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ABSTRACT

This paper proposes long-term insurance (LTI) as an alternative to the standard annual homeowners policy using lessons from the mortgage market as a benchmark. LTI has the potential to significantly increase social welfare by reducing insurers' administrative costs, lowering search costs and uncertainty for consumers and providing incentives for long-term investment in mitigation measures to protect property. A two-period model illustrates situations that would make a long-term contract attractive to both insurers and consumers under competitive market conditions.

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1. INTRODUCTION

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. There was a radical increase in insured losses in the early 1990s, with Hurricane Andrew (1992) in Florida ($23.7 billion in 2007 dollars) and the Northridge earthquake (1994) 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.

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. 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.[1] In addition to this hard reinsurance market, insurers also faced increases in catastrophe risk estimates by modeling firms and more stringent criteria by rating agencies for measuring the financial strength of companies. Insurers responded to these changes by filing for significant rate increases in states subject to hurricanes. While only a portion of these increases were granted, a study undertaken by the Wharton Risk Center (2008), in conjunction with Georgia State University and the Insurance Information Institute, reveals that the average homeowner's premium in Florida

[1] 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 (2007 and 2008).

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 tripled or even quadrupled for some homeowners. While the market price of insurance has significantly increased in those 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 homeowner 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 occurred?

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 simply cancel their policies or double or triple their rates from one year to the next.

There are also issues on the demand side. 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). 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 homes with severe wind damage from these hurricanes, 23,000 (more than one-third) did not have insurance against wind loss. (U.S. GAO, 2007).

To address the problem of volatility of insurance premiums and homeowners' failure to protect their property against disaster, we propose in this paper a new approach to providing homeowners' coverage: long-term insurance contracts (LTI) rather than the usual annual policies on residential property. The paper is organized as follows. **Section 2** discusses the need for LTI and some of the reasons why a market for this type of coverage does not exist today. **Section 3** provides lessons from the mortgage market that can serve as a benchmark for LTI. **Section 4** applies concepts from long-term mortgages to insurance, and describes how fixed rates and adjustable insurance contracts would function. **Section 5** introduces a simple two-period model to capture some of the features in designing an LTI contract. **Section 6** raises questions for future research and challenges for implementing this concept.

2. DEVELOPING LONG-TERM INSURANCE (LTI)

Our proposal for LTI is aimed at homeowners' insurance for residential properties with reference to protection against natural disasters. 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 restricted insurers from canceling policies or from 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.[2] As pointed out above, some 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]

2.1. Need for Long-Term Insurance

Short-term insurance policies foster significant social costs. 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.[4] Evidence from recent disasters reveals that consumers who fail to adequately protect their home or even insure at all, create a welfare cost to themselves and a possible cost to all taxpayers in the form of government disaster assistance. Under the current U.S. system, the Governor of the state(s) can request that the President declare a "major disaster" and offer special assistance if the damage is severe enough. 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).

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

[3] In a survey of homeowners in flood-prone areas in Austria and Germany, Raschky and Schwarze (2007) found that distrust of insurance companies was one of the principal reasons for lack of interest in purchasing flood coverage.

[4] Kunreuther, H., W. Sanderson and R. Vetschera (1985). Following the 1989 Loma Prieta earthquake, there was a significant increase in the purchase of earthquake insurance; This was also observed after the 1994 Northridge earthquake in California; in 1996 over 30 percent of the population had purchased quake insurance; but this figure has continuously decreased over time: it is estimated that only 12 percent of homeowners bought the quake coverage in 2006. (Insurance Information Institute, http://www.iii.org/media/hottopics/insurance/earthquake).

The development of LTI should encourage individuals to invest in cost-effective mitigation measures. Many homeowners do not invest in such measures due to myopia and budget constraints. They are unwilling to incur the high upfront cost associated with these investments relative to the small premium discount they would receive the following year which reflects the expected reduction in annual insured losses (Kunreuther, Meyer and Michel-Kerjan, forthcoming). If an LTI policy were coupled with a long-term home improvement loan tied to the mortgage, the reduction in insurance premium would exceed the annual bank loan payment. The social welfare benefits of LTI coupled with long-term mitigation loans over N years could 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.[5]

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

In his seminal work on uncertainty and welfare economics, Arrow defined "the absence of marketability for an action which is identifiable, technologically possible and capable of influencing some individuals' welfare (…) as a failure of the existing market to provide a means whereby the services can be both offered and demanded upon the payment of a price." (Arrow, 1963). Here we shall discuss several factors which have contributed to the non-marketability of LTI for protecting homeowners' property against losses from fire, theft and large-scale natural disasters. We discuss elements which affect both the supply and demand sides.

Supply Side

Today, due to political pressure, insurance rates are frequently restricted to be artificially low in hazard-prone areas. The result is that the risks most subject to catastrophic losses also

[5] Mooney (2001) has argued for long-term homeowners' policies for this reason.

become the most unattractive for insurers to market. A second stumbling block, derived from premium regulation, is that insurers are unclear as to how much 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 the insurance regulator presumed to be representing consumers interests, may not allow these costs to be embedded in the approved premiums. Furthermore, it is unclear what the voluntary demand for coverage will be, given the resulting premium. In a real sense, a new and less intrusive format for government regulation of insurance markets may be required if the private markets are to be successful in dealing with time-varying risks and capital costs.

Impediments to risk spreading across insurance firms are another source of market failure. A key benefit of organized insurance markets is, of course, the ability to spread risks across a large number of individuals and entities. To achieve this benefit, an organized market must be available for reinsurance or for capital market access based on insurance linked-securitization. The creation of such risk-sharing facilities, however, might face a fundamental coordination problem, since simultaneously there must arise both primary insurers who are willing to write policies, and reinsurers (or capital market investors) who are willing to provide reinsurance protection. For some cases such coordination problems may be difficult for private markets to solve alone. In other words, no one wants to be the first to enter the market, so a critical mass does not develop.[6] However, if there is a welfare gain that can be achieved through coordination efforts, then government entities could help facilitate this by providing the

[6] See Ibragimov, Jaffee, and Walden (2008).

necessary conditions for this market to develop (Baumol, 1952). An extreme form of coordination is for the government to require all insurers to participate in this market. One recent example of such an intervention is the U.S. Terrorism Risk Insurance Act (TRIA) legislation of 2002. The development of a large terrorism insurance market in the United States post September 11, 2001 can be attributed, at least in part, to the "make available" clause of the law which required all insurers to participate in the market.

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. Two factors contribute to the answer. First, until 1999, banks were prohibited from operating an insurance 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 five 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 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 homeowners may 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 clearly states 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 insurers set premiums that reflect the uncertainty associated with long-term risks. Furthermore, those who have not suffered a loss for 10 years but have a 25-year LTI may feel that the premiums are unfairly priced. It is thus essential that the design of an LTI contract anticipates these concerns. The policy may also include specific features that allow contract terms to change over time.

3. BENCHMARK FOR LTI: LESSONS FROM MORTGAGE MARKETS

3.1. History of Mortgages in the U.S.[7]

Until the Great Depression, long-term (20- or 30-year maturity) mortgages were rare. U.S. bank mortgages were commonly short-term (maturities 1 to 4 years) with the full principal due at maturity. In practice, the loans were regularly renewed at each maturity date. However, as the Great Depression took hold, banks refused to renew these contracts. The problem was that most bank depositors had the right to withdraw their funds on demand, and, fearing a bank run, were doing so. As a result, the banks did not renew the mortgage loans, using the funds instead 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

[7] This section is based in part on Jaffee and Quigley (2007). Aaron (1972) provides a useful discussion of the role played by various government agencies in the development of the U.S. mortgage market during the 1930s.

addition, a vicious circle ensued, as falling house prices begot more mortgage defaults and mortgage defaults begot greater declines in house prices. To curtail this process, the federal Home Owners Loan Corporation (HOLC) was created in 1933 to recycle the failing home mortgages (reminiscent of government programs now being proposed to deal with subprime mortgages); the HOLC also expanded the use of long-term, fixed payment, and fully amortizing mortgages in the U.S. The HOLC finished its business and was closed by 1935, a notable achievement. It was replaced by the Federal Housing Administration (FHA), established under the National Housing Act of 1934, to oversee a program of home mortgage insurance against default and it continued to promote the use of long-term mortgages (Aaron, 1972).

The entry of the FHA greatly facilitated the long-term mortgage 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 became a *de facto* "standard" even for loans made by private lenders. It is plausible that the actions of the HOLC and FHA hastened the standardization of long-term mortgages in the U.S. by a decade or more relative to what private markets would have achieved.

When it started in 1934, the FHA mortgage program had no counterpart in the private sector. 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 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.[8]

[8] See Jaffee (2006) for a discussion of the PMI industry as monoline insurers.

Following World War II, the Veteran's Administration (VA) created a parallel program of mortgage guarantees. 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 the origin of the entire U.S. MBS market.

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) even suggest that the FHA program was instrumental in allowing the reestablishment 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.

3.2. Reasons for Long-Term (LT) mortgages

LT mortgages developed because of the need by homeowners for liquidity 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 their 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

Fixed-rate mortgages (FRMs) 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 designed to protect the lender.[9]

[9] There exist some assumable mortgages under which the homeowner can transfer the existing mortgage to a new home buyer under certain conditions.

Adjustable-rate LT mortgages

The interest rates on adjustable-rate mortgages (ARMs) have been systematically lower than comparable rates on fixed-rate mortgages. The spread has been as high as 3.5 percentage 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.

The ARM percentage of all originated mortgages has varied significantly over time, reaching almost 60 percent in 1987, but falling to only 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. It is apparent that all else being equal, 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 it is economically rational to take out ARMs when they expect market interest rates will soon be falling. There is evidence that the borrowers are somewhat successful in this regard.[10]

States generally 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 by more than a given percentage (e.g. 5 percent). The payment caps are usually applied in terms of annual changes,

[10] See, for example, Campbell (2006); Van Hemert (2007); and Koijen, Van Hemert, and Van Nieuwerburgh (2007).

whereas rate caps may apply to both annual changes and lifetime 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 incurring additional charges. 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.[11]

4. APPLYING CONCEPTS FROM LT MORTGAGES TO LT INSURANCE

4.1. Reducing the Uncertainty

The loss distribution for homeowners insurance in hazard-prone areas of the country is not always well specified because of the infrequency of major catastrophes. The ambiguities associated 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 somewhat 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).

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) 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.

[11] 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 was passed in 1980 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.

A web-based survey by the Wharton Risk Center in 2007 measured actuaries' and underwriters' decision making under risk, uncertainty without conflict, and uncertainty with conflicting information on risk estimates. 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 1. Participants were asked to determine the annual premium they would charge to cover a homeowner against a risk, assuming a 1-year contract and a long-term insurance contract (e.g., 20 years) tied to the homeowner's mortgage.

TABLE 1. 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).

Under a 1-year contract, insurers would charge on average $1,521, which reflects their estimate of the expected loss plus a loading factor (administrative cost and cost of capital). The mean annual premiums when the probability is ambiguous are 25 percent higher than when the probability is given precisely. The source of uncertainty however does not affect insurers. As shown in Figure 1 under the 20-year contract, the premium with precise probability is $1,589 (or about 5 percent above $1,521, the amount which insurers would charge for a one-year contract with precise probability). But aversion to ambiguity increases significantly has the length of the

contract increases. Depending on whether the probability is imprecise or there are conflicting probability estimates, mean annual premiums are 41 percent and 34 percent higher, respectively, than when there is no ambiguity ($2,246 and $2,133).

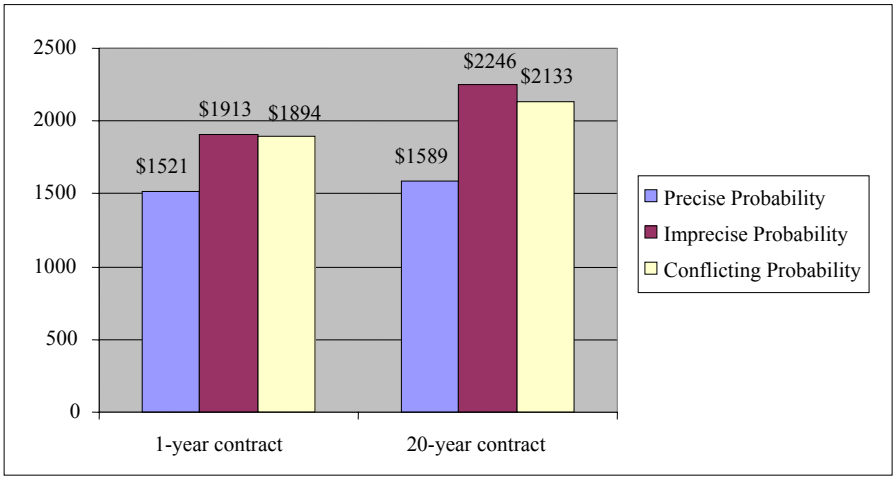

FIGURE 1. ANNUAL MEAN INSURANCE PREMIUMS IN DOLLAR, ACROSS NATURAL HAZARDS (N=78)

4.2. Fixed Rate LTI Contracts

The above survey data suggests that insurers are likely to charge higher premiums for long-term contracts than for annual policies because of the perceived uncertainty associated with the risk. If the risk increases over time, then the LTI premium will be too low relative to what the insurer would need to charge. If the risk decreases over time, the homeowner will want to cancel her policy and purchase coverage 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 a need for longer-term reinsurance contracts and alternative risk transfer instruments such as catastrophe bonds. Today, reinsurance contracts are typically for one or two

years. But alternative transfer instruments such as cat bonds are longer. In 2007 there were 20 catastrophe bonds (of the 29 issued that year) that covered a term of 3 years or more.[12] There is thus a need to assess the constraints on the availability and volume and contract length of securities that diversify catastrophe risk, 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.

4.3. Adjustable Rate LTI Contracts

There will be a significant benefit to homeowners if their insurer will guarantee coverage for a fixed period (e.g. 15 years), even if premiums vary from year to year to reflect changing risks. 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 Property Claims Services regularly tabulates the total insured losses from major events. This could help creating such an index, but regulators and policyholders need to be assured 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 and payment amounts can change annually on adjustable-rate mortgages (ARMs).

4.4. Risk Exposure Indices and Capital Costs for LTI

Risk Exposure Indices

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

[12] The only catastrophe bond issued for longer than 5 years was a 10-year cat bond issued in 1997. For more details on the trends in cat bonds and other insurance-linked securities, see Michel-Kerjan and Morlaye (2008).

issues. Today catastrophe modeling and risk assessment face a number of informational challenges as well as acceptance by the market and regulatory agencies. For example, 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 was certified after resubmitting its model based on hurricane activity estimates using historical averages of the number of hurricanes recorded since 1900 (Risk Management Solutions, 2007).

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 contend 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 that an insurer typically invests in modeling. Asymmetric information in favor of the insurer can have important market implications as it might lead to a selection process where only the low-risk individuals are fully covered at the equilibrium (Henriet and Michel-Kerjan, 2008).

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).

Cost of Capital

The second important element that enters insurance pricing is the cost of capital that the insurer has to access for its entire portfolio. The importance of including capital costs in setting premium for insurers to secure an adequate rate of return is often not sufficiently understood.[13] In particular, the prices charged for catastrophe insurance must be sufficiently high to cover not only the expected claims costs and other expenses, but also 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 likely to be high relative to its loss expenses, in order for the insurer to earn a fair rate of return on equity and thereby maintain its credit rating (Doherty 2000; Wharton Risk Center, 2008)

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. We thus define a fair price for insurance as a premium that provides a fair rate of return on invested equity.

There are other considerations that can dramatically increase the capital cost, notably the impact of double taxation. Harrington and Niehaus (2001) 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

[13] Discussion in this section is based on Wharton Risk Center (2008).

inputs, transaction costs and taxes), catastrophe insurance premiums often are several multiples of expected claims costs.

There are parallels between insurance and mortgage lending with respect to the importance of incorporating the cost of capital in pricing decisions. The cost of capital for fixed-rate mortgages is a serious issue 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.

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 mortgage-backed securities 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.[14]

5. DESIGNING OPTIMAL CONTRACTS

5.1. Relevant Literature in Economics, Insurance and Finance

An extensive literature now exists on the optimal design of financial securities and contracts.[15] The mechanism used to design securities in this literature assumes an economic decision-making environment with actions of the various economic agents affected by income, consumption and balance sheet constraints. Other features of the market, such as transaction costs, incomplete contracts and asymmetric information must also be specified. A solution is a

[14] For more details, see Bardhan and Jaffee (2007).
[15] See Allen and Gale (1994) for a book-length survey.

contract that maximizes consumer expected utility subject to the above constraints. This often has a highly mathematical and abstract form. A real-world approximation to the abstract optimal contract is then proposed.

To illustrate, 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 flow only in the hopefully infrequent situations in which the borrower fails to make the scheduled payments. A recent example is the paper by Piskorski and Tchistyi (2006) which derives certain features of subprime mortgages as the optimal design when borrowers have highly uncertain and fluctuating income, 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.

5.2. A Two-Period Model for LTI

Here we propose a simple model that highlights some of the tradeoffs facing insurers and policyholders who have the option to purchase either a long-term (LT) policy at a fixed premium for each of the two periods or two one-period contracts. For such a comparison to be meaningful, it is necessary that insurance premiums reflect risk.[16] This is a key principle that has guided the recent Wharton Risk Center (2008) study.

[16] As stated in the 2007 *Economic Report of the President*, which for the first time devotes 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." (White House, 2007, Chapter 5, p. 122-123).

Assumptions

We assume a competitive market in which insurers are homogenous and maximize expected profits. Consumers are homogenous and buy full coverage for periods 1 and 2. Insurers offer an LT policy or two one-period policies. At the beginning of period 1, experts provide a single estimate of a disaster occurring in period 1; however, they are uncertain as to whether there is a high (H) or low (L) probability of a disaster in period 2. At the end of period 1, insurers and consumers both 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

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 per period of processing a policy

λ = cost of capital held by the insurer to cover potential damage

Premiums Charged by Insurer for One-Period Insurance

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

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

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

Premium Charged by Insurer for LT Insurance

For 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:

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

The premium in (2a) reflects the upfront costs of marketing a policy, the administrative costs in each period and the expected losses with the appropriate adjustment for the cost of capital.

Consumers are given the right to cancel an LT contract at the end of period 1 but at a cost. The insurer marketing an LT contract 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 separate policy to cover losses in period 2. If the consumer cancels its LT contract at the end of period 1, then the LT 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:

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

where $\lambda[p_1 D + a\, p_{2L} D + (1\text{-}a)\, p_{2H} D]$ represents the cost of the capital to the insurer in period 1 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:

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

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 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:

$$Z_{2L} + C < Z(LT) \qquad (3a)$$

Equation (3a) can be written as

$$C < \tfrac{1}{2}\{M + 2A + (1+\lambda)\,[p_1 D + a\, p_{2L} D + (1\text{-}a)\, p_{2H} D]\} - \{M + A + (1+\lambda)\, p_{2L} D\} \qquad (3b)$$

$$C < 0.5(1+\lambda)[p_1 D + (1\text{-}a) p_{2H} D + (a\text{-}2) p_{2L} D] - 0.5M \qquad (3c)$$

Let the RHS of (3c) be denoted as C*. Then 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 so that $C > C^*$, then 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}.

5.3. Choosing Between Two One-Period Policies and an LT Policy

Notation

q = 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[17]

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 Two One-Period Policies

The total cost of two one-period policies purchased at the beginning of period 1 and period 2 are:

$$Z(ST) = Z_1 + qS_1 + Z_2$$

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 incentive to cancel her 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.

[17] 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.

Optimal Choice by Consumer

To determine the optimal choice by the consumer in period 1, one needs to determine the total 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:

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

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 one-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 q)

(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 importance to the consumer of having stability with respect to her insurance contracts and peace of mind in knowing that she is fully protected against damage from disasters as long as she owns her home

5.4. 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 the well known proof of Arrow (1963) of the optimality of full insurance to motivate the analysis. 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 does not occur, weighted by its probability. The second term is the weighted utility if the disaster 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. This can be written 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 occurs in period 1 or 2 and I_i represents the amount of insurance purchased in period *i*.

For this two-period horizon, we first assume the consumer is offered only a sequence of one-period contracts. In particular, we assume the actuarially fair premium for period 2 is not determined until the end of period 1. The consumer will still purchase full coverage in both periods, since premiums are actuarially fair in both periods.

Now assume instead, that a long-term contract is available at the beginning of period 1, offering the consumer actuarially fair insurance to cover possible events in both periods 1 and 2. Given the time separable structure of the problem and the actuarially fair premiums, it is clear that the consumer will choose full insurance in both periods; that is, $I_1 = I_2 = D$. Further, given the concavity of the utility function, the consumer will always prefer to be charged a fixed per period 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. Figure 2 shows that the utility at P will exceed the expected utility based on uncertain but equally likely premiums of $P-\varepsilon$ or $P+\varepsilon$.

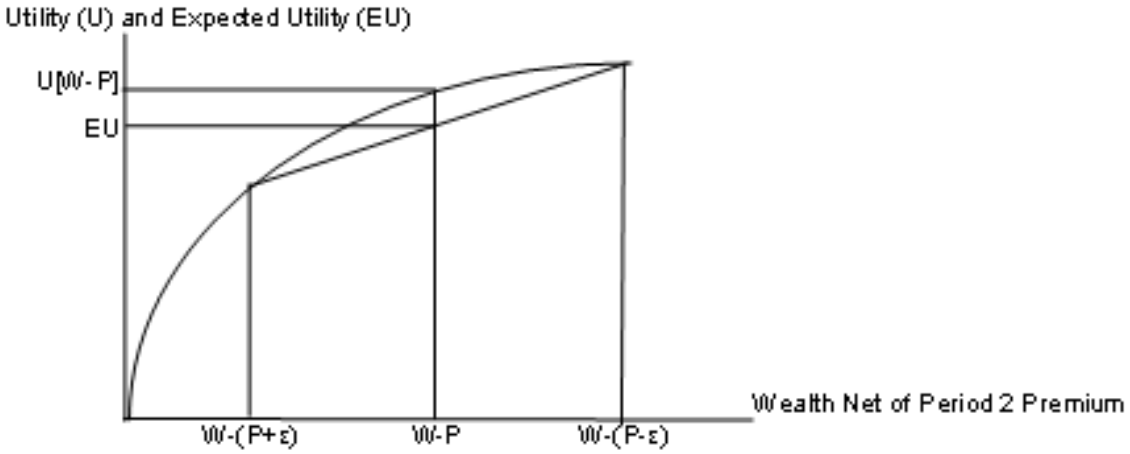

FIGURE 2: EXPECTED UTILITY AS A FUNCTION OF WEALTH AND FIXED VERSUS VARIABLE PREMIUMS

5.5. Social Welfare Implications

Based on the two-period model, one can determine the social welfare implications of providing long-term insurance (LTI) contracts to consumers in a manner similar to analyses undertaken by Arrow (1963) in his path breaking study on the welfare benefits of insurance markets. Although Arrow's paper is written in the context of the market failure for medical insurance, it is remarkable that almost all his points apply today to similar market failures with respect to the provision of catastrophe insurance. For example, Arrow's discussion focuses on such issues as the welfare loss when insurance markets or contracts are incomplete, when there are search costs and administrative costs, when there can be high variability in the risk level, and when there is informational asymmetry or moral hazard. He also emphasizes the welfare loss when the absence of insurance markets causes individuals to forgo activities that they would otherwise pursue. Finally, in passing (p. 964), he mentions the benefits of "insurance with a longer time perspective" that might have level premiums as illustrated by life insurance.

As pointed out in Section 3, LTI encourages individuals who are myopic in their thinking to invest in cost-effective mitigation measures where they would not do so if they had purchased one-period contracts. In addition, LTI reduces transaction costs from the consumer's and insurer's point of view. More specifically, an insurer who offers an LTI policy has reduced marketing costs (M) since this is only incurred at the time the contract is offered rather than at each period. Similarly, consumers with single-period policies whose contracts are canceled at the end of period 1 are able to avoid the search costs (S_1) of looking for another policy by buying an LTI policy. The expected social welfare benefits to the consumer based on our two-period model are qS_1.

6. 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:

6.1. 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).

6.2. Understanding Terms of the 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) 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.

6.3. Protection Against Catastrophic Losses

To protect themselves 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. In principle, insurers could raise funds by issuing new equity under

these circumstances, but this is usually not a practical alternative.[18] Another possibility is for the government to use an auction process to provide reinsurance coverage on an ex ante basis.[19] Still another possibility is for the government to stand ready to make loans to insurers after an event.[20] The latter mechanism would allow the government to function as a lender of last resort to insurance firms just as the Federal Reserve does currently to commercial banks (and, in the case of Bear Stearns, to investment banks).

6.4. Pricing LTI

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.

6.5. Requiring Insurance Coverage

Should insurance be required on all residential property? This would not be a radical change from the current situation – homeowners who have a mortgage are normally required by the bank which finances the loan to purchase coverage against wind damage for the length of the mortgage. Similarly, those in flood-prone areas are required to purchase flood insurance under

[18] See Jaffee and Russell (1997).
[19] See Lewis and Murdoch (1996).
[20] See Jaffee and Russell (2008).

the National Flood Insurance Program if they have a federally insured mortgage. Insurance coverage is required today for other consumer purchases. Today in all states, motorists must show proof of financial responsibility on their automobile insurance policy, or bodily injury and property damage liability in order to register their car.

If all homes were required to be covered by a homeowners policy, insurers would be able to more easily diversify their risks and hence reduce the likelihood of suffering catastrophic losses over the length of the long-term contract. Another advantage of requiring homeowners' insurance is that it will reduce the likelihood of liberal disaster assistance following the next large-scale disaster since victims will be indemnified by their insurer. Some European countries, such as France and Spain, have made insurance against catastrophe risks mandatory for all (Vallet, 2004; Michel-Kerjan and deMarcellis, 2006).

Whether long-term insurance will be attractive to insurers, homeowners, regulators and other relevant stakeholders will certainly depend 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.

REFERENCES

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

Aaron, H. (1972), *Shelter and Subsidies: Who Benefits from Federal Housing Policies*, The Brookings Institution, Washington, D.C.

Arrow, K. (1963), "Uncertainty and the Welfare Economics of Medical Care," *American Economic Review*, 53(5):941-973.

Bardhan, A. and D.M. 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

Baumol, W. (1952), *Welfare Economics and the Theory of the State*, Harvard University Press, Cambridge, MA.

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

Campbell, J. (2006), "Household Finance", Presidential Address to the 2006 Meetings of the American Finance Association, *Journal of Finance*, 61, 1553-604.

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

Guy Carpenter (2007), "The World Catastrophe Reinsurance Market: New Capital Stabilizes Market," Sept. 2007.

Guy Carpenter (2008), "2008 Reinsurance Market Review: Near Misses Call for Caution."

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.

Henriet, D. and E. Michel-Kerjan (2008), "Looking at Optimal Risk-Sharing in a Kaleidoscope: The (Market Power, Information) Rotational Symmetry", Working Paper # 2008-01-21, Wharton Risk Center, The Wharton School.

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.

Ibragimov, R., D.M. Jaffee, and J. Walden (2008), "Non-Diversification Traps in Markets for Catastrophic Risk (joint with Johan Walden and Rustam Ibragimov), forthcoming Review of Financial Studies).

Jaffee, D.M. (2006), "Monoline Restrictions, with Applications to Mortgage Insurance and Title Insurance," *Review of Industrial Organization*, 28: pp 83-108.

Jaffee, D.M. (2008), "The U.S. Subprime Mortgage Crisis: Issues Raised and Lessons Learned, Commission on Growth and Development Working Paper #28, available at: http://www.growthcommission.org/storage/cgdev/documents/djsubprimeapr07.pdf

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 at http://urbanpolicy.berkeley.edu/publist.htm#Working%20Papers

Jaffee, D.M. and T. Russell (1997), "Catastrophe Insurance, Capital Markets, and Uninsurable Risks", *Journal of Risk and Insurance*, Vol 64, No 2, pp 205-230.

Jaffee, D.M. and T. Russell (2008), "Financing Catastrophe Insurance: A New Proposal" in John M. Quigley and Larry A. Rosenthal editors, *Risking House and Home: Disasters, Cities, Public Policy*, Berkeley Public Policy Press.

Koijen, R., O. Van Hemert, and S. Van Nieuwerburgh (2007), "Mortgage Timing." NBER Working Paper No. 13361, September 2007.

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

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

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

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.

Lewis, C. and K. Murdoch (1996), "The Role of Government Contracts in Discretionary Reinsurance Markets for Natural Disasters," *Journal of Risk and Insurance*, Vol. 63, No. 4, pp. 567-597.

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

Michel-Kerjan, E. and N. deMarcellis (2006), "Public-Private Programs for Covering Extreme Events: The Impacts of Information Distribution and Risk Sharing," *Asia-Pacific Journal of Risk and Insurance*, Vol. 1 (2), pp. 21-49.

Michel-Kerjan, E. and F. Morlaye (2008), "Extreme Events, Global Warming, and Insurance-Linked Securities: How to Trigger the 'Tipping Point'", *The Geneva Papers on Risk and Insurance,* 33(1): 153-176.

Mooney, S. (2001), "Long-term Homeowners Policies Make Sense", *National Underwriter,* February 26, p. 19.

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

Raschky, P.A. and Schwarze, R. (2007), "An Empirical Investigation of Charity Hazard in Austria and Germany". mimeo, University of Innsbruck.

Risk Management Solutions (RMS) (2007), "Hurricane Model Re-Certified by Florida Commission," Press release, June 25.

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

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

Van Hemert, O. (2007), "Household Interest Rate Risk Management", Working paper, New York University.

Vallet, S. (2004), "Insuring the Uninsurable: The French Natural Catastrophe Insurance System," in E. N. Gurenko (ed). *Catastrophe Risk and Reinsurance. A Country Risk Management Perspective,* Risk Books.

Wharton Risk Center (2008), *Managing Large-Scale Risks in a New Era of Catastrophes*. Insuring, Mitigating and Financing Recovery from natural Disasters in the United States, Philadelphia, PA, March.

White House (2007), Economic Report of the President. Council of Economic Advisors, Washington, DC, February.