Why do homeowners, insurers, and banks not use simple measures to mitigate the risk from hurricanes and earthquakes?

Managing Catastrophe Risk

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RISK MITIGATION MEASURES (RMMS) ARE investments made to homes, office buildings, and other structures that reduce expected losses from hurricanes and earthquakes. In theory, property owners, insurers, and developers would all benefit from RMMs. In reality, however, there appears to be little interest in employing these measures. Few property owners voluntarily invest in RMMs. Few insurers offer premium reductions or other incentives for structures that incorporate mitigation measures. And few developers and contractors have economic incentives to build safer structures because potential buyers undervalue the capital costs of the RMMs. This results in insurance customers and taxpayers bearing a larger portion of the cost of disaster losses, because of large insurance pools and government-financed disaster relief, than they would if property owners adopted these risk reduction measures.

Using risk assessments of geographic areas that routinely experience natural disasters, a Wharton School study examined the effect that increased use of RMMs would have on property owners and insurers. This study led us to conclude that property owners and insurers, in general, have far more economic incentive to adopt these measures than either the homeowners or insurance companies appear to realize.

WHAT THE COMPUTER MODELS SHOW

OVER THE PAST FOUR YEARS, THE WHARTON SCHOOL HAS worked with three prominent natural hazard modeling firms as part of a project on managing catastrophic risk. We constructed statistical models of two earthquake-prone cities, patterned after Oakland and Long Beach, Calif., and a hurricane-prone area, patterned after Miami-Dade County, Fla. We then examined the reduction in damages that increased use of RMMs would have on these areas. We also studied the effect that increased use of RMMs would have on the performance of two prototypical insurance companies — one a Small Insurance Company and the other a Large Insurance Company — that hypothetically provided coverage to residential property owners in the model cities. The analysis that we present in this article is based on data from the Oakland and Miami models.

For both cities, we randomly picked 5,000 and 10,000 residential structures, respectively, to constitute the maximum books of business (BOB) that the Small Insurance Company and Large Company, respectively, could write. All structures in "our" Oakland were wood frame, single-family residences. The properties of interest in "our" Miami were also single-family residences that mirrored the general distribu-

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Table 1

Books of Business

OAKLAND MODEL

Era constructed	Small Insurance Co.	Large Insurance Co.
Don't Know	259	599
Pre-1940	3,091	6,196
Post-1940	1,650	3,205
Total	5,000	10,000

MIAMI MODEL

Type of construction	Small Insurance Co.	Large Insurance Co.
Wood Frame	496	993
Masonry Veneer	1,005	1,802
Masonry	3,117	5,910
Semi-Wind Resistive	260	248
Wind Resistive	122	1,047
Total	5,000	10,000

tion of structure types in that area. The distribution of structures for both the Small and Large insurance companies in both cities is shown in Table 1.

For Oakland, we looked specifically at the mitigation measure of bracing the cripple wall — the wall between the top of the foundation and the first floor diaphragm — and bolting the structure to the foundation on all pre-1940 wood frame single family residences. For Miami, we considered the mitigation measure of bracing roof trusses and gable end walls, applying wood adhesive where the roof decking and roof supports meet, installing hurricane straps or clips where the roof framing meets the top of the studs, and anchoring the walls to the foundation.

In both cities, we then examined three levels of mitigation: 100 percent, 50 percent and zero percent. In the full mitigation scenario (100 percent), every applicable structure (all pre-1940 houses in Oakland as well as a proportionate share of houses of unknown age, and all houses in Miami) installed the RMM. In the 50-percent scenario, half of the pre-1940 houses in Oakland and half the houses in Miami installed the RMM. In Oakland, mitigation costs were defined as 1.2 percent of the cost of the structure — a percentage derived from engineering estimates. In Miami, engineering estimates of mitigation costs of $3,000 were for the typical single-family dwelling.

Our models showed that, in the 100-percent mitigation scenario (using a discount rate of seven percent and a time horizon of 20 years), all ZIP codes in Oakland and 93 percent of the ZIP codes in Miami experienced a reduction in expected losses that exceeded the mitigation costs. Higher real interest rates or shorter time horizons reduced the number of ZIP codes for which the cost-effectiveness condition would be satisfied.

Effects of Mitigation on Losses and Insurer Behavior Given the effects of these mitigation measures, what would be their impact on total losses? Table 2 shows our statistical projections for the full book of business (BOB) for the Small and Large insurance companies in both geographic areas, under the 100-percent, 50-percent, and zero-percent mitigation scenarios.

To compile Table 2, we annuitized the RMM investment, again using the seven-percent discount rate and the 20-year time horizon. The "Annual Total Cost to Homeowners" shown in Table 2 is the sum of insurance premiums, expected deductible losses, and the annual costs of mitigation. The "Probability of Insolvency" is the likelihood that the insurer's losses will exceed the sum of its premiums and assets when it has a full BOB.

The entries following "Percentage of Properties Insured" are the percent of the full BOB that each insurer can cover without having its probability of insolvency exceed one percent. For example, when none of the homes are mitigated in Oakland, then the Small Insurance Company can only insure 88.72 percent of its full book of business. As the percentage of owners who adopt mitigation increases, so does the feasible BOB. According to our estimates, if 50 percent of the homes adopt the RMM, an insurer could provide a full BOB and still have a probability of insolvency below one percent. In general, as the percentage of homes that are mitigated increases, the solvency-constrained book of business for each insurer will also increase until it reaches 100 percent.

The computer models indicate that mitigation reduces aggregate losses to the insurer and the homeowner in both Oakland and Miami. Consider the Large Insurance Company's losses in Oakland, as depicted in Table 2. If all homeowners mitigate, the estimated reduction in expected annual losses is $2.38 million (the difference between the $9.51 million in expected losses for zero-percent mitigation and the $7.13 million in losses for 100-percent mitigation). However, the annualized mitigation costs are less than $1 million. In Miami, the Large Company's total cost for mit-

Table 2

Expected and Worst Case Losses

(in millions of dollars)

Insurance Company data	Mitigation Level		
	0%	50%	100%
Small Ins. Co. Pool Losses: Oakland			
Expected Losses	$4.76	$4 .17	$3.57
Worst Case Losses	$153.64	$139.74	$125.76
Mitigation Costs	$0	$.23	$.47
Probability of Insolvency	1.10%	0.97%	0.58%
Total Cost to Homeowners	$6.08	$5.52	$4.98
Percentage of Properties Insured	88.72%	100%	100%
Large Ins. Co. Pool Losses: Oakland			
Expected Losses	$9.51	$8.33	$7.13
Worst Case Losses	$306.87	$279.21	$251.12
Mitigation Costs	$0	$47	$.94
Probability of Insolvency	1.10%	96%	0.57%
Total Cost to Homeowners	$12.12	$11.14	$9.93
Percentage of Properties Insured	88.97%	100%	100%
Small Pool Losses: Miami			
Expected Losses	$3.18	$2.79	$2.41
Worst Case Losses	$61.05	$50.36	$38.28
Mitigation Costs	$0	$.71	$1.42
Probability of Insolvency	1.63%	1.35%	0.94%
Total Cost to Homeowners	$6.15	$6.10	$6.06
Percentage of Properties Insured	61.89%	77.21%	100%
Large Pool Losses: Miami			
Expected Losses	$9.01	$7.92	$6.83
Worst Case Losses	$169.48	$135.90	$102.29
Mitigation Costs	$0	$1.42	$2.83
Probability of Insolvency	1.74%	1.39%	0.99%
Total Cost to Homeowners	$17.36	$16.63	$15.90
Percentage of Properties Insured	58.25%	73.09%	100%

igating all the homes is $2.83 million. Employing the RMMs in Miami would reduce the total cost to homeowners (including the mitigation cost of $2.83 million) by $1.46 million — the difference between the $17.36 million in total cost for homeowners in the zero-percent scenario and the $15.90 million in total cost, including mitigation cost, for homeowners under the 100-percent scenario.

WHY IS THERE LIMITED INTEREST IN MITIGATION?

THESE STATISTICAL MODELS CLEARLY INDICATE THAT SIMPLE mitigation investments would provide benefits for insurers and homeowners that exceed the RMMs' upfront costs. But empirical data suggest that individuals in hazard-prone areas of the United States are not willing to invest in mitigation measures despite large damage losses from recent disasters. For example, after Hurricane Andrew hit Florida in 1992, most state residents in hurricane areas apparently did not choose to make improvements to existing dwellings that could reduce the amount of damage from future storms. A July 1994 telephone survey of 1,241 hurricane-zone residents by the Insurance Institute for Property Loss Reduction revealed that 62 percent of respondents indicated they had *not* installed hurricane shutters, used laminated glass in windows, installed roof bracing, or made sure that side walls were bolted to the foundation either before or after Hurricane Andrew.

Residents in earthquake areas are also not adopting such simple mitigation measures as securing their gas water heaters with plumber's tape — a mitigation measure that costs less than $5 in materials and one hour of labor. A 1989 survey of 3,500 homeowners in four quake-prone California counties reported that only between five and nine percent of the respondents had adopted any loss reduction measures.

Why do homeowners not invest in loss prevention measures? Some individuals may perceive the probability of a disaster causing damage to their property as being sufficiently low that they cannot justify the investment in the protective measure. Other individuals may have little interest in investing in protective measures if they believe that, because of insurance and government disaster relief, they will be financially responsible for only a small portion of their losses should a disaster occur. Also, if their assets are relatively limited in relation to their potential loss, then the property owners may simply walk away from their destroyed home without being financially responsible.

Other property owners may have relatively short time horizons over which they want to recoup their investment in a mitigation measure. Even if the expected life of the house is 25 or 30 years, individuals may only look at the RMM's potential benefits over the next three to five years. They may reason that they will not be residing in the property for longer than that period of time, or they may want a quick return on their investment before adopting the measure. Similarly, if people have budget constraints, they will be averse to the initial cost of protective measures simply because they feel they cannot afford the measures. Many people who live "payday to payday" are not inclined to invest in protective measures for future disasters that, they believe, may never happen to them.

Examining Individual Decisions In a set of controlled experiments conducted in Pennsylvania and California, we investigated individual decisions to invest in RMMs. We asked survey participants their maximum willingness to pay (WTP) for bolting their homes to the foundations — a mitigation measure employed to prevent earthquakes from shaking homes off of foundations. In the experiment, participants were told that the cost of putting a house back on its foundation after an earthquake was $20,000. They were also told that the RMM reduced the annual probability of an earthquake causing the structure to topple off its foundation from one chance in 20 to one chance in 40. Hence, the expected annual benefit of the RMM per household would be approximately $500 ($20,000 multiplied by the difference between 1/20 and 1/40). Finally, we told respondents to assume that they would live in the house for exactly five years. As a follow-up, we asked each of the participants to reassess the value of the RMM on the assumption that he or she would live in the house for exactly 10 years.

Table 3 presents the distribution of these WTP figures for 84 students surveyed at the University of Pennsylvania. Half of the students were not told the installation cost for the RMM, while the rest of the students were told that the installation cost was $1,500. The survey revealed that only 12 percent of the individuals would be willing to pay over $2,000 for the mitigation measure if the price was not given and they expected to live in the house for 5 years. For those who were told the cost was $1,500, 18 percent would be willing to pay over $2,000. If the length of stay in the home was lengthened to 10 years, seven percent of the subjects who were not given the price chose to spend more than $3,000; 17 percent of the subjects who were told the price of the mitigation indicated that they were willing to spend more than $3,000.

A risk-neutral person should be willing to pay as much as $2,085 for an annual benefit of $500 if his annual discount rate was 10 percent and he expected to live in the

Table 3

Distribution of Maximum Willingness to Pay (WTP) (Individuals in Each Category)

	Price Not Given		Price Given = $1,500	
	5 Years	10 Years	5 Years	10 Years
$0-$500	5%	5%	7%	4%
$501-$1,000	7%	7%	16%	16%
$1,001-$1,500	45%	17%	43%	44%
$1,501-$2,000	31%	36%	16%	19%
$2,001-$2,500	5%	14%	3%	0%
$2,501-$3,000	5%	14%	3%	0%
$3,000 up	2%	7%	12%	17%
	Number of Subjects = 42		Number of Subjects = 42	

Source: Kunreuther, Onculer and Slovic (1998)

house for five years. If the time horizon is lengthened to 10 years, the maximum WTP for a risk-neutral investor increases to $3,380. From the survey data, we see that a relatively small proportion of the respondents behaved as if they made decisions based on benefit-cost comparisons using a reasonable discount rate. These results suggest that RMMs may need to be very cost effective if property owners are to adopt them through normal private choice without regulation.

These general conclusions were reinforced in a follow-up survey of 252 individuals visiting the Exploratorium Museum in San Francisco who were more likely to experience an earthquake. Participants were given three different time horizons for residing in the house: five, 10, and 20 years. The price of the quake RMM was specified as $1,500. As in the earlier experiment, a significant proportion of the respondents exhibited high effective annual discount rates (the mean value varied between 67 percent and 74 percent, depending on the time horizon) and they did not alter their maximum willingness-to-pay as the time horizon for residing in the house increased. For example, when the length of time in the house was increased from five to 10 years, 45 percent of the subjects did not change their expressed WTP for the protective measure. The large group of individuals who maintained the same WTP as the time horizon changed may have been concerned about their inability to pay more, or their belief that the cost of the RMM is fully capitalized in the selling price of the property regardless of their likely period of ownership.

In summary, the empirical and experimental data suggest that many property owners are reluctant to invest in cost-effective RMMs because they do not make the implied tradeoffs between spending money on mitigation now in return for potential benefits over time. They also may lack knowledge about mitigation measures, or they may feel they will only have to bear a portion of the damage costs if a disaster occurs. In addition, they may not have the financial resources to afford the measure, or they may fear that the contractor will not do the job properly. Developers may exacerbate this behavior by believing (perhaps correctly) that they cannot recover the cost of RMMs by increasing the prices of their structures.

THE NEED FOR A PUBLIC-PRIVATE PARTNERSHIP

IF HOMEOWNERS VOLUNTARILY ADOPTED COST-EFFECTIVE mitigation measures and if insurers set premiums that reflected the reduction in losses from RMMs to their insured structures, this would decrease disaster losses in hazard-prone areas and would lower the probability of insurer bankruptcy. Despite these benefits, most property owners have limited interest in investing in mitigation measures and insurers do not encourage mitigation in hazard-prone areas because state regulations often do not allow premiums to reflect the risk. That is, low-risk, insured individuals subsidize high-risk clients. If insurers based their rates on the risk of suffering damages in certain hazard-prone areas, the insurers would want to encourage mitigation and would reduce premiums for property owners who adopted RMMs.

Government, insurers, and banks could encourage mitigation by instituting a number of public-private partnership programs. Such programs could include the following:

Building Codes Local governments could adopt building codes that require property owners and developers to employ mitigation measures. Such codes may be desirable when property owners would otherwise not adopt cost-effective RMMs because they either misperceive the mitigation measures' benefits or they underestimate the probability of a disaster occurring. For example, suppose a property owner believes that earthquake damage to his structure would result in losses of $20,000 while the developer knows that the losses would be $25,000 because the structure is not well constructed. The developer has no incentive to relay the correct information to the property owner because the developer is not held liable in the event that an earthquake causes damage to the building. If the insurer is unaware of the quality of a building's construction, the information cannot be conveyed to the property owner through insurance premiums.

Researchers Linda Cohen and Roger Noll, in their article "The Economics of Building Codes to Resist Seismic Shocks," (*Public Policy*, Winter 1981) provide an additional rationale for building codes. When a building collapses, it may create costs for others in the community (externalities) that property owners do not take into account when they evaluate the importance of adopting a specific mitigation measure. For example, if a building topples off its foundation after an earthquake, it could break a pipeline and cause a major fire that would damage other homes not directly affected by the earthquake. All financial institutions and insurers responsible for these other at-risk properties would favor building codes to protect their investments.

Taxpayers will also benefit from building codes designed with disaster mitigation in mind, because they foot the bill for disaster assistance and reconstruction. In a study estimating the physical and human consequences of a major earthquake in the Memphis-Shelby County, Tenn., area, researchers found that the temporary losses in economic output stemming from damage to workplaces could be as much as $7.6 billion based on the magnitude of unemployment and the accompanying losses in wages, profits, and indirect "multiplier" effects.

Seals of Approval Another way to encourage the adoption of cost-effective mitigation measures is for banks and financial institutions to provide a seal of approval to each structure that meets or exceeds building code standards. The Institute for Business Home and Safety (IBHS) has taken the lead in the creation of a Showcase Community Program in which structures that meet predefined criteria would receive a certificate of disaster resistance. These certificates would enable property owners to take advantage of special incentives provided by banks (e.g. lower mortgage rates) and insurers (e.g. lower premiums). The success of such a program requires the support of the building industry and a cadre of qualified inspectors to provide accurate information as to whether existing codes and standards are being met. Insurers may want to limit coverage only to those

structures that receive a certificate of disaster resistance.

Linking Bank Loans with Insurance If insurers were to reduce premiums for property owners who employed RMMs, property owners would be more likely to adopt these measures. But premium reductions might not be sufficient inducement if homeowners are reluctant to incur the initial capital cost of mitigation because of budget constraints or capital market imperfections. To overcome this financial constraint, insurers and bankers could link capital and insurance markets explicitly so that, if banks provide funds for mitigation through a home improvement loan with a payback period identical to the life of the mortgage, homeowners might be more likely to mitigate.

For example, a 20-year loan for the $1,500 cost of earthquake mitigation at an annual interest rate of 10 percent would result in payments of $170 per year. If the annual premium reduction from insurance were to reflect the expected benefits of the mitigation measure (e.g., $500 in our earthquake example), then the insured homeowner could lower his total payments by investing in cost-effective mitigation. To date, banks have not offered such loans, primarily because mortgages do not require earthquake coverage and insurers have not offered premium reductions for those who adopt mitigation measures. But there is no reason why such a joint capital market and insurance program could not be instituted in the future.

Lower Deductibles Tied to Mitigation An alternative way to encourage consumers to adopt mitigation measures would be to change the nature of their insurance coverage rather than reduce the premium. More specifically, the insurer could offer a lower deductible to those who adopt mitigation. Property owners would likely favor such a program, according to empirical and experimental evidence.

Using our statistical models of Oakland and Miami, we examined the impact of lowering the deductible for property owners who adopted cost-effective RMMs. In our models, insurers would base their premiums on their expected losses from future disasters.

Table 4 compares the total expected costs for homeowners who do, and do not, adopt mitigation measures. The comparison uses two different deductible levels for each area; in Oakland the levels were 15 percent and 10 percent of loss, while in Miami they were $1,000 and $0.

The results shown in Table 4 are interesting in two ways. First, both homeowners and insurers tend to be better off when they mitigate and are given a lower deductible than when they fail to adopt protective measures. Thus, homeowners in our model of Oakland who were insured by the Large Insurance Company experienced a total loss of $12.12 million when they did not mitigate and had a 15 percent deductible. In comparison, they had a total loss of $10.52 million when they mitigated and were given a 10 percent deductible. Insurers' insolvency probability fell from 1.10 percent to 1.07 percent if mitigation and the lower deductible were in place. Similar results were derived from models of the Small Insurance Company in Oakland and the Large Insurance Company in Miami.

Homeowners and insurers would be even better off in terms of their expected losses if they chose to maintain the higher deductible after they invested in cost-effective RMMs. For instance, residents in Oakland who were insured by the Large Insurance Company would have had their expected losses reduced from $12.12 million to $9.93 million had they mitigated and maintained the 15 percent deductible. Insurer insolvency probability would also have fallen from 1.10 percent to .57 percent. We should not be surprised by this result because of the extra loading cost and higher claims associated with a low deductible. But property owners do not see the merit of higher deductibles because they focus on their out-of-pocket expenses following a disaster when they buy coverage.

Table 4

Effect of Deductibles and Mitigation on Homeowner Cost (in Millions of Dollars) and Chance of Insurer Insolvency

	OAKLAND MODEL		MIAMI MODEL	
	Deductible		Deductible	
SMALL INS. CO. POOL	15%	10%	$1000	$0
0% Mitigation				
Homeowner Cost	$6.08	$6.48	$6.15	$6.36
Probability of Insolvency	1.10%	1.20%	1.63%	1.76%
100% Mitigation				
Homeowner Cost	$4.98	$5.27	$6.06	$6.24
Probability of Insolvency	.58%	1.07%	.94%	1.07%
LARGE INS. CO. POOL				
0% Mitigation				
Homeowner Cost	$12.12	$12.92	$17.36	$18.02
Probability of Insolvency	1.10%	1.20%	1.74%	1.94%
100% Mitigation				
Homeowner Cost	$9.93	$10.52	$15.90	$16.49
Probability of Insolvency	.57%	1.07%	.99%	1.10%

Broadening Protection Against Catastrophic Losses New sources of capital from the private and public sectors could provide insurers and government with funds against losses from catastrophic events. They range from capital market instruments to insurance pools to federal solutions, and they would alleviate insurers' concerns that the next major disaster might leave them insolvent. Recently, investment banks and brokerage firms have shown considerable interest in developing new financial instruments for protecting against catastrophic risks. Their objective is to find ways to make investors comfortable with trading new insurance-linked, securitized instruments covering catastrophic exposures, just like the securities of any other asset class.

Catastrophic bonds, or CAT bonds, pay investors if disasters do not occur. If disasters do occur, the bonds do not pay and the issuer uses the proceeds to cover the cost of damages. The CAT bonds pay rates that compensate investors for

the probability of nonpayment. In June 1997, the insurance company USAA floated act-of-God bonds that provided them with protection should a major hurricane hit Florida. A month later, Swiss Re Capital Markets Corp. and Credit Suisse First Boston put together a two-year CAT bond with loss triggers tied to California insurance industry earthquake losses based on the Property Claims Insurance index for the state. Since that time, there have been a number of other CAT bonds issued in Japan and other countries.

Turning to the role of the public sector, researchers Christopher Lewis and Lewis Murdoch, in their article "The Role of Government Contracts in Discretionary Reinsurance Markets for Natural Disasters" (*Journal of Risk and Insurance*, 1996), developed a proposal that the federal government offer catastrophe reinsurance contracts that would cover insurance industry losses of between $25 billion and $50 billion from a single natural disaster. The Treasury would hold annual auctions of a limited number of these excess-of-loss (XOL) bonds, and insurers and state and national reinsurance pools would be eligible purchasers.

CONCLUSION

MANY SIMPLE RISK-MITIGATION MEASURES WOULD SAVE homeowners, insurers, and taxpayers a lot of money. But homeowners do not invest voluntarily and insurers do not reward such investment behavior because of a variety of existing policies as well as decision-making limitations. Limitations in individuals' ability to judge and prepare for the consequences of rare events also decrease their willingness to invest in RMMs. And housing developers do not reveal information about the disaster resistance of their structures because potential purchasers do not seem to value mitigation and banks and insurers do not have enough incentive to care.

Existing government programs dull the incentives for individuals and institutions to prepare for catastrophic natural disasters. Despite the best intentions, government has not been able to fulfill a commitment to withhold assistance from those who do not purchase private coverage; the aftermath of a major disaster usually brings special legislation to provide some form of financial assistance to those in need. What is more, states regulate insurance rates in ways that reduce insurance company incentive to encourage their greatest risks to invest in mitigation.

In a first-best world, we would advocate insurance and mortgage reform so that the key players in the housing market would have the incentive to encourage homeowners to mitigate. For example, if Freddie Mac were to indicate to investors those bundles of securitized mortgages that included structures that were mitigated and those that included unmitigated structures, mortgage issuers would have incentives to encourage homeowners to mitigate. But the combination of individuals' lack of concern before a disaster and government coming to the rescue after the event puts us in a second- or third-best world. Thus, we favor policy interventions that save taxpayers money by regulating decisions between willing buyers and sellers.

Linking mitigation investments and insurance to mortgages will take the decision out of the hands of the residents in hazard-prone areas. More specifically, if banks are willing to make long-term loans for mitigation that are tied to mortgages, and if insurers reduce premiums to reflect the benefits of these measures, then property owners will increasingly come to view cost-effective RMMs as attractive.

Should banks take the additional step of requiring insurance as a condition for a mortgage, then the three parties will all be better off. The homeowner will have lower total payments, the insurer will reduce its future losses, and the bank will be protected against a disaster victim walking away from the damaged home due to insolvency.

The open question is whether policymakers, bankers, and insurers can implement these steps before the next major disaster. Hopefully, we will not have to wait for another catastrophe before seriously discussing these and other ways of reducing future losses from natural disasters. R

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