AIR Worldwide, EQECAT and Risk Management Solutions (RMS).

[44] Cabantous, L. (2007), "Ambiguity Aversion in the Field of Insurance: Insurers' Attitude to Imprecise and Conflicting Probability Estimates," *Theory and Decision*, 62: 219-235.

nine different scenarios were developed by crossing three different types of natural hazards (fire, flood and hurricane) with three types of information about the probability of a disaster with a loss of $100,000 (precise probability, imprecise probability and conflicting probability), using the same type of questions as in the survey of actuaries in France, as described in Table 2.

Participants were asked to determine the annual premium they would charge to cover a homeowner against a risk, assuming a 1-year contract. We were also interested in how insurers would behave if they had the opportunity to offer a long-term insurance contract (e.g., 20 years) tied to the homeowner's mortgage.

TABLE 2. SCENARIOS OF THREE RISKY SITUATIONS

No ambiguity	**Source of the Ambiguity**	**Source of the Ambiguity**
Precise Probability	**Imprecise Probability**	**Conflicting Probability**
Both modeling firms estimate that there is a **1 in a 100** chance that a flood will severely damage homes in this area this year (i.e., the annual probability is 1 percent). They both are confident of their estimate.	Both modeling firms recognize that it is difficult to provide a precise probability estimate. The two modeling firms agree that the probability that a hurricane will severely damage homes in this area this year ranges somewhere between a **1 in 200 chance** and **1 in 50 chance**.	One modeling firm confidently estimates that there is **1 in a 200 chance** that a fire will severely damage homes in this area this year (i.e., the annual probability is 0.5 percent). The other modeling firm however, confidently estimates that the chance that a fire will severely damage homes in this area this year is much higher: **1 in 50 chance** (i.e. the annual probability is 2 percent).

When there was no ambiguity, the probability of the loss was 1 in 100 so the expected loss is $1,000. In the two ambiguous cases, we specified 1 in 200 and 1 in 50 as the minimum and maximum estimates of the probability of the loss so the expected loss for these two situations was $500 and $2,000 respectively. The preliminary results shown in Figure 8 reveal that the type of hazard does not have a significant effect on mean premiums. However, the quality of the probabilistic information can change the premium significantly.

Under a 1-year contract, mean annual premiums when the probability is ambiguous are 25 percent higher than when it is given precisely. The source of uncertainty however does not affect insurers. The estimated premiums when there is conflict between experts are not significantly different from premiums when the probability of a disaster is imprecise. Contrary to results by Cabantous (2007), in this population of U.S. insurers, imprecision is only of slightly greater concern than conflict. The mean premium under imprecision is 5 percent higher than the mean premium under conflict. Under the 20-year contract, aversion to ambiguity is even stronger. Depending on whether the probability is imprecise or there are conflicting probability estimates, mean annual premiums are 34 percent and 41 percent higher respectively than when there is no ambiguity.

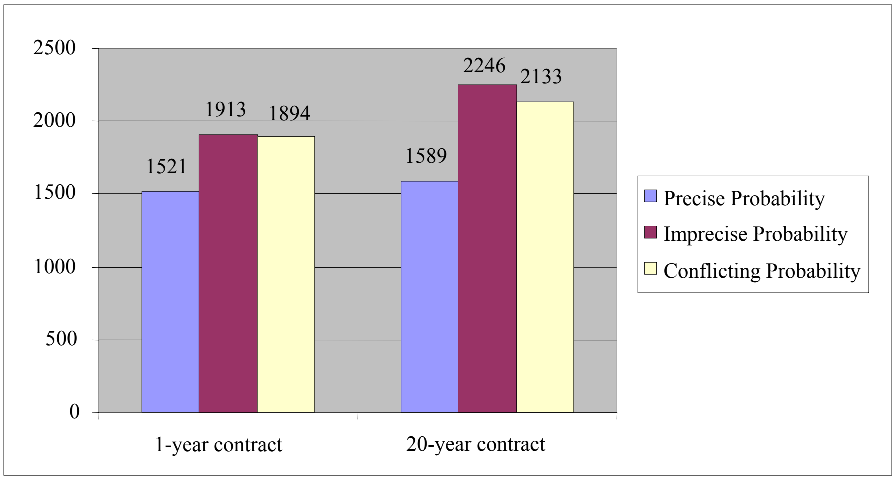

FIGURE 8. ANNUAL MEAN INSURANCE PREMIUMS IN DOLLAR, ACROSS NATURAL HAZARDS (N=78)

5-B. Fixed Rate LTI Contracts

Insurers are likely to charge higher premiums for longer term contracts due to the uncertainty associated with the risk. If risk increases over time, the premium is too low relative to what the insurer would like to charge. If risk decreases over time the homeowner will want to cancel her policy and purchase a new policy at a lower premium. To address this issue we propose that homeowners pay a penalty to the insurer if they opt out of their policy for any reason other than home sale. This parallels the treatment of mortgages.

To deal with insurers concerns with catastrophic losses during the length of the LTI contract there is likely to be a need for an expansion of alternative risk transfer instruments and longer term reinsurance contracts. Capital markets emerged in the 1990s to complement reinsurance in covering large losses from natural disasters through new financial instruments, such as industry loss warranties, catastrophe bonds and, more recently, sidecar reinsurers. Several forces combined to make these new instruments attractive. The shortage of reinsurance following Hurricane Andrew in 1992 and the Northridge earthquake in 1994 led to higher reinsurance prices and made it feasible for insurers to offer catastrophe bonds with high enough interest rates to attract capital from investors. In addition, the prospect of an investment that is uncorrelated with the stock market or general economic conditions is also attractive to capital market investors. Finally, catastrophe models emerged as a tool for more rigorously estimating loss probabilities, so that disaster risk could be more accurately quantified and priced than in the past.

Following Hurricane Katrina, there has been a significant increase in the number and volume of catastrophe bond issuances and the creation of sidecars, but the total volume of financial protection remains somewhat limited compared to what is currently provided by traditional reinsurance. There will be a need to enhance this market even more significantly in the future.[46] For insurers to be willing to promote LTI, they may require long-term protection

[46] In 2006, twenty cat bonds were issued ($4.7 billion issued and $8.7 billion capital outstanding), compared with eleven in 2005 ($2.1 billion issued and $2.9 outstanding), the previous record. In 2007, the total value of cat bonds issued for natural disasters alone was $7.1 billion. See Michel Kerjan, E. and F. Morlaye (2008), "Extreme Events,

against catastrophic losses through reinsurance and alternative risk transfer instruments. Today, reinsurance contracts are typically for one year or two, and relatively few of the insurance-linked security (ILS) contracts have a maturity longer than 3 years (only 2 out of the 20 cat bonds issued in 2006). There is thus a need to assess the constraints on the availability and volume and contract length of securities that diversify catastrophe risk and how the use of these vehicles could be expanded to augment reinsurance capacity and the role that the government can play to promote this market.

5-C. Adjustable Rate LTI Contracts

There will be a significant benefit to homeowners if their insurer guarantees coverage for a fixed period (e.g. 15 years), even if the premiums can vary from year to year depending on the risk. In theory, premiums could decrease as well as increase. It is critical that the premium variations be based on an external index. For example, the insurance industry regularly tabulates the total insured losses from major events (Property Claims Services). This would provide a natural index, but regulators and policyholders need to assure that it cannot be manipulated. There may also have to be caps on how much the premium can change year to year just as there are limits on how much the interest rate can change annually on adjustable rate mortgages.

The experience with the rates on adjustable rate mortgages confirms that the premium changes must be linked to some external index, distinctly beyond the control of the lender. The lending banks, in particular, wanted to tie the rates on their adjustable mortgages to their own cost of funds. The Federal Home Loan Banks obliged by creating a Cost of Funds Index (COFI) for the lending institutions in their regions. While a number of mortgages were created on the basis of COFI, it lost out in the market place to a more transparent measure, namely the yield on Treasury bills of various maturities.

5-D. Risk Exposure and Capital Cost Indexes for LTI

Risk Exposure Indexes

Whether the LT insurance contract uses fixed or adjustable premiums, one of the challenges will lie in establishing a transparent mode of evaluating **risk exposure** for the long period of time covered under the LTI contract. Catastrophe models developed by modeling firms have been the source of these estimates in recent years but controversies in the post-Hurricane Katrina period reveal raises some challenging issues.

In the first part of the twentieth century, scientific measures of natural hazards advanced rapidly. Two separate developments – mapping risk and measuring hazard – came together in a definitive way in the late 1980s and early 1990s, through catastrophe modeling. Computer-based models for measuring catastrophe loss potential were developed by linking scientific studies of natural hazards' measures and historical occurrences with advances in information technology and geographic information systems (GIS). The models provided estimates of catastrophic losses by overlaying the properties at risk with the potential natural hazard(s) sources in the

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Global Warming, and Insurance Linked Securities: How to Trigger the 'Tipping Point,'" *The Geneva Papers on Risk and Insurance,* 33(1): 153 176.

geographic area. With the ability to store and manage vast amounts of spatially referenced information, GIS became an ideal environment for conducting future, easier, and more cost-effective hazard and loss studies.

Around the same time, several new companies developed computer software for analyzing the implications of natural hazard risk. Three major modeling firms emerged: Applied Insurance Research (AIR) Worldwide was founded in 1987 in Boston; Risk Management Solutions (RMS) was formed in 1988 at Stanford University; and EQECAT began in San Francisco in 1994 as a subsidiary of EQE International. In 2001, EQE International became a part of ABS Consulting. Over the past ten years, these companies have become important players in the field of catastrophe insurance and reinsurance. These firms were subject to some criticism for failing to increase their risk assessment in advance of the 2004-2005 storm seasons.

It should be noted that catastrophe modeling and risk assessment face a number of informational challenges as well as acceptance by the market and regulatory agencies. For instance, the Florida Commission on Hurricane Loss Projection Methodology refused to certify RMS's medium-term view of hurricane activity filed in 2006 that reflected the recent increase in hurricane frequency and intensity being experienced in the Atlantic basin. RMS had to modify its model, so hurricane activity estimates for the next five years are now based on a straight historical average of the number of hurricanes recorded since 1900 (RMS, 2007).[47] Ultimately, it may have been necessary to experience the recent increased hurricane activity for RMS and other firms to adjust their models. Due to parameter uncertainty, it is not possible to know whether a given model has accurately estimated the true underlying risk of loss and associated probability distributions.

The development of an index is important for transparency and to limit potential problems related to asymmetric information between interested parties. In the case of catastrophe risk insurance, one might argue for instance that large insurance companies have more information about hurricane risks in a specific region than a family living there who does not have the financial resources an insurer typically invests in modeling; that *reversed* asymmetric information in favor of the insurer might lead to *advantageous* selection where only the low-risk individuals are fully covered at the equilibrium, while high-risk individuals are not (Henriet and Michel-Kerjan, 2008).[48]

Risk evaluation, of course, is an issue common to most financial instruments. The recent U.S. subprime mortgage crisis illustrates that capital market investors are willing to purchase and hold new and risky classes of securities, especially if the risk is thought to have a low correlation with systematic market risk and the risk-adjusted return is judged to be adequate. The subprime investments turned out to be a large mistake, but the market meltdown has been primarily the result of falling house prices, which have created highly correlated defaults. Furthermore, there is a parallel record of investments in securitized auto, credit card, student, commercial mortgage and other loans, all of which have been highly successful to date. (Jaffee, 2008).

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[47] RMS (2007), "Hurricane Model Re-Certified by Florida Commission," Press release, June 25.
[48] Henriet, D. and E. Michel-Kerjan (2008), "Looking at Optimal Risk-Sharing in a Kaleidoscope: The (Market Power, Information) Rotational Symmetry", Working paper, Wharton Risk Center, The Wharton School. Available at: http://opim.wharton.upenn.edu/risk/library/WP2008-01-21_DH,EMK_OptimalRiskSharing.pdf

Capital Cost Indexes

Incorporating Capital Costs in Insurance Premiums The second important element that enters insurance price is the cost of capital that the insurer has to access for its entire portfolio. The importance of capital as a requisite for insurers to secure an adequate rate of return is often not sufficiently understood.[49] In particular, the prices charged for catastrophe insurance must be sufficiently high to cover the expected claims costs and other expenses, but also must cover the costs of allocating risk capital to underwrite this risk. Moreover, because large amounts of risk capital are needed to underwrite catastrophe risk relative to the expected liability, the resulting premium is high relative to its loss expenses, simply to earn a fair rate of return on equity and thereby maintain the insurer's credit rating.

There is indeed a temptation for parties to imbue the notion of a fair premium to serve their own interests. For example, the term *actuarially fair premiums* has a precise definition: the premium is equal to the expected loss. Much of the public debate surrounding a fair price of catastrophe insurance implicitly uses the concept of actuarially fair premium because it is simple and results in a low cost to the policyholder. However, while *actuarially fair* is a useful statistical concept, the implied premiums are not economically sustainable. Insurers must cover all their costs (not only expected claims) in order to survive and attract capital.

An expanded notion of fair premiums derives from the notion of a *fair rate of return on capital*. A fair return is one that offers the investor a competitive return on capital so that the investor will want to place her funds with the insurer rather than elsewhere. A fair premium would then be one that just offered the investor a fair rate of return. To offer a fair return, the premium would have to cover all costs (expected claims, expenses of various sorts and taxes), and then produce an expected return to the investor which was equal to the cost of capital or fair return. The premium would yield some profit, but only the normal level of profit necessary to attract and maintain the insurer's capital base.

While a sustainable premium must offer a return consistent with the cost of capital, we must also pay attention to how much capital the insurer will need to pay claims with an acceptably low probability of default. The required amount of capital depends on the risk characteristics of its liability portfolio, its asset portfolio and the effectiveness of its risk management strategy. What is an acceptably low risk will be interpreted differently by prospective policyholders, by regulators and by rating agencies who impose standards ostensibly on behalf of such policyholders. For current purposes, we can think of the economic capital as that required to maintain the insurer's credit rating or the capital needed to satisfy regulatory requirements if this is higher than the rating agency's requirements.

Each policy the insurer sells imposes its own capital burden. If an additional policy were sold without adding to the insurer's overall capital, there would normally be a small increase in the likelihood that the insurer would default. Just how much of a change depends on the riskiness of the policy and its covariance with other policies and assets held by the insurer. The appropriate allocation of capital to a policy would be that amount required to maintain the insurer's credit status; i.e., the addition of the policy and the accompanying capital would leave the insurer with the same credit status as before.

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[49] Discussion in this section is based on Wharton Risk Center (2008), *Managing Large-Scale Risks in a New Era of Catastrophes* (Chapter 6). We thank Neil Doherty for providing us with this analysis.

We thus define a fair price for insurance as a premium that provides a fair rate of return on invested equity. To illustrate, we construct a somewhat conservative hypothetical example that ignores taxes and regulatory constraints. Consider a portfolio that has $1,000 in expected losses, E(L). Let k be the ratio of capital to expected losses for the insurer to maintain its credit rating. For this example k=1, a value utilized by many property liability insurers for their combined book of business (Doherty, 2000).[50]

In addition to paying claims, the insurer is assumed to set aside capital for covering additional expenses (X) in the form of commissions to agents and brokers, and underwriting and claims assessment expenses. For this example, X = $200. Given the risk characteristics of the portfolio, investors require a return on equity (ROE) of 15 percent to compensate for risk. The insurer invests its funds in lower-risk vehicles that yield an expected return, r, of 5 percent. What premium π would the insurer have to charge its policyholders to cover them against natural disasters and to secure a return of 15 percent for its investors?

The formula is given by:

$$\pi = \frac{E(L) + X(1+r)}{(1+r) - k(ROE - r)}$$

which yields a value of π = $1,274 for this hypothetical example. We can think of this premium now as the expected loss of $1,000 plus a proportionate loading, λ, of 0.274. Thus, the premium is $(1+\lambda)E(L)$ = (1 + 0.274)$1,000 = $1,274

This calculation is very sensitive to the ratio of capital to expected liability, k, needed to preserve credit. In the above example, the ratio was one dollar of capital for one dollar of expected liability. This ratio is in the ballpark for the combined books of business of many property liability insurers. However, for catastrophic risk, with its very large tail risk (which severely affects the insurer's credit risk), the capital to liability ratio needs to be higher. Indeed, the capital to liability ratio depends on volatility of the catastrophe liability and its correlation with the insurer's remaining portfolio. For the catastrophe risk premium for individual homeowners, this may translate into a loading, λ, perhaps approximating 0.5. Thus the premium would be 150 percent of the expected loss. This does not reflect undue profitability, but simply that insurers need considerable capital to supply this insurance and the cost of that capital is included in the premium.

A second issue with respect to catastrophic risk is that it can be expensive to underwrite since it requires extensive modeling. Many companies buy commercial models and/or use their own in-house modeling capability. We recalculate the premium formula with X = $600 and k = 5. The required premium is now $2,964, more than twice the value of π computed above and now nearly three times the expected loss. Notice this translates into a loading, λ, of 1.965, so the premium is $(1+\lambda)E(L)$ = (1 + 1.965)$1,000 = $2,965

[50] Doherty, N. (2000), *Integrated Risk Management*, New York; McGraw-Hill.

There are other considerations that can dramatically increase the capital cost, notably the impact of double taxation. Harrington and Niehaus (2001)[51] have simulated the tax burden over many parameters and show that tax costs alone can reasonably be as much as the claim cost and lead to further increases in premiums. When we account for all these factors (i.e., high capital inputs, transaction costs and taxes), catastrophe insurance premiums often are several multiples of expected claims costs.

Cost of Capital in Mortgage Lending Here again, there are parallels between insurance and mortgage lending with respect to the importance of incorporating the cost of capital in pricing decisions. U.S. mortgages range from adjustable-rate contracts to 30-year (or now even 40-year) fixed rate mortgages. The discussion above noted that adjustable-rate mortgage (ARM) lenders first tried to index their ARMs to their own cost of funds, but transparency ultimately required they use a market index, most commonly Treasury bill rates.

The cost of capital for fixed-rate mortgages is a more serious issue, particularly so because bank depositors are generally unwilling to accept certificates of deposit with maturities beyond even 1 or 2 years. The main solution was the securitization of fixed-rate mortgages, which provided a highly efficient mechanism for the lenders to sell the mortgages. GNMA MBS are the simplest case, since they have a full U.S. government guarantee. The spread between the mortgage rate paid by the borrower and U.S. Treasury bonds consists of 4 main components (i) a fee of perhaps 25 basis points (bps) paid to the FHA or VA for the mortgage guarantee, (ii) a fee also of perhaps 25 bps paid to the Servicer who runs the securitization, (iii) a market cost of perhaps 50 bps that investors require for accepting the prepayment option provided the borrowers, and (iv) a market illiquidity premium of perhaps 25 bps required by investors. The spread of somewhat more than 1 percentage point between FHA/VA mortgage rates and U.S. Treasury bond rates makes the U.S. mortgage market the most efficient in the world.

The largest share of fixed-rate mortgages today in U.S. mortgage markets are "conforming mortgages" that meet the conditions for purchase and securitization by Fannie Mae and Freddie Mac, the two enormous government sponsored enterprises (GSEs). The GSEs have been creating MBS since the early 1970s, and they now represent close to half of all U.S. mortgages. Although the underlying mortgages have default risk, investors generally price the GSE MBS as if there is no default risk, based on the presumption of an implicit guarantee from the U.S. government. The resulting spread between the interest rates on "conforming mortgages" and U.S. Treasury rates is thus generally only a bit larger than the FHA/VA spread. However, when trust in the implicit guarantee weakens, then the spread widens, possibly even doubles; this is currently the case due to investor fears created by the subprime mortgage crisis.

The last component of fixed-rate mortgages are non-conforming mortgages that will not be purchased or securitized by the GSEs, either because they are too large or too risky. This includes "prime jumbo" mortgages as well as subprime mortgages. Non-conforming mortgages have been securitized since the mid-1980s. Investors in these MBS face a definite default risk, and the market has succeeded as a result of the innovation of using a senior/junior structure—

[51] Harrington, S.E., and G. Niehaus (2001), "Government Insurance, Tax Policy, and the Affordability and Availability of Catastrophe Insurance," *Journal of Insurance Regulation,* 19(4): 591-612.

hence the term structured finance—that allows the risk to be allocated among various investors depending on their risk tolerances. That is, the cash flows from the underlying mortgages are allocated first to the most senior tranche until it is redeemed, then to the next most senior, and down the priority schedule. Mortgage defaults are charged first to the lowest tranche and then work their way up the structure. The various tranches are evaluated by the rating agencies, with the most senior tranches normally receiving AAA ratings and intermediate tranches receiving B to BBB ratings. The most risky tranches are normally not rated, since they are either held by the issuer or sold in a private transaction to an informed investor such as hedge fund. The effect of this structure is that non-conforming mortgage rates have historically averaged only about 25 bps higher than conforming mortgage rates, although these spreads are currently wider as a result of the subprime mortgage crisis.

The overall conclusion is that the cost of capital issue for long-term mortgages has been very effectively solved by a combination of ARMs that are held in lender portfolios and securitization which allows fixed-rate mortgages to be sold to capital market investors. The investors purchasing these MBS are primarily institutional investors, including mutual bond funds, pension and hedge funds, and insurance companies. Foreign investors, particularly Asian investors have also become an important investor class as a result of the U.S. trade deficit; see Bardhan and Jaffee (2007).[52]

6. Designing Optimal Contracts

6-A. Relevant Literature in Economics, Insurance and Finance

An extensive literature now exists on the optimal design of financial securities and contracts; see Allen and Gale (1994) for a book-length survey.[53] The mechanism used to design securities in this literature can be briefly summarized as:

(1) An economic decision-making environment is assumed with utility functions for the various economic agents whose actions are affected by income, consumption and balance sheet constraints. Other features of the market such as transactions costs, incomplete contracts and asymmetric information must also be specified.

(2) A solution is a contract format that maximizes utility subject to the above constraints. This often has a highly mathematical and abstract form.

(3) A real-world approximation to the abstract optimal contract is proposed.

For example, debt contracts—in which the borrower promises to make specified payments, while the lender has the rights to certain assets if (and only if) the borrower fails to make the scheduled payments—can be derived as the optimal design when lenders face large costs of verifying the borrower's ability to repay. The debt contract is optimal because the lender needs to verify the borrower's cash flows only in the, hopefully infrequent, situations in which the borrower fails to make the scheduled payments. A recent example is the paper by

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[52] Bardhan, A. and D. Jaffee (2007), "Impact of Global Capital Flows and Foreign Financing on US Interest Rates," Research Institute for Housing America, September 2007, available at: http://housingamerica.org/default.html

[53] Allen, F. and, D. Gale (1994), *Financial Innovation and Risk Sharing*, MIT Press.

Piskorski and Tchistyi (2006)[54] which derives certain features of subprime mortgages as the optimal design when borrowers have highly uncertain and fluctuating income flows, and where direct observation of their consumption and saving is impossible. With this background, we now turn to a model for designing a LTI contract.

6-B. A Two Period Model for LTI

Here we propose a simple model that highlights some of the trade-offs facing insurers and policyholders who have the option to purchase a long-term (LT) policy for two periods or two one-period contracts. For such a comparison to be meaningful it is necessary that insurance premiums reflect risk[55]. This is a key principle that has guided the recent Wharton Risk Center (2008) study. This principle is formulated as follows: *Insurance premiums should be based on risk in order to provide signals to individuals as to the hazards they face, and to encourage them to engage in cost-effective mitigation measures to reduce their vulnerability to catastrophes.*[56]

Assumptions

We assume a competitive market in which insurers are homogenous and maximize expected profits. Consumers are homogenous and buy full coverage for the first period, then for the second period, or for two periods at once. At the beginning of period 1 experts provide a single estimate of a disaster occurring in period 1 and are uncertain as to whether the likelihood of a disaster in period 2 will be high (H) or low (L). At the end of period 1, insurers and consumers learn whether the probability of a disaster in period 2 is H or L.

Notation

Z_1 = insurance premium in period 1 for a one-period policy

Z_2 = insurance premium in period 2 for a one-period policy

Z(LT) = fixed insurance premium per period for LT coverage if consumer stays with insurer for two periods

Z′(LT) = total amount that the insurer needs to collect from the insured under LT coverage if consumer cancels policy after period 1

C = penalty cost to consumer if he cancels an LT policy at the end of period 1

D = insured damage if disaster occurs

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[54] See Piskorski, T. and A. Tchistyi "Optimal Mortgage Design" (November 2006). Available at SSRN: http://ssrn.com/abstract=971223

[55] As stated in the 2007 *Economic Report of the President*, which devotes for the first time ever an entire chapter to the question of catastrophe risk insurance, "Effective insurance underwriting serves an important social function by tying the premiums and terms of insurance policies to the risks covered. When insurance prices reflect underlying economic costs they can encourage a more efficient allocation of resources. Efforts to keep premiums for insurance against catastrophe hazards artificially low, whether through regulation or through subsidized government programs, can encourage excessively risky behavior on the part of those who might be affected by future catastrophes". (Chapter 5, p. 122-123)

[56] See Wharton Risk Center (2008), *Managing Large-Scale Risks in a New Era of Catastrophes* (Chapter 14) for a more detailed discussion of this principle.

p_1 = probability of D in period 1
p_{2H} = high probability of a disaster in period 2 ; p_{2L} = low probability of a disaster in period 2
We assume $p_{2L} < p_1 < p_{2H}$
a = weight placed by experts in period 1 on the likelihood of p_{2L} in period 2.
M = upfront cost to insurer of marketing a policy
A = administrative cost of marketing a policy
λ = cost of capital held by the insurer to cover potential damage.

Premiums Charged by Insurer for One-Period Insurance

$$Z_1 = (1+\lambda)\, p_1.D + M + A \quad (1)$$

$$Z_{2L} = (1+\lambda)\, p_{2L}.D + M + A \quad \text{with likelihood+ a} \quad (1a)$$

$$Z_{2H} = (1+\lambda)\, p_{2H}.D + M + A \quad \text{with likelihood (1-a)} \quad (1b)$$

Premium Charged by Insurer for LT Insurance

For the sake of simplicity we assume that the discount factor is zero between the period 1 and period 2 costs. If the consumer purchases a LT contract then she will pay the same premium Z (LT) in each of the two periods, which is:

$$Z(LT) = ½.\{M + 2A + (1+\lambda)\, [p_1 D + a\, p_{2L} D + (1-a)\, p_{2H} D]\} \quad (2a)$$

Consumers are given the right to cancel a contract at the end of period 1 but at a cost. The insurer knows that if the probability of a disaster in period 2 is p_{2L} then a consumer will be able to purchase coverage more cheaply from an insurer offering a policy in period 2. If the consumer leaves the insurer in period 2, then the insurer wants to make sure it receives Z′(LT) in period 1 to cover its administrative cost and cost of capital incurred in period 1 and its expected loss for period 1. Since the consumer leaves at the end of period 1, the insurer is not liable for period 2, except for the cost of capital held during period 1 for covering the potential loss to the insured in period 2.

The value of Z′ (LT) is:

$$Z' (LT) = M + A + p_1 D + \lambda.[p_1 D + a\, p_{2L} D + (1-a)\, p_{2H} D] \quad (2b)$$

where $\lambda.[p_1 D + a\, p_{2L} D + (1-a)\, p_{2H} D]$ represents the cost of the capital that the insurer is holding to cover potential losses occurring in either period 1 or 2.

The difference C = Z′ (LT) - Z(LT) can be viewed as a penalty cost imposed on the insured who decides to leave the two-period contract at the end of period 1. More specifically:

$$C = 0.5\{M + (1+\lambda)\, p_1 D + (\lambda-1)[a\, p_{2L} D + (1-a)\, p_{2H} D]\} \quad (2c)$$

As discussed in section 5, λ can easily vary from 0.1 to 2 or 3 for truly catastrophe risks. In the latter case, the penalty cost can be substantial.

When does the insured have an incentive to leave at the end of period 1? The consumer has to balance the price charged in period 2 under a two-period contract with the sum of what she can get elsewhere for a coverage (Z_{2L}) when the probability of a loss is p_{2L} and there is a penalty cost C specified by equation (2c). This condition can be written as follows:

$$Z_{2L} + C < Z(LT)$$

$$C < ½.\{M + 2A + (1+\lambda) [p_1 D + a\, p_{2L} D + (1-a)\, p_{2H} D] \} – \{M + A + (1+\lambda)\, p_{2L}.D\}$$

$$\mathbf{C < C^* = 0.5(1+\lambda)[p_1 D + (1-a)p_{2H} D + (a-2)p_{2L}.D] – 0.5M}$$

If C < C*, the insured would have an interest in leaving and purchasing a new policy for period 2.

If the insurer sets the penalty cost such that C > C*, the insured will have an incentive to stay for the second period and pay Z(LT) even though she knows the probability of a disaster in period 2 is p_{2L}.

6-C. Cost to Consumer of Two One-period Policies and of an LT Policy

Notation

b = likelihood of the insurer canceling homeowner's policy at end of period 1

S_1 = search cost to consumer at end of period 1 for a new policy if insurer cancels policy at the end of period 1

S_2 = search cost in period 2 if consumer decides to cancel LT policy[57]

Z* = cost of an LT policy if probability of loss in period 2 is p_{2H}

Z** = cost of an LT policy if probability of loss in period 2 is p_{2L}

Z(ST) = cost of two one period policies (ST for short term)

Z(LT) = cost for each period of a long term contract

Cost of One-period Policies and LT Policy

The cost of two one-period policies purchased at the beginning of period 1 and period 2, respectively, is:

$$Z(ST) = Z_1 + b\, S_1 + Z_2$$

A consumer who is considering an LT policy is faced with two situations. If experts estimate the probability of a disaster in period 2 to be high (i.e. p_{2H}) then the homeowner has no

[57] The reason search costs are different is that when an insurer cancels a policy (S_1) and when the insured cancels it (S_2) is due to different market conditions. When an insurer cancels (for instance because the insured is viewed as too exposed or in the aftermath of a catastrophe in order to reduce the insurer's exposure in a given area) it will be much harder to find another insurer than when an insured cancels.

incentive to cancel its policy. On the other hand, if the experts estimate the probability of a disaster in period 2 to be low (i.e. p_{2L}) then the homeowner may wish to incur the penalty cost of canceling the LT policy at the end of period 1 and search for another policy at a lower cost in period 2. These two situations are represented as follows:

Optimal Choice by Consumer

To determine the optimal choice by the consumer in period 1 one needs to determine the premium (Z*) if the consumer purchases an LT policy in period 1 and the probability of a disaster in period 2 is revealed to be p_{2H} and the premium (Z**) if the probability of a disaster in period 2 is revealed to be p_{2L} . More specifically:

$$Z^* = 2\,Z(LT)$$

$$Z^{**} = Z\,(LT) + \min\,\{\,(S_2 + C + Z_{2L})\,,\ \ Z(LT\,)\,\}$$

The expected cost E(Z) of an LT Policy at the beginning of period 1 is thus:

$$E(Z) = (1\text{-}a)\,Z^* + aZ^{**}$$

The optimal choice by the consumer is given by the following decision rule:

Purchase two 1- period policies if $Z(ST) < E(Z)$
Purchase an LT policy in period 1 if $Z(ST) > E(Z)$

Conditions Leading to Preference for an LT policy

In a competitive market there are several factors that will make an LT policy attractive to consumers over two 1-period policies:

(1) If the consumer believes that there is a high likelihood that the insurer may cancel the policy at the end of period 1 (i.e. a high value of *b*).

(2) If there is a high search cost for a new policy in period 2 if either the insurer cancels the policy (i.e. a high value of S_1) or the consumer decided to look for a cheaper policy in period 2 (i.e. a high value of S_2)

(3) There is a high penalty cost to the consumer for defaulting on an LT policy (i.e. a high value of C)

(4) The important to the consumer of having stability with respect to their insurance contracts and peace of mind in knowing that they are fully protected against damage from disasters as long as they own their home

6-D. The Benefits of Long-Term Insurance for Risk-Averse Homeowners

We now demonstrate that risk-averse homeowners will prefer fixed-price LT insurance over a sequence of one period variable-price contracts if insurance premiums are actuarially fair (premiums equal expected insurance reimbursements) and that consumers maximize expected utility with respect to a time separable utility functions. We use Arrow's well known proof of the optimality of full insurance to define the notion. For a one period model, the consumer maximizes expected utility EU:

$$EU = (1-p)U(W - pI) + pU[W - pI - (D-I)]$$

where

p = probability of the loss event,
I = the amount of the insurance,
D = the amount of loss if the event occurs,
W = initial wealth.

The first term is the utility if the disaster not occurring weighted by its probability. The second term is the utility if the disaster does occur, which reduces wealth by (D – I) (i.e. the amount of uninsured damage). The first order condition shows that it is optimal to purchase full coverage, making D = I so that the utility in both states is the same, namely U(W – pD).

Now consider a consumer with a 2-period horizon and a time separable utility function, with the discount rate assumed to be zero, which we can write as:

$$U = U_1[W, p_1, I_1, D] + U_2[W, p_2, I_2, D].$$

U_1 and U_2 are the utility functions for periods 1 and 2 respectively, p_1 and p_2 are the event probabilities for the two periods with the damage remaining the same whether the disaster occurred in period 1 or 2 and I_i represents the amount of insurance purchased in period *i*.
We interpret a long-term contract where at the beginning of period 1 the consumer is offered actuarially fair insurance to cover possible events in both periods 1 and 2. Given the time separable structure of the problem, it is clear that the consumer will choose full insurance in both periods; that is, $I_1 = I_2 = D$.

We now consider a two-period horizon, but with only a sequence of 1-period contracts. In particular, we assume the actuarially fair premium for period 2 is not determined until the end of period 1. It will still be the case that the consumer will purchase full coverage in both periods, since the consumer still faces actuarially fair premiums in both periods. Given the concavity of the utility function, the consumer will always prefer to be charged a fixed expected premium (P) to cover the losses in periods 1 and 2 [i.e. $P = .5 (p_1 + p_{2)} D$] rather than a variable premium for period 2, which will be determined at the beginning of that period. Figure 9 shows that the utility at P will exceed the expected utility based on uncertain but equally likely premiums of P-ε and P+ε.

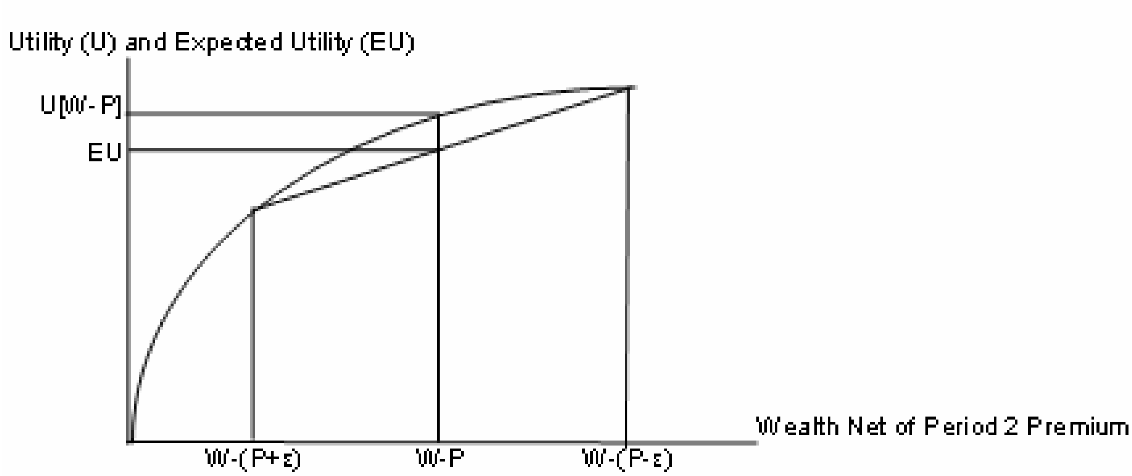

FIGURE 9: EXPECTED UTILITY AS A FUNCTION OF WEALTH AND FIXED VERSUS VARIABLE PREMIUMS

7. OPEN QUESTIONS FOR DESIGNING CONTRACTS

There are a number of issues and questions associated with the development of a long-term insurance policy which have a direct impact on insurers and homeowners, and indirect effects on other stakeholders, which require further research and analysis. Some of the issues that need to be resolved include:

7-A. Nature of the Contract.

Long-term insurance could be offered by insurers in the form of a fixed-price contract (FPC) for the full term of the policy (e.g., 20 years) or an adjustable premium contract (APC) at a variable premium with guaranteed renewal for the term of the policy. The annual premium would be reset based on an index that would have to be simple and transparent. Policyholders will want the option to terminate the contract; mortgage markets provide examples of both good and bad practices. On FPCs, formal arrangements to make the insurer whole through provisions such as yield maintenance and defeasance (the two most common methods for dealing with prepayment costs on commercial mortgages) may be necessary. On APCs, the borrower would want the right to terminate the contract without cost within a certain time period of a premium increase notification (e.g., 3 months).

7-B. Protection Against Catastrophic Losses.

One would also need to know how the rating agencies will view long-term FPC commitments, since the insurer is now locked into the premium even if the expected losses rise. To protect itself against possible increases in the probability of catastrophic losses over time, insurers marketing FPCs would have to be able to invest in cat bonds or other forms of securitized risks. Some type of government guarantee might be necessary to deal with both insurers' and policyholders' concerns with respect to the ability to pay claims in the future following a catastrophic loss. As for the pricing of the product, FPC premiums would likely be somewhat higher than APC premiums to protect insurers against an increase in the risk during the contract period. This behavior would be similar to the pricing of fixed-rate mortgages relative to adjustable rate mortgages.

One of the central issues will be how high the price of a long-term contract will be, given the ambiguities associated with the risk and the capital costs for covering catastrophic losses. Without some type of protection against large losses either through long-term risk transfer instruments (which currently do not exist) and/or a government reinsurance program at the state or federal level, the premiums for FPCs are likely to be extremely high so that there would be little demand for this type of coverage.

7-C. Understanding the Contract

Those who purchase insurance policies often have a difficult time understanding every aspects of the terms of the contract – what risks are covered, what risks are not, and the basis for being charged a specific rate. The problem is likely to be compounded for a long-term insurance contract. There is an opportunity for insurers to educate consumers as to the basis for the premiums they charge by providing more detail on the types of risks that are covered and the amount charged for different levels of protection. More specifically, insurers could break down the premium into coverage against fire, theft, wind damage and other losses included in a homeowners policy, and how the premium varied with the length of the long-term contract.

It would be very beneficial for insurers to reveal this information, so that homeowners will be able to make better decisions by understanding the nature of the contract and what alternative options cost them. They will then be able to make tradeoffs between costs and expected benefits – impossible for them to do today. Thaler and Sunstein (2008)[58] argue for this type of information disclosure by proposing a form of government regulation termed RECAP (Record, Evaluate and Compare Alternative Prices). They recommend that the government not regulate prices but require disclosure practices – not in a long, unintelligible document, but in a spread-sheet-like format that includes all relevant formulas.

7-D. Institutional Details

Some of the open questions regarding institutional details which require further analysis and discussion with key stakeholders are:

- Under what circumstances could a property owner change her insurance policy over time?
- What role would the modeling companies and the scientific community studying climate science play in providing estimates for developing risk-based premiums and suggesting a rationale for changes over time as new risk models become available? What about other catastrophe risks such that earthquakes?
- How would insurers deal with significant changes in risk estimates over time?
- What types of risk transfer instruments would have to emerge from the reinsurance market as well as from the capital markets to protect insurers against catastrophic losses

[58] Thaler R. and C. Sunstein, (2008) *Nudge: The Gentle Power of Choice Architecture*. New Haven: Yale University Press.

and changes in risk estimates over time? Can the maturity of insurance-linked securities be extended to 10 or 20 years? Could we develop a secondary market on which some of that risk could be tranched and transferred to a broader basis of speculators as a new type of assets?[59]

- How concerned will consumers be at possible insolvency of insurers providing long-term contracts, and what steps should be taken to protect homeowners should this occur?
- What role would the public sector play in providing protection against catastrophic losses? How could different levels of government (federal, state and local) enhance the development of LTI to be linked to long-term risk-protection loans tied to the property?
- Would flood insurance, which is provided today through the federal national flood insurance program, be a natural candidate for LTI?

Whether long-term insurance will be attractive to insurers, homeowners, regulators and other relevant stakeholders will certainly depends on the market conditions that come with it. What is clear today, however, is that we need innovative programs for reducing future losses from disasters that involve combined strengths of the public and private sectors. For insurance to play an important role in this regard, one needs to understand what a policy can and cannot do as a function of the nature of the risk, the type of coverage provided by the insurer and the premium structure.

[59] In the U.S. Treasury's March 2008 report, "Blueprint for a Modernized Financial Regulatory Structure," a federal regulatory structure for the insurance industry is recommended. The report also offers a variety of recommendations concerning the future regulation of securitization.