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Chapter Author: Christopher Lewis, Kevin C. Murdock

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Christopher M. Lewis and Kevin C. Murdock

Since 1989, the costs of natural disaster have risen dramatically. Combined insurance losses from Hurricane Andrew ($15.5 billion) and the Northridge Earthquake ($12.5 billion) alone totaled almost $30 billion. Insured and uninsured losses from these two events exceeded $40 billion. In fact, after adjusting for housing-price inflation, insured losses over the period 1989–95 totaled almost $75 billion, more than five times the average real insured losses during the prior four decades.[1]

The years 1989–95 by no means represent an unusual period of heightened disaster activity; new research shows that society's exposure to disaster risk is far greater than previously recognized. During 1995, more tropical storms were formed (nineteen) than at any time since 1933, foreshadowing a return to the higher tropical storm activity patterns experienced earlier this century (ISO 1996).[2] At the same time, geologic studies of earthquake recurrence intervals in the United States indicate that there is a very high probability of another Northridge-magnitude or larger earthquake occurring during the next decade.

Christopher M. Lewis is senior manager and risk management consultant at Ernst & Young LLP. Kevin C. Murdock is associate professor of strategic management in the Graduate School of Business, Stanford University.

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1. Based on "PCS Catastrophe History Database," version 1.3, Property Claims Services, adjusted for housing-price inflation using owner-occupied housing-value information from the U.S. Bureau of the Census, Ser. HC80-1-A.

2. Most of these storms did not make landfall, but those that did contributed to the $8.5 billion in total insured catastrophe losses for 1995 (ISO 1996).

More significantly, the value of properties exposed to natural disaster risk has increased rapidly. From 1970 to 1990, the population density along the Southeast Atlantic Coast increased by nearly 75 percent, far in excess of the 20 percent increase experienced for the nation as a whole (ISO 1994). More troubling, insured coastal property values in the United States grew 69 percent from 1988 to 1993 to $3.15 trillion. Similarly, the average annual growth rates in the population per square foot in California (2 percent) and Florida (3.2 percent) over the past fifteen years have been double and triple the average national growth rate for the whole United States (U.S. Bureau of the Census 1994).

This increased recognition of disaster exposure has sent reverberations throughout the private-sector financial markets. In Florida, computer models of hurricane risk were reporting expected average annual hurricane losses of $1.4–$1.5 billion relative to total homeowner's premiums of just $1.2 billion (premiums earned on related lines totaled another $1.2 billion). In California, average annual earthquake exposures were quickly approaching $1 billion, compared with industry premiums of just $524 million (Insurance Information Institute 1994).

Reinsurance companies responded to this increased exposure quickly by raising rates. According to a study by Goldman Sachs, the average rate on line (ROL) for catastrophe covers jumped from 7.93 to 15.09 percent between 1985 and 1995, while the average attachment point for a single catastrophe increased from $1.14 to $2.57 billion in industry losses (Litzenberger, Beaglehole, and Reynolds 1996). Discussions with insurance-company executives indicate that reinsurance rates increased by as much as 150 percent from 1993 to 1995.

With a rise in reinsurance rates, an increased catastrophe-exposure retention, and a realization of their overexposure to disaster risk, primary insurers sought comparable rate increases. When these rate-increase proposals were pared down in the process of state insurance rate approval, insurers started to withdraw from the market, causing a drop in the availability of insurance coverage for individuals living in high-risk areas of the country. In response, states instituted new regulations restricting insurer exits, established new state insurance facilities, and approved modest increases in primary-insurance rates. The net result, however, was a continued overexposure of insurance companies to natural disaster risk. Similar disruptions occurred after the Northridge Earthquake.

The concern over natural disaster expenditures after Hurricane Andrew was not limited to the insurance industry. In 1994, the U.S. Congress raised concerns over the growth in long-term disaster-recovery expenses incurred by the federal government. Thus, at the same time as the insurance industry started seeking federal assistance in reducing its catastrophe exposure, the federal government was concerned with the budgetary implications of disaster-recovery expenses that were already being incurred.

As a result, homeowners, insurers, financial markets, and state and federal governments have started evaluating options for improving society's ability to

finance disaster risk: New state programs have been developed in Florida (the Florida Catastrophe Fund), California (the California Earthquake Authority), and Hawaii to increase insurer capacity in these high-risk markets. New financial market instruments have been developed to help insurers hedge natural disaster risk (e.g., catastrophe options at the Chicago Board of Trade, surplus notes, and act-of-God bonds). An insurance swap market (CATEX, the Catastrophe Risk Exchange) has been developed to allow for enhanced geographic diversification of disaster risk. Finally, a federal excess-of-loss reinsurance program has been proposed to better diversify claims intertemporally.

These efforts to devise alternative means of financing disaster risk represent attempts to address the primary question gripping the U.S. economy with respect to catastrophic risk: How can catastrophic risk be more efficiently managed? This paper examines the current distribution of catastrophic risk in the United States and presents a general public-policy framework for evaluating the role that *federal* policy can play in improving this allocation of disaster risk. Within this framework, this paper then evaluates two major federal disaster reform initiatives.

First, the paper analyzes why a requirement for the purchase of natural disaster insurance on new structures could be an effective mechanism for reducing total societal losses from natural disasters. Currently, the system for allocating natural disaster risk in the United States is inefficient and allows individual propertyowners to ignore their disaster-risk exposure when making construction decisions—promoting inefficient construction location and design. A requirement for the purchase of all-hazards insurance on new construction could help promote more efficient construction and reduce the incentives for moving to high-risk areas of the country, mitigating the costs of future disasters.

Second, this paper suggests that the creation of a new financial instrument (an industry excess-of-loss contract) could provide the insurance industry with an important tool for intertemporally diversifying natural disaster risk. Intertemporal diversification is an important component of disaster-loss financing given the large variance in aggregate disaster claims and the large differentials between annual premium volume and annual disaster losses. This type of risk can often be best hedged through market-based securities. Hence, the paper also suggests that having the federal government provide the initial liquidity for the market (with sufficient mechanisms for the private sector to "crowd out" the public sector) could allow insurance and reinsurance companies to make the necessary investments in business systems to support this new market. The creation of this new mechanism would likely promote a gradual transition to a more efficient risk-allocation mechanism for natural disasters where insurance companies and reinsurance companies are able to better pool risks geographically and intertemporal risk is managed through private market–based mechanisms.

Section 2.1 reviews the existing mechanisms used to finance catastrophic

risk in the United States. Section 2.2 highlights some of the weaknesses within the current system that have given rise to the disruption in insurance markets following the recent rise in disaster activity. A framework for analyzing federal policy options for addressing these weaknesses is discussed in section 2.3. Section 2.4 applies this framework in analyzing two specific policy options designed to improve the management of disaster risk in the United States. A conclusion follows.

2.1 Financing Natural Disaster Risk

In the aggregate, all losses from natural disasters are paid out of individual incomes, through either direct losses, insurance premiums, losses on insurance stocks, charity, or taxes. However, the magnitude of future disaster losses depends on the level of ex ante disaster mitigation, and these mitigation investments, in turn, depend on the manner in which disaster risks are allocated and financed. The primary objective of natural disaster policy is to reduce the effect on welfare of a given disaster event. This paper focuses on how the choice of ex ante financing mechanisms for disaster risk can directly affect the size of the welfare loss associated with natural disasters within a context of disaster-risk management.

2.1.1 Recent History

Historically, losses from natural disasters have been financed using one of six mechanisms: private insurance, capital market securities, federal taxpayer assistance, state taxpayer assistance, self-insurance, or charity. Figure 2.1 shows the allocation of financing sources (excluding self-insurance) for the two largest disaster events in the United States: Hurricane Andrew and the Northridge Earthquake. The allocation of disaster expenditures differs significantly between the two events. For example, as ground-movement events, earthquakes tend to cause far more extensive damage to infrastructure than do hurricanes. As such, government assistance for infrastructure reconstruction tends to cover a larger percentage of earthquake losses. Also, hurricanes can create far greater damage from flooding, leading to a larger percentage of losses being covered through the federal flood-insurance program. (The largest percentage of losses from Hurricane Hugo came from flood damage.) Finally, since only 35–40 percent of Californians carried earthquake-insurance coverage, a smaller portion of personal property losses in Northridge was covered by insurance, shifting more losses to individuals, taxpayer assistance, and, where the loss of property value resulted in a mortgage default, investors in mortgage securities.

Figure 2.1 also shows the magnitude of cross-subsidization of disaster risk from low-risk to high-risk areas. In the case of state taxpayer assistance, cross-subsidies exist between low-risk and high-risk properties within the state. At the federal level, cross-subsidies are broader, with taxpayers in low-risk states

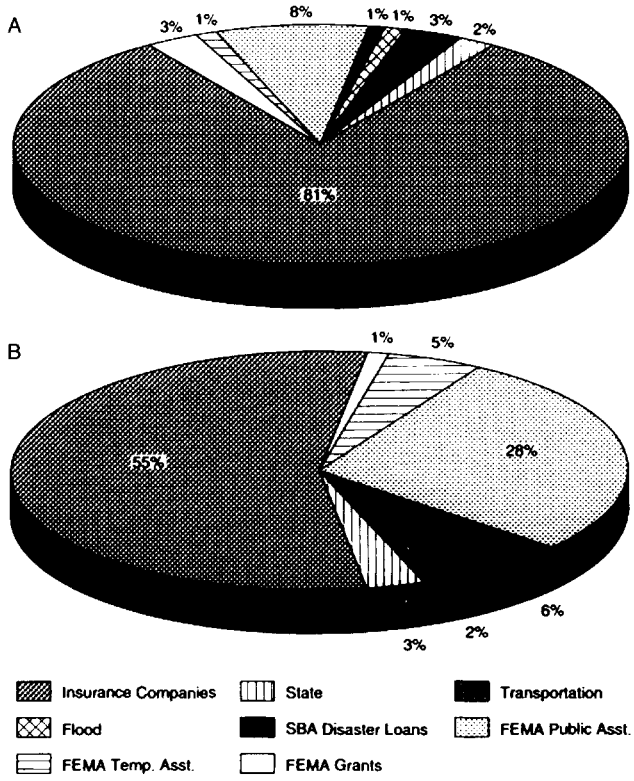

Fig. 2.1 Allocation of financing sources: *A*, Hurricane Andrew ($18 billion); *B*, Northridge Earthquake ($23 billion)

paying for losses in disaster-prone areas. To the extent that the federal or state governments borrow to cover disaster expenditures, disaster risk is also cross-subsidized intertemporally. Charity obviously represents a direct transfer from nonaffected parties to those who experienced a disaster loss.

In the case of purchased insurance and capital market instruments, however, the risk of loss should be incorporated in the purchase price of the coverage provided (assuming that the price of the instrument is efficient).[3] As such, the risk is internalized in the purchase decision. In the case of self-insurance, the degree of internalization is unclear. However, the buildup of property values in disaster-prone areas of the country and the lack of disaster-mitigation investment in these areas suggest an underrecognition of risk internalization.

Experience over the last six years has demonstrated that traditional channels

3. To the extent that state insurance commissioners impose price ceilings on insurance rates, the price of insurance will only partially internalize the disaster risk.

for financing disaster losses are adequate to cover losses of the magnitude of \$10–\$20 billion, but only with disruption in the market for disaster insurance and rapid increases in federal and state disaster spending. Fueling congressional and industry concerns is a recognition that, as disaster losses start to exceed \$30–40 billion, the functioning of the entire insurance system may be at risk. While the probability of such an event occurring is relative small—1–2 percent according to some estimates (Cummins, Lewis, and Phillips, chap. 3 in this volume)—it is important to examine this contingency.

2.1.2 Efficient Market Allocation of Disaster Risk

The question of how to allocate disaster risks most efficiently is best understood by first examining the simple case in which all individuals have perfect knowledge concerning the joint distribution of claim amounts and others' attitudes toward risk. The basic theory for understanding the markets for risk bearing was initially developed by Arrow (1953, 1964) and Debreu (1959), with a specific extension to insurance markets by Borch (1974). Even after twenty-five years of advances in the theory of insurance and capital markets, the most fundamental propositions of these papers offer insights into the problem of managing catastrophic risk.

As concisely demonstrated in Lemaire's (1990) summary of Borch's theorem and in Arrow (1996), the basic risk-exchange model starts with a set of N individuals in the economy $N = \{c_1, \ldots, c_n\}$, each with an initial wealth of w_i and subject to a risk of loss characterized by distribution function $F_j(x_j)$. Then, assuming that each individual possesses a utility function $u_j(x_j)$ such that $u_j'(x) > 0$ and $u_j'(x) < 0$ (diminishing marginal utility), the expected utility of c_j's ex ante position is defined by

$$(1) \qquad u_j(x_j) = u[w_j, F_j(x_j)] = \sum_{i=1}^{n} u_j(w_j, x_j)\pi_j,$$

where π_j represents the probability that the state of the world x_j will occur. To maximize their ex ante utility, the n individuals will then enter into risk-sharing transactions to form a risk pool defined by

$$(2) \qquad [y] = [y_1(x_1, \ldots, x_n), \ldots, y_n(x_1, \ldots, x_n)],$$

where $y_j(x_1, \ldots, x_n) = y([x])$ is the sum that agent c_j has to pay if the claims for the different agents respectively amount to $x_1, \ldots, x_n$. Then, assuming that the market clears (a closed exchange),

$$(3) \qquad \sum_{j=1}^{n} y_j([x]) = \sum_{j=1}^{n} x_j = \text{total amount of all claims.}$$

Both Lemaire (1990) and Arrow (1996) show that, under mild assumptions, the Pareto-optimal risk-sharing treaty among the individuals depends only on the *sum* of individual claim amounts x_j, not on individual results. As Arrow

(1996) concludes, the probability-adjusted price for obtaining a wealth transfer contingent on the realization of a given state of the world depends *only* on the total of all endowments available in that state of the world, not on the wealth effect on the insured individual.[4]

Thus, in efficient Arrow-Debreu markets with perfect information, individuals can manage their exposure to contingent disaster liabilities by taking (long and short) positions in state-contingent risk-exchange securities. That is, individuals agree to enter into state-contingent risk-shifting contracts that allocate wealth from individuals who benefit from the realization of a specific state of the world to individuals who would suffer disaster losses in that state of the world. Thus, to construct a Pareto-optimal risk-sharing arrangement, agents simply need to form a pool of all claims and specify a formula for distributing the burden of such claims, independent of their origin (Lemaire 1990). This observation, which Debreu extended into a multigood, multiperiod model, launched an enormous body of research dedicated to specifying the optimal pool risk-sharing formulas for various risk preferences, utility-curve representations, individual versus collective rationality, and market structure (Lemaire 1990).

The efficiency of the Arrow-Debreu solution centers on the ability of individuals to share perfect knowledge over the probabilistic outcomes associated with future states of the world. As a result, through the operation of a price system, individuals can obtain an efficient ex ante allocation of risk bearing. While an efficient allocation of risk bearing does not eliminate the losses associated with a natural disaster, it makes the losses to society as small as possible. Of course, even in the Arrow-Debreu world, as the size of the disaster loss increases and the state-contingent endowments fall, the market for transfer payments decreases. Thus, for perfectly correlated catastrophic disaster events that universally affect society, the extent of transfer payments is relatively small.

Unfortunately, an examination of the market for risk bearing in the United States demonstrates that the conditions posed by the Arrow-Debreu model of allocating risk do not hold in today's markets. Instead, several real-world inefficiencies restrict the ability of the market for risk bearing to function efficiently. First of all, individuals do not have access to perfect information concerning their disaster-risk exposure. As a result, individuals cannot internalize an accurate assessment of their risk exposure in their decisions to purchase insurance or mitigate hazard losses (Kunreuther 1996).

Second, the process of managing individual insurance contracts entails considerable administrative costs associated with evaluating risks, processing claims, and monitoring risk (Epstein 1996). In addition, insurance must contend with the ability of the insured to influence his or her endowment (and

4. Thus, for two states with the same total of endowments, the prices (premiums) of payments conditional on those states are in proportion to their probabilities.

therefore the endowments of others through risk-shifting) in future states of the world without being observed. This ability to shift risk is the classic problem of moral hazard that introduces inefficiencies into the competitive insurance equilibrium (Arnott and Stiglitz 1990). Finally, the existence of ex post government subsidies imposes inefficiencies and disincentives for risk sharing (Priest 1996).

We now turn to a discussion of these factors to gain a better understanding of how risks currently are allocated in the U.S. economy. After examining problems associated with the process of internalizing risks at the individual level, we focus on the structure of existing mechanisms for risk financing. Finally, we demonstrate where the existing systems for financing disaster risks break down.

2.1.3 Internalization of Risk at the Individual Level

Associated with every property or structure in the United States is a probability of loss due to a natural disaster. Knowingly or unknowingly, buyers implicitly accept this liability to disaster risk when they build or purchase property. The value of this liability is given by a disaster-loss distribution derived from the product of two probability distributions—the probabilities of disaster occurrences on the property in question and the conditional distribution of loss severities associated with those disaster occurrences.

In a world of perfect information and efficient markets, propertyowners would accurately value the disaster liability associated with a property. As such, propertyowners could assess (*a*) the relative value of properties with or without the disaster liability included in the offer price, (*b*) how the risk of loss to a particular property can be reduced through mitigation actions (i.e., actions that lower disaster severities), and (*c*) the net benefits of alternative means of financing the losses that do occur. Essentially, propertyowners would recognize that they hold a long position in natural disaster risk and would incorporate the value of this exposure in their utility-maximization process—utilizing actions to reduce their disaster exposure when it proves a value-enhancing option.

First, mitigation measures that pass a benefit/cost test from the market's perspective—not just the individual's assessment—will be undertaken. When calculating the benefits derived from a mitigation action, propertyowners would incorporate the flow of benefits during and *after* their tenure of ownership since the value of all benefits would be reflected in the market price of the property. Of course, if mitigation generates positive externalities not captured in the market price, the socially optimal level of mitigation may still exceed the market's valuation of mitigation.

Also, propertyowners would have an incentive to purchase insurance to reduce their risk of loss from a disaster. By purchasing insurance, propertyowners can short a portion of their disaster risk exposure in exchange for a premium that, because of the diversification benefits offered by insurance, should be less than the value of continuing to hold the full position in disaster risk.

Finally, prospective propertyowners would incorporate the (negative) value of the disaster liability into the price that they are willing to pay for new property, increasing the return to lower-risk properties, and reducing the incentives for building new properties in disaster-prone areas.

Unfortunately, propertyowners do not appear to have a good assessment of their relative disaster exposure, and many individuals invest little in protective actions to reduce their exposure to disaster risk. In essence, propertyowners are not internalizing their risk of exposure in their decisions governing where they live, the extent of mitigation investment undertaken, or the decision to purchase insurance.

Kunreuther (1996) cites two possible reasons for this lack of investment—an underestimation of exposure to loss and high personal discount rates in valuing the benefits of disaster mitigation, possibly reflecting the attitude that "it won't happen to me." First, underestimating the value of the contingent disaster liability will create a disconnect between the price of insurance required by an insurer properly valuing the exposure of the property and the price the propertyowner is willing to pay. This disconnect will reduce the likelihood that the propertyowner will finance disaster losses through the purchase of insurance. Furthermore, understating the value of the disaster risk may raise the benefit/cost threshold for mitigation actions by understating the absolute reduction in loss associated with a given mitigation activity. Also, above-market personal discount rates reduce the present value of benefits derived from mitigation relative to the up-front cost incurred, reducing the likelihood that mitigation actions would be undertaken.

Another possible factor creating an underinvestment in mitigation is the large differential between the expected arrival time of disaster events and the expected length of ownership tenure for properties. If propertyowners incorporate only the value of benefits generated over the expected length of ownership tenure (six to seven years for homes based on a mobility rate of 10 percent per year), and if the residual benefits are not incorporated into the market price of the property, then propertyowners would have a disincentive to undertake potentially beneficial mitigation efforts that accrue benefits over a longer period of time.

On the other hand, it does appear that homeowners are willing to incorporate disaster risk into their calculations if given appropriate information on disaster risk. In a survey of Florida homeowners, the Institute for Property Loss Reduction found that nine of ten homeowners in coastal areas were willing to pay as much as $5,000 (or 5 percent) more for a house built to withstand hurricane damage (IPLR 1995). In fact, 91 percent of homeowners supported a requirement that builders follow stricter building codes to make dwellings less vulnerable to hurricane damage. At the same time, only 29 percent expressed a willingness to retrofit their existing homes if the cost exceeded $2,000, with another 18 percent indicating a willingness to spend between $1,000 and $2,000 (IPLR 1995).

Furthermore, Bernknopf, Brookshire, and Thayer (1990) studied the effect on property values of posting information on the relative threat of earthquake and volcano damage in the area of Mammoth Lakes, California. Their study showed that, while recreational visitation was largely unaffected by the posting of new information on the area's disaster exposure, the information created a significant and persistent drop in the value of properties in the region. Thus, the important question that must be addressed is whether individuals simply lack access to adequate data on their disaster exposure or simply do not incorporate this information into their decisions on where to live, how much insurance to purchase, and what level of mitigation to undertake.

2.1.4 Private Market Mechanisms for Financing Disaster Risk

Arrow-Debreu markets provide a context for viewing an "ideal" risk-exchange economy in which individuals, armed with perfect information, can purchase pure state-contingent securities that pay the holder after the realization of a particular state of the world and otherwise pay nothing. Once the assumptions of perfect and shared information are relaxed, however, one must contend with the difficulties involved in diversifying individual risks in an economy with transactions costs. At this point, the economic role of financial intermediaries as low-cost transactors in the financial markets becomes central. Currently, there are two principal methods of undertaking the financial intermediation of risk in today's financial markets—the purchase of private insurance and the trading of market-based securities.

The Role of Securities Markets in Diversifying Claims

Individuals living in a classic Arrow-Debreu world can purchase pure state-contingent securities that pay the holder only on the realization of a specified state of the world. In cases where the information about the underlying risk-generating process of an asset is public (or at least not asymmetrically distributed), today's securities markets function as an efficient mechanism for diversifying risks very much in the spirit of the Arrow-Debreu model. Securities markets in the United States are highly liquid, quickly incorporate new information in the value of securities, and have relatively low transactions costs.

Advances in the theory of derivatives over the past twenty-five years have reinforced the ability of the capital markets to optimize the allocation of financial resources in the economy. In 1973, Black and Scholes (1973) and Merton (1973) developed the general theory of options pricing for derivative securities—allowing for the valuation of untraded assets whose payoffs were a function of traded assets. A few years later, Ross (1976), Hakansson (1976), Banz and Miller (1978), and Breeden and Litzenberger (1978) linked this theory of options pricing to the Arrow-Debreu world of state-contingent securities by demonstrating that portfolios of options can be used to replicate pure securities and that these pure securities could be used to price derivative securities

(Merton 1990). Thus, in a world of no transactions costs, investors could efficiently diversify their risks by constructing optimal portfolios of derivative securities.

Once transactions costs are introduced, however, the role of low-cost financial intermediaries becomes important. Financial intermediaries are needed to provide individuals with financial instruments that cannot be traded directly in the capital markets, usually owing to information asymmetries that require the screening, monitoring, and pricing of individual risks. Financial intermediaries sell these individual financial products, aggregating their exposure from these products, and establishing positions in the secondary market to hedge their exposure. The role of a financial intermediary is to provide a bridge between the capital markets and the specific financial needs of individuals. As such, intermediaries can minimize the distortions created by transactions costs and accomplish an efficient allocation of resources in the economy by helping individuals diversify their financial positions.

Insurance Companies as Intermediaries

Property-casualty-insurance companies are the primary intermediary financing the insurance of natural disaster risk in the United States today. As mentioned above, individuals living in disaster-prone areas of the United States hold a long position in disaster risk. In providing disaster insurance, an insurance company offers to assume a portion (e.g., over a deductible) of the policyholder's disaster-risk exposure in exchange for a premium. After accumulating these policyholder positions, the insurance company can diversify its net disaster exposure through portfolio diversification and through the purchase of either reinsurance or capital market derivatives that directly hedge the insurer's exposure. Any remaining disaster exposure is borne by the stockholders of the insurance company. Therefore, insurance firms add value to the market for disaster risk through their role as a low-cost transactor in the capital market and their ability to diversify disaster risks through risk pooling (aggregation), risk identification and segregation, and risk monitoring (Priest 1996).

Diversification through risk pooling is achieved by creating a large portfolio of independent and identically distributed risks, the result being that (by the law of large numbers) the variance of the average expected loss in the portfolio becomes smaller. That is, for independent risks, the mean risk for an insurance pool, and for society in general, is less than the individual risks in the pool. Of course, for statistically correlated risks, the benefits of risk pooling are significantly reduced, and insurance becomes less attractive. The opportunities for risk diversification through pooling are more limited in the market for catastrophic risk, where risks are highly correlated. Even for a pool containing the entire U.S. market, the mean risk will have substantial variance, and the annual flow of insurance premiums will vary greatly from actual disaster losses.

Insurers also diversify through risk identification and segregation. Insurance companies serve an important function in the processing of information—as-

sessing and pricing the risk inherent in the property being insured. For many risks covered by insurance contracts, information on the underlying insured risk is not generally available. As a result, insurance companies are needed to identify and segment risks into appropriate risk categories. This information-intensive evaluation process is accomplished through explicit insurer screening mechanisms, offering a menu of contracts that enable different risk groups to self-select the best available contract given their own private information and through a continuous monitoring of the underlying risk. By segregating risks into risk pools, insurers improve the predictive accuracy of the aggregate risk insured and reduce the mean risk to society in a manner analogous to risk aggregation. For example, the variance in expected losses of two independent risk pools with different expected losses will be less than the variance in expected losses associated with the combined pool.

Furthermore, by charging insurance premiums commensurate with risk, insurers relay valuable information to the insured concerning their relative risk exposure: information that will often influence the behavior of the insured. For example, if insurers provided premium discounts for hazard mitigation, high-risk properties would have an incentive to undertake cost-effective mitigation actions to reduce their insurance rates, thereby reducing the aggregate exposure. Similarly, higher-priced premiums increase the cost of undertaking riskier activities; and, to the extent that risk-taking activity is reduced, total risk in the economy is lower.

Insurance companies also control risk through the use of deductibles, coinsurance, and coverage exclusions to limit moral hazard and other forms of distributional risk shifting by the insured. By transferring a portion of the risk of loss back to the insured party, deductibles and coinsurance attempt to align the interest of the policyholder with the interest of the insurance company—to mitigate the risk of a claim. As a result, these provisions lower insurance costs and expand the availability of insurance to more of society.

Limited Liability and Default Risk

Insurance companies clearly serve a valuable role in identifying, monitoring, pricing, and controlling the individual risks associated with property coverage: risks that are too asymmetrically under the control of the insured to be effectively traded directly in the capital markets. However, as financial intermediaries, insurance companies suffer from a problem endemic to all intermediaries: the risk of financial insolvency. When a policyholder purchases an insurance policy from an insurer, he or she obtains an option to collect from the intermediary under certain states of the world. The policyholder's ability to collect on this contract, however, is contingent on the claims-paying ability of the intermediary under that state of the world. The claims-paying ability of the intermediary, in turn, depends on its entire structure of the insurer's assets and liabilities and its ability to hedge its aggregate exposure in the broader capital markets.

The problem with natural disaster risk (and any risk subject to catastrophic loss) is that the exposure to a catastrophic event has a substantial effect on the solvency of the insuring firm. Since customers often cannot diversify away this institutional exposure by taking positions in the market (given transactions costs), the premium levels that the customer is willing to pay for this insurance will be a function, not only of the pure financial instrument purchased, but also of the intermediary's financial condition.

Thus, it is interesting to note that, if there is an exogenous increase (decrease) in the perceived risk exposure of insurance companies owing to the arrival of new information on the nature of the risk being insured, and if this new information decreases (increases) the policyholders' perception of the financial solvency of the insurance firm, policyholders should decrease (increase) the amount that they are willing to pay in premiums for a given level of insurance. Ironically, this reduction in demand would occur exactly when insurance companies would be lobbying to raise rates to cover their overexposure to the insured risk—possibly compounding any perceived "availability" gap in the market for insurance coverage.

To enhance their claims-paying ability, reduce their disaster-risk exposure, and maximize franchise value, insurance companies attempt to hedge the net exposure of their portfolio in the capital market. In this regard, insurance companies have relied almost exclusively on stockholder capital and reinsurance.

While financial theory suggests that reinsurance is redundant in the conditions of capital market equilibrium for diversified firms, many companies and their stockholders do not have well-diversified portfolios and cannot diversify the residual nonsystemic risk inherent in an insurance company's portfolio (Doherty and Tinic 1981). Furthermore, factors such as taxes, bankruptcy costs, regulations, real service advantages, and overinvestment decisions make reinsurance an attractive option for insurance companies (for a review, see Lewis and Murdock [1996]).

Like all firms, insurance companies must hold capital as a buffer for losses. In 1995, the market value of capital and surplus in property-casualty lines was roughly $232 billion, with approximately $20 billion representing the capital in U.S. reinsurance firms (ISO 1994). However, this more than $200 billion in capital supports all property-casualty lines, with as little as one-tenth supporting property losses from disaster-related claims. Furthermore, while some insurance firms may hold sufficient capital to buffer disaster losses, many regionally concentrated firms do not.

While reinsurers provide a useful source of capital for regional and local insurance firms and play an integral role in expanding capacity in the primary-insurance market, the comparative advantage of reinsurers is to enhance spatial diversification. In terms of intertemporal diversification of disaster risk, reinsurance firms must also look to the capital markets to hedge their exposure there. As a result, stockholders in insurance and reinsurance companies bear significant exposure to catastrophic-disaster-insurance losses. After Hurricane

Andrew, firms in at-risk areas of Florida experienced a significant decline in their stock value as a result of their hurricane exposure (Lamb 1995).[5] Unfortunately, three factors inhibit the ability of disaster losses to be effectively diversified through capital market investments by stockholders in insurance companies: (*a*) Stockholders do not receive an ex ante premium on their investments associated with their catastrophic exposure, nor can they hedge their net exposure to disaster risk through other capital market securities. (*b*) Stockholders have had little information on the basis of which to assess the catastrophic exposure of the insurance company. (*c*) Stockholders have limited liability to cover the losses of an insurance firm: as a result, the residual losses of insolvent insurers can be pushed back to policyholders, solvent insurers, or state taxpayers through the state-guarantee system, creating an incentive for management to undertake higher-risk ("go-for-broke") investment strategies.

For the most part, insured losses from disasters have been covered within the insurance industry. In Florida, losses from Hurricane Andrew did result in the failure of twelve insurance companies, but these firms were relatively small, and claims owed under their policies were covered by shareholders and the state-guarantee system (ISO 1996). The prospect of larger disasters in the near future, however, has led to considerable concern over the ability of the insurance system to meet catastrophic disaster claims. In response, considerable attention has been focused on creating alternative market mechanisms for insurance companies to hedge their exposure to natural disaster risk.

The Development of a Secondary Market for Catastrophic Risk

After Hurricane Andrew and the Northridge Earthquake, insurance and reinsurance companies were concerned that a large catastrophic disaster would quickly exhaust the existing capital base in the insurance and reinsurance industry. As a result, insurers started looking for alternative forms of inexpensive capital. The natural place to look was the $19 trillion capital markets.

The prospect of finding a cheap source of capital through disaster derivatives or securitization was alluring to insurance and reinsurance firms because of the sheer size of the market. If financed through the capital markets, natural disaster losses of the magnitudes of the Northridge Earthquake and Hurricane Andrew would often be swamped in normal trading volatility in the market. Furthermore, insurers hoped that capital market instruments would provide a cheaper source of funding than reinsurance and, therefore, would be more supportable at given primary-insurance rates.

At the same time, catastrophe securities offer advantages to institutional investors. On the investor side, the attraction of securities in disaster risk is the ability to better diversify the investment portfolio by adding a nonredundant

5. Interestingly, property-casualty stocks appreciated following the Loma Prieta Earthquake, suggesting an investor anticipation of higher demand for insurance (Shelor, Anderson, and Cross 1992; Aiuppa, Carney, and Krueger 1993). Stock prices of real estate firms, however, fell after the earthquake (Shelor, Anderson, and Cross 1990).

security with a return that is largely uncorrelated with the returns associated with stock and bond portfolios (Litzenberger, Beaglehole, and Reynolds 1996). Furthermore, an examination of the reinsurance market suggests that the potential investor return from catastrophe securities could be significant. An industry analysis performed by J. P. Morgan estimated that, while investor returns on capital investments in reinsurance companies were volatile, the expected return over a three-year period was in the neighborhood of 18–22 percent per year (English 1996). Thus, it is likely that catastrophe securities can be structured to yield an attractive risk-adjusted rate of return for investors.

Prior to the advent of catastrophe bonds, the only way an investor could take a position in disaster risk was through ownership of a property-casualty insurance or reinsurance company, as demonstrated by the growth in the Bermuda reinsurance market. However, investing capital through a reinsurance or insurance company requires the assumption of a larger bundle of risks. For example, even if a reinsurer provided only catastrophic disaster coverage, the investor in the reinsurance firm would bear the credit risk associated with the reinsurer's investment policies. Thus, a capital market mechanism that allows a reinsurance company to evaluate, underwrite, and monitor the risks, but allows investors to invest directly in the catastrophe exposure, may be more efficient.

The private mortgage market for nonconforming loans provides a useful example of the effective role that a financial intermediary can play. Mortgage assets are underwritten, pooled, and serviced by a primary originator of mortgages. The originator then packages the assets into a pool and sells the pool to a private conduit. The conduit then sells securities in the capital markets representing direct or indirect rights in the package of assets. In this way, the risks inherent in the cash flows of the assets can be diversified through the capital markets. As a result, these securities transactions, which also provide tax and regulatory relief, are a valuable source of competitively priced capital for mortgage banks (Han and Lai 1995).

The mortgage market provides a direct analogue for the property-casualty insurance market. In the case of mortgages, an intermediary (e.g., a bank) evaluates and monitors the risk of loss to the mortgage pool from a mortgage default. In many cases, such a default is determined by a decline in the value of the property supporting the mortgage, giving the mortgagor the incentive to default on the mortgage. The cash flows associated with the mortgage pool are passed through to the pool and distributed to investors in mortgage-backed securities. In the case of property insurance, an intermediary (i.e., an insurance company) underwrites the risk of loss from an event (e.g., natural disaster) that could reduce the insured value of the property on which the policy is written. The cash flows associated with all property-casualty policies are then pooled internally within the insurance company, with residual earnings distributed to stockholders or, if the policies were securitized, the investor in the disaster-liability securities.

The first attempt to market a natural disaster–related security was made by

the Chicago Board of Trade (CBOT) in 1992. After recent revisions, the CBOT now offers catastrophe futures and call-spread options based on nine catastrophe-industry-loss indices calculated by Property Claims Services. CBOT contracts are available to cover exposures on a national, regional, or high-risk-state basis. By basing the payout of the CBOT contracts on industry losses, the CBOT eliminates the ability of insurers to pass moral hazard and adverse-selection risk to the financial counterparty in the transaction. At the same time, the CBOT contracts force insurers to manage "basis" risk—the differences in claim patterns between an individual insurer's portfolio and the industry index (as well as any error introduced by discrepancies between the index and the actual loss experience).

Starting in 1997, insurance and reinsurance companies can enter into direct risk swaps through the Catastrophe Risk Exchange (CATEX) to enhance their diversification of disaster risk. A CATEX swap entails exchanging equal amounts of relative units of catastrophe exposure by peril. While not infusing new capital into the insurance market, CATEX leverages the existing capital resources of the industry by enhancing the ability of the insurance industry to diversify low to medium levels of catastrophic risk. However, since the CATEX market is operated outside a formal exchange with no counterparty risk controls, the catastrophe swap market has been slow in developing.

Other derivative markets that have developed during the past four years include contingent lines of credit, contingent equity financing, and credit-linked notes: (*a*) A contingent line of credit (CLOC) is a commitment by a bank to provide a revolving line of credit to an insurer in the wake of a prespecified range of catastrophe losses, subject to the insurer's continued financial solvency. While usually representing only a marginal source of additional funding, these CLOCs help insurers mitigate a run-up in debt-funding costs created by postevent financing. (*b*) Pioneered by AON's CatEPut, contingent equity financing represents the sale of an over-the-counter put option to an insurer that allows the insurer to "put" a portion of its catastrophic losses to the issuer in exchange for a transfer of equity shares. (*c*) Credit-linked notes or surplus share notes are closely akin to selling investors a credit derivative packaged in a standard debt-financing scheme. In exchange for bearing the credit risk of the insurer, the investors receive an additional interest spread (option premium). Examples of credit-linked notes include the Nationwide (1994), St. Paul Reinsurance (1997) and Hanover (1997) transactions.

Finally, several attempts have been made to "securitize" the catastrophic liability exposure of individual insurance companies or state reinsurance pools directly in the capital markets. For instance, Guy Carpenter, J. P. Morgan, and other capital market institutions have offered "act-of-God" bonds as a source of financing for insurance companies. Act-of-God bonds are debt instruments that are subject to principal reductions in the event of a disaster loss to the

insurance firm. To compensate investors for the risks of lost principal, these bonds carry high coupon rates (e.g., 10 percent over Treasury securities).

While the success of these catastrophe bonds has been mixed over the past two years, the issuance of over $400 million in act-of-God bonds by USAA in 1997 and 1998 may represent a turning point in the evolution of these securities. Under these transactions, bondholders stand to lose interest payments (principal protected securities) or interest and principal payments (principal unprotected securities) if USAA's losses from a catastrophic hurricane over the next twelve to eighteen months exceed $1 billion. Investors cover a share of losses in excess of $1 billion up to a cap of $1.5 billion, with USAA maintaining a 20 percent share between the trigger and the cap to mollify concerns over moral hazard or adverse selection. In 1997, investors earned 273–576 basis points over the London Interbank Offered Rate (LIBOR) depending on whether they purchased a principal protected or a principal at-risk participation.

Thanks to an aggressive marketing campaign, the 1997 USAA transaction was actually oversubscribed by investors, and USAA was able to place $100 million in principal protected and $300 million in principal unprotected debt securities. Furthermore, the transaction demonstrated a willingness on the part of investors to bear a portion of the risk for events that, on an industrywide scale, would result in losses of $25–$35 billion. As such, the USAA transaction set the stage for several additional deals in late 1997 and 1998, including earthquake bonds covering California (Swiss Re) and Japanese (Tokio-Marine) earthquake exposure. In total, approximately $1 billion in cat bonds was issued in 1997, with a similar volume of deals in 1998.

Still, some pessimism remains concerning the capacity of the private capital markets to absorb a large number of USAA-type transactions. The problem for institutional investors appears to be the great deal of uncertainty concerning the assessment of catastrophic disaster risk, the lack of standardization in measuring disaster losses and exposures, and the absence of an institutional structure for disaster securities. For insurers, the current soft reinsurance market, the tax and accounting advantages of reinsurance, and the little leverage offered by the cat bonds provides additional hurdles. As a result, the ultimate fate of the catastrophe-securities market remains uncertain. (For a further summary of catastrophe-risk capital market instruments, see Lewis and Davis [1998].)

2.1.5 Government Assistance

Complicating the allocation of disaster risk in the United States is the provision of subsidized postdisaster assistance. Through postdisaster assistance, individuals can reduce their ex ante insurance coverage and shift losses to lower-risk individuals after a disaster occurs through a government reallocation of wealth through taxes and transfers.

Federal Postdisaster Assistance

For uninsured disaster losses, the federal government provides a wide variety of emergency relief and disaster reconstruction assistance.[6]

The Federal Emergency Management Agency (FEMA) provides emergency relief for individual disaster losses in the form of individual and family grants of up to $12,200 for renters and homeowners not eligible for Small Business Administration (SBA) loans (with a 75/25 percent cost share); $10,000 for minor home repairs (100 percent federal share); rental (or mortgage) assistance for the payment of rental costs (local fair market rent) for a period of up to eighteen months for individuals and families unable to occupy their homes; crisis counseling; and disaster-unemployment assistance.

At the state and local levels, FEMA provides cost-share grants, with at least 75 percent covered by the federal government, to fund debris removal; emergency work assistance; and the reconstruction of public buildings and facilities damaged in a disaster.

In the case of hurricanes, FEMA also provides direct insurance coverage for flood damage through the National Flood Insurance Program.

The SBA provides subsidized disaster loans of up to $200,000 for uninsured losses to property and up to $4,000 for uninsured losses of personal contents. For businesses, the SBA provides disaster loans of up to 100 percent of uninsured losses up to a maximum of $1.5 million. In determining the interest rate on the loan, the SBA differentiates on the basis of whether credit is available to the borrower from other sources, but both types of loans are heavily subsidized. (The loan rate is 3.63 percent when credit is determined not to be available and 7.25–7.7 percent when credit is available.) After the Northridge Earthquake, approximately $1.5 billion in SBA disaster loans was appropriated in disaster supplementals by Congress.

The Department of Transportation (DOT) bears a large portion of the financial responsibility for repairing damage to infrastructure (e.g., roads, bridges, etc.) through its emergency relief fund for disasters. For example, the DOT spent roughly $1.3 billion repairing infrastructure damage following the Loma Prieta Earthquake.

Funds appropriated under these programs come directly from federal taxes and, therefore, represent a form of social insurance that cross-subsidizes areas exposed to disaster risk. While Kunreuther (1996) finds little explicit evidence supporting the argument that individuals do not purchase insurance because of the existence of subsidized postdisaster assistance, federal assistance may still implicitly affect homeowners' incentives to purchase insurance. Consider the counterfactual. If no disaster aid had been provided after the Northridge Earthquake, large numbers of individuals would have suffered greater losses associated with their earthquake exposure. These losses would have generated infor-

6. Not including federal disaster programs for farmers (e.g., federal crop insurance).

mation (news stories) that would have informed a much wider population of the costs of not purchasing disaster insurance. It is reasonable to expect that, if this occurred, many more individuals would have the incentive to purchase disaster insurance today.

State Disaster Programs

Disaster losses are also financed through taxes levied on individuals within the state in which the disaster occurred. Given geographic constraints associated with state borders, state taxpayer assistance usually spreads the burden of disaster recovery intertemporally through deficit financing—imposing an intergenerational tax on future generations of state taxpayers. In addition, premium assessments levied by the state-guarantee system on surviving firms to cover the claims of an insolvent insurer can be deducted as a business expense and reduce premium taxes otherwise due. Thus, state taxpayers ultimately bear a portion of the cost of a disaster.

In recent years, however, high-risk states have taken a more active role in designing state programs for financing disaster risk. Just within the past two years, Florida, Hawaii, and California have established hurricane- and earthquake-financing facilities funded through a combination of insurance, reinsurance, and state taxes.

The Florida Hurricane Catastrophe Fund is a mandatory, state-sponsored catastrophe-reinsurance pool for property insurers writing business in Florida. Property insurers are required to maintain a retention against qualifying catastrophes (a hurricane as classified by the National Hurricane Center), but they may select to participate at one of three coverage levels: 45, 75, or 90 percent. The fund is financed through insurer premiums of approximately $500 million per year (ISO 1996). However, the fund also has emergency borrowing authority and the ability to assess insurers in the wake of a disaster. The catastrophe fund currently does not have the capacity to handle losses from large hurricanes like Hurricane Andrew. As a result, there is a concern among participating firms that the residual liability of the fund represents a growing liability against future earnings (Marlett and Eastman 1998).

The California Earthquake Authority (CEA) is a state-sponsored insurance facility designed to provide up to $10 billion in earthquake insurance in California. The fund is financed using a combination of up-front and contingent insurer contributions, traditional reinsurance, and revenue bonds (CEA 1996). The insurance policies provided under the CEA include a 20 percent deductible, cover only primary residential buildings, and provide limited coverage for building contents. As a result of the more limited earthquake-insurance policy, the CEA is expected to cover property losses from earthquakes at least as large as Northridge.

The Hawaii Hurricane Relief Fund provides limited hurricane-insurance coverage for the state. The fund is limited to just under $2 billion in coverage, with all residual risk shifting back to taxpayers in the state.

Of course, the advantage of these state-run facilities is that they are supported by institutions with taxing authority (the state). Therefore, unlike insurance companies, the risk of insolvency is much lower for state pools. In fact, if states could enforce a closed exchange of risk within their boundaries, state pools could theoretically be structured to replicate efficient risk-sharing pools—with disaster claims reallocated after a disaster in accordance with the ex ante provision of state-insurance contracts to all homeowners. This approach would clearly force homeowners within the state to internalize the risk of their disaster exposure and could lead to an optimal sharing of disaster risk within the state.

Unfortunately, the provision of federal assistance, the incentives to redistribute disaster losses to future generations, and the spreading of claims payments to other states through the state-guarantee system introduce leakages into the state pooling system that limit the ability of the states to create effective risk pools. Furthermore, state programs offer little benefits for larger-scale disasters where the in-state correlation in claims is high. The disaster risks of the individual states in the United States can be better diversified through the creation of larger risk pools on a national or an international level. Finally, politics at the state level could result in an underpricing of the true risk assumed by the state facility.

A recognition of this limitation has resulted in proposals for the creation of multistate pools. However, multistate pools must confront a serious problem of moral hazard. If a multistate pool is inadequately structured, any one state in the pool would have an incentive to suppress insurance rates within its boundaries for political gain while shifting additional liability to other states through the pool. As such, there is little incentive for lower-risk states to participate in such pools. Finally, research suggests that government-run insurance mechanisms have no comparative advantage over insurance and reinsurance firms in assessing, pricing, or controlling the risks in an insurance or reinsurance portfolio (Priest 1996).

2.2 Weaknesses in the Current System

The discussion in the previous section identified two major sources of inefficiency in the current allocation of disaster risk in the United States: (1) the failure of individuals to internalize the risk exposure of their properties, which results in a socially suboptimal level of disaster mitigation, and (2) the absence of any private funding mechanism for spreading disaster claims intertemporally. In this section, we discuss these two weaknesses in more detail.

2.2.1 Inappropriate Incentives for Mitigation in New Construction Decisions

As discussed in section 2.1.3, individuals do not appear to internalize the disaster-risk exposure of their properties when they decide where to live,

whether to purchase insurance, or how much they should mitigate against future losses. At this point, it is not clear whether this failure to internalize disaster risk is caused by individuals' lack of adequate information about their disaster exposure or a divergence between individual and societal objectives in reducing disaster risk. In either case, the current system for managing natural disaster risks does not provide appropriate incentives for mitigation, especially with respect to decisions about new construction.

This absence of mitigation incentives has repercussions across a number of dimensions. First, buildings continue to be constructed in high-risk areas, actually increasing society's overall exposure to disaster risk. One example of such a situation would be when a new home is constructed on a soft foundation over a fault rather than in a safer location on more solid ground. Second, designs, building materials, and the nature of construction are held to a less rigorous standard than is efficient for society as a whole. This is particularly problematic because, once a building is constructed, it is far more costly to retrofit the building than it is to incorporate mitigation investments during construction. For example, once a building is completed, retrofitting against earthquake risk often requires tearing out interior walls to add new structural framing.[7] As such, owners may view the risk of loss from natural disaster as a "sunk cost." From the vantage point of society, a more efficient management of natural disaster risks would internalize the full cost of natural disaster risks in the construction process.

By examining the private market process by which new construction is built, we can gain a clearer understanding of why the present system fails to internalize these risks fully. For simplicity, we will consider the case of a new residential home—although a parallel analysis could be described for other types of construction as well. The incentive for the home builder is to maximize profits. This requires buying land, building a home that maximizes the difference between the perceived value by the customer and the cost of construction, and then selling the home to its first purchaser. If the first homeowner derives no perceived value from mitigation investments and these investments have a cost, the builder has little incentive to undertake mitigation investments. The builder's incentives to internalize natural disaster risk in the value of the home critically depend on the first customer's perceived value of these investments.

For the purchaser, most mitigation investments are hidden from view—built into the structural design and dependent on the quality of the workmanship (nail density, types of fasteners used, quality of framing materials, etc.). The design is somewhat observable—if the purchaser were to study the blueprints—but few homeowners have the ability or interest to study blueprints. Second, even if consumers could observe all mitigation investments, it is not

7. Of course, some mitigation actions can be completed with far less reconstruction (e.g., strapping down water heaters, bolting the walls to the foundation, and improving the structural integrity of the roof).

clear that they would value them at a socially efficient level. Large natural disasters occur infrequently, and it is well documented in the field of psychology that consumers have nonconvex preferences around small-probability, large-magnitude events (Tversky, Sattath, and Slovic 1988). Intuitively, because a 500-year-cycle earthquake is not expected to happen for another 250 years, a homeowner's children, grandchildren, and great-grandchildren will probably not even be alive when the earthquake hits. It may be difficult to internalize this kind of risk in decision making, especially since homeowners are often looking to move after a period of six to seven years.

Finally, we can look at the role of financing in property purchases. Under current underwriting rules for most mortgages, prospective home buyers are limited in the amount of housing that they can purchase by constraints that limit total monthly payments for the loan, taxes, insurance, etc. to a fraction of the purchaser's income. Included in these underwriting guidelines is a requirement that buyers have homeowner's insurance to protect the collateral supporting the mortgage. However, few lenders require the purchase of natural disaster insurance. Therefore, homeowners have little incentive to purchase additional disaster insurance because (*a*) it is not required by the lender and (*b*) the additional insurance payments would further limit the amount of housing that the home buyer could afford.

Thus, if we examine the new construction process as a whole, we see the following dynamic. Builders maximize their customers' (the first purchasers) perceived value of the property. Owing both to their inability accurately to monitor the value of mitigation investments and to the paucity of information on individual disaster exposures, these customers do not fully value disaster-mitigation investments. As a result, there are (from a societal viewpoint) too few incentives to incorporate mitigation in new construction decisions. Furthermore, because most lenders do not require the purchase of disaster insurance, a natural mechanism to create incentives for mitigation (one based on the monthly cost of disaster insurance) is not a part of the current private mechanism for managing natural disaster risk.

2.2.2 Lack of Reinsurance Coverage for Large (over $30 Billion) Risks

Although the magnitude of losses from natural disasters over the last decade has been significantly greater than it has been over any previous decade in the postwar period, there exists a significant risk that a disaster causing far greater damage may occur. As an example, if Hurricane Andrew had struck Miami, insured losses alone may have exceeded $40 billion (Van Anne and Larsen 1993). A loss of this magnitude would present a considerable strain on the solvency of the U.S. insurance industry.

Unfortunately, as discussed in section 2.1 above, neither the insurance nor the securities model is sufficient to diversify the risk of loss arising from a large-scale natural disaster. In the case of a natural disaster, losses occur mainly in traditional property lines, where information on the properties at risk is not

generally publicly available and is asymmetrically distributed in favor of the insured (i.e., property maintenance, the quality of building construction, and the enforcement of building codes). As a result, protection against loss for property has traditionally been provided through insurance products.

The losses associated with a natural disaster, however, are not statistically independent within the affected region but geographically correlated within that risk pool. As a result, the larger the population area affected by the disaster, the less effective insurance is as a diversification tool. Furthermore, the losses arising from large natural disasters are idiosyncratic through time in the aggregate and hence not diversifiable through the creation of a large portfolio of like risks. This creates stress on an insurance-based risk-management mechanism because, as the size of the event increases beyond some level, the underlying loss characteristics of disaster risk diverge from the characteristics best served by the insurance model. On the other hand, the magnitude of loss that arises from a given event depends in large part on the quality of construction of individual property units—information that is not publicly available and that is asymmetrically distributed in favor of the insured. Thus, disaster risk cannot be solely diversified through the trading of securities.

Lewis and Murdock (1996) contend that the shortcoming of this system is that, given the infrequency and magnitude of losses from natural disasters, catastrophe risks need to be diversified intertemporally as well as spatially. For small and medium-sized disasters, the geographic diversification accomplished through traditional insurance and reinsurance markets is clearly adequate for financing disaster losses. However, the existence of limited liability and bankruptcy costs prevents insurance and reinsurance firms from fully diversifying disaster risk intertemporally. While growing, private securities markets (where private agents also have limited liability) currently lack the information, standardization, and institutional structure to support a high volume of catastrophe risk financing. Consequently, these markets have yet to fill the gap in the market for financing upper-middle layers of disaster risk.[8]

This lack of reinsurance capacity has significant repercussions in terms of the availability of primary insurance for homeowners, particularly in such disaster-prone states as California and Florida. When primary insurers cannot purchase reinsurance, they must pay claims after a large disaster out of their accumulated reserves. When their total (unhedged) exposure equals a significant fraction of their individual reserves, it is only prudent to stop writing policies. This results in a lack of availability of primary insurance. Therefore, any effort to expand insurance coverage for disaster risks must include a solution for improving the private sector's ability to spread disaster claims over time.

8. Clearly, the discussion in this paper is limited to disaster risks that can be estimated and priced with a certain degree of precision. Excluded from consideration are disaster risks for which the probability of occurrence is so uncertain that the estimation error swamps the estimates of loss, such as a $200 billion earthquake in New York City.

2.3 Framework of Government Policy

From the vantage point of society, it is important to understand the repercussions of the weaknesses identified in the previous section. If homeowners' decisions on where to locate, how much insurance to purchase, and what level of mitigation to undertake fail to reflect the natural disaster risk inherent in their properties, the aggregate exposure of the U.S. economy to disaster losses will increase. If the losses associated with these decisions implicitly to absorb more risk were completely borne by the individuals making these decisions, then the interests of the individuals and the interests of society would be aligned. However, the current system for financing disaster risk incorporates a significant degree of cross-subsidization. Thus, individual decisions to absorb disaster risk result in a shifting of risk to other members of society, creating a suboptimal level of hazard protection.

For society, disaster policy should look to increase the internalization of disaster risk in individual decisions, reducing the ability of individuals to increase (and shift) society's exposure to disaster events. At the same time, enhancing society's ability to finance disaster risk across time will allow for a greater degree of risk internalization in the economy. Thus, natural disaster policy should examine ways to encourage better coordination in the private sector's attempts to develop a new financing mechanism for diversifying large disaster claims over time. This section examines the role of federal policy in addressing these concerns.

As discussed above, a large portion of natural disaster risk management is performed by property-casualty insurance companies that are regulated at the state level. The system of state insurance regulation has evolved at the state and local level over the past two hundred years. However, the strict delegation of insurance regulation to the states (except in instances where federal law specifically supersedes state law) was formally codified in 1945 with the passage of the McCarren-Ferguson Act. However, the state insurance system, which focuses on the premiums, market practices, and solvency of insurance companies, remains in flux (Klein 1995).

Like that of regulation in other areas of the economy, the theory of regulation in the insurance industry generally falls into one of two camps: laissez-faire or government intervention. That is, the first group believes that the market equilibrium, even if second best, represents the most efficient outcome available. When asked to explain the existence of regulation in the insurance industry, members of this school often adopt a public choice interpretation of regulation: regulation reflects the special interests of the regulated entities setting rules to bolster their market power (Buchanan and Tullock 1966; Stigler 1971).

In contrast, supporters of government intervention in the market generally support a public interest theory of regulation (see Musgrave and Musgrave 1976). Public interest theory holds that the existence of market failures (e.g.,

imperfect competition, externalities, public goods, economies of scale, etc.) can lead to a suboptimal allocation of scarce resources in the economy and that government intervention designed to correct these market failures can be used to improve this market equilibrium. In this framework, government intervention is often seen as a *substitute* for coordination in the private markets.

In this paper, we introduce a different framework, one in which the goal of government policy is not to substitute for, or to replace, coordination in the private marketplace but rather to *facilitate* more efficient coordination in the private sector. This is the *market-enhancing view* of government policy (Aoki, Murdock, and Okuno-Fujiaara 1996). Underlying this framework is the presumption that decentralized decision making is, in general, more efficient than centralized control. Thus, private-sector coordination is preferable to significant government intervention. Therefore, the goal of this approach is to promote the creation of private-sector institutions that increase the efficiency of private-sector coordination.

2.3.1 "Traditional" Views of Government Action

First, let us examine the more traditional policy prescriptions, beginning with the laissez-faire policy. Here, the presumption is that, in the absence of distortion-inducing government interventions, the outcome from decentralized private-sector activity would be efficient (or at least more efficient than the alternative with government intervention). In many instances, this view has merit. For example, if state insurance commissioners suppress insurance rates to a "politically acceptable" level where insurers can no longer cover the variable cost of providing insurance or recoup their initial investments in providing service to that state, the market will withdraw capacity, creating an availability crisis (Harrington 1992). Attempts by insurance commissioners to impose exit restrictions to prevent this exodus from the market will only compound the misallocation of resources in the insurance market and provide strong disincentives for future entry into that state. In contrast, if price ceilings are not imposed, insurance premiums will rise to the point where natural disaster insurance will be available to all willing to pay the market-clearing price.[9]

Unfortunately, laissez-faire policy does not adequately address the weaknesses in the current system for internalizing natural disaster risk in new construction decisions or provide suggestions for filling the current gap in the lack of capacity to diversify claims over time. For example, with respect to upper tiers of disaster financing, the laissez-faire approach has a presumption that, in the absence of any price controls, primary and reinsurance capacity would appear and the market would clear. There is some evidence supporting this conclusion. Two years after the Northridge Earthquake, and four years after Hurri-

9. If the government were concerned about the real "affordability" of insurance, it could allow premiums to rise to market-clearing levels and then subsidize the purchase of insurance for those individuals whose budget constraint is binding at the market-clearing price.

cane Andrew, new capital started flowing into the reinsurance industry. By the end of 1997, industry experts estimated that over $5 billion in new risk capital had been accumulated in the Bermuda market alone, resulting in considerable downward pressure on reinsurance rates. When faced with large catastrophic claims, however, this new capacity may prove to be an unstable source of risk capital, especially given the rapidity with which reinsurance capital has exited the insurance market in the past (Berger, Cummins, and Tennyson 1992). Soft reinsurance markets are already causing many of these new reinsurers to look for alternative ways of leveraging their risk capital.

The other traditional policy alternative is to look to government intervention to "solve" these "market failures." With respect to the internalization of risk, the government could simply increase the requirements of building codes to a sufficiently high level so that disaster-risk protection is always incorporated into new construction. Again, there is some merit to this view. By providing some minimum base level of expectations, all participants in the construction process—architects, builders, inspectors, etc.—raise their standards for how buildings are constructed.

Unfortunately, this "command and control" policy has a number of flaws. Any building code is a rule book, and, even though these rules have some flexibility, a rule book has the effect of imposing a "one-size-fits-all" solution to any building problem. In reality, a huge variety of circumstances face any particular builder in any given location. In the case of earthquakes, the local geography, proximity to fault lines, the likely character of a given earthquake (whether the shaking is vertical or horizontal), etc. all differ widely for each project. It is simply not feasible for building codes to specify all possible contingencies.

More important, for codes to be effective, they must be enforced, and there are insufficient incentives, at present, to ensure proper enforcement of building codes. From a builder's perspective, building codes only impose costs. From the local government's perspective, building inspectors and more effective inspections cost money. Furthermore, cities have an incentive to remain lax on building-code enforcement when competing with neighboring cities for new developments, as seen in the experience of Florida after Hurricane Andrew. Even though very rigorous building codes were on the books, builders simply ignored the codes. As a consequence, homes suffered significant damage in the storm because their roofs were improperly attached to the rest of the structure.

In the case of reinsurance capacity, the government-intervention approach would simply call for the federal government to step in and provide disaster insurance. This approach has significant risks, as government agencies are notoriously unreliable at providing efficient, unsubsidized insurance (Priest 1996). Furthermore, there are significant political pressures to hold premiums at artificially low levels, and government bureaucrats may have less incentive to manage the risk exposure of the government than do the agents of private insurance companies (Kane 1996). A large-scale government program may

succeed at providing disaster-insurance capacity, but at the cost of significant losses on claims paid out in the future and a worsening of the incentives to build new construction more efficiently (since arguably the government would be less apt to set risk-based insurance premiums properly).

Thus, neither traditional approach offers an attractive option for improving the market's allocation of disaster risk once the costs of intervention or inaction are assessed. Therefore, we turn to a discussion of a new framework for federal policy, a framework that we believe is appropriate for an industry regulated at the state level.

2.3.2 The Market-Enhancing View

The *market-enhancing view* of government policy is a fundamentally different approach than either the laissez-faire or the public interest theory. The market-enhancing approach looks for the role of government to facilitate more efficient private-sector coordination, complementing the market while respecting the advantages of decentralized information processing. In contrast to traditional government intervention, which centralizes decision making, the market-enhancing view promotes the decentralization of decision-making power in the market. At the same time, this view recognizes that there are potential inefficiencies associated with decentralized coordination that are left unaddressed under a laissez-faire approach to government policy. These inefficiencies arise when the decentralized agents have inefficient incentives that are not aligned with maximizing social welfare (e.g., individuals' failure to internalize disaster risk) or when there exists a need for significant coordination of a large number of these decentralized agents to promote a shift to a more efficient equilibrium (e.g., the need to develop new financial markets for catastrophic risk).

An important dimension of the market-enhancing view that distinguishes it from the public interest theory of regulation is the emphasis on the importance of local information. Whereas most government interventions require some kind of central agent to process information and make decisions that affect a large number of outcomes, an intervention designed to be market enhancing simply attempts to align the incentives of decentralized private agents with socially efficient incentives. Then the decentralized private agents can use the locally available information to come up with market-based solutions that are significantly more efficient than those that could be imposed by a central authority.

2.4 Applications of the Framework

In this section, we apply the framework of the market-enhancing view to analyze two of the many public policy proposals that have been suggested in the debate over managing catastrophic disaster risk. The first policy is to require the purchase of disaster insurance on all new construction (i.e., all new homes that are built after 1 January 2000). The purpose of this policy is to

create a mechanism whereby private-sector agents (in this case, new home builders) internalize the risk of natural disasters into the construction decision. The second policy is to have the federal government develop a financing mechanism that enhances the intertemporal diversification of natural disaster risks and then have the government gradually cede the market to the private sector.

2.4.1 An Insurance Requirement on New Construction

In section 2.2 above, we identified the root cause of why there was insufficient incentive for builders to construct "disaster-safe" houses—because purchasers do not fully perceive the value of mitigation investments. Recognizing this issue as the central question, we ask whether there is any mechanism to overcome this market failure. In this section, we analyze one possible solution—instituting a requirement that all homeowners obtaining a mortgage from a federally related institution for new construction must obtain all-hazards insurance in addition to traditional homeowner's insurance.

If enacted as a government policy, this approach would result in a gradual "phase-in" of disaster insurance so that, ultimately, disaster-insurance capacity will be available to all homeowners. Once new home buyers are required to buy disaster insurance on new construction, the price of insurance will affect homeowners' decisions on where to locate and their desired level of investment in mitigation against future disaster losses. As a result, builders will have incentives to manage the cost of disaster insurance for their home buyers. If they can design a home that has a lower cost of disaster insurance, they will be able to capture a higher price for their homes. Thus, to the extent that there are differential rates on disaster insurance, builders will have incentives to design in mitigation measures that are cost effective.[10]

Equally important, builders and insurance companies will have incentives to work together to develop varying grades of certification for the new disaster-proof construction. This will allow the insurance companies to price the risk of natural disaster loss more accurately and will increase the builders' ability to reduce the cost of disaster insurance for homeowners (and thus allow the builders to capture higher profits). Thus, in their search for higher profits, these two industries will choose to work together to come up with mechanisms to reduce the risk of loss from natural disasters.

Once this policy of a disaster-insurance requirement for new construction has been put in place (and after an initial period of adjustment), new construction will be designed and built with a much higher level of investment in disaster mitigation. Moreover, these investments will be determined in a decentralized manner, by builders responding to a price mechanism, which in this case is the differential price of disaster insurance between varying grades of mitigation investment.

10. Of course, state regulations governing insurance pricing may interfere in the pricing of relative risks for new construction and thereby mute the effect of this proposal.

While this policy suggestion may seem overly intrusive, there are several arguments in its favor: (*a*) Mortgage lenders require the purchase of fire insurance to secure the value of the collateral underlying a mortgage loan. This policy simply extends that principle to include natural disaster risks. (*b*) Because the risk of disasters will be internalized in the cost of new buildings via the insurance premium, new structures will be built only in areas for which the home buyer is willing to pay for the risk associated with the property's location, reducing current incentives to build in high-risk areas to a more efficient level. (*c*) Individuals will have a greater incentive to undertake mitigation investments in order to lower their insurance premiums, again lowering the aggregate exposure of society (Kunreuther 1996). (*d*) A larger portion of the responsibility for funding the payment of disaster claims will be allocated to individuals with control over the disaster exposure being created—reducing the level of cross-subsidies in the market. (*e*) By linking the proposal to new construction, primary-insurance capacity will have to expand only at a rate equal to new construction in the United States to meet the increase in insurance demand generated by this proposal. Of course, the willingness of insurers to expand their supply of all-hazards insurance will be a function of state insurance regulation and insurers' current exposure. (*f*) By linking the provision of insurance to mortgages, this requirement will also provide additional protection to mortgage pools exposed to disaster-related mortgage defaults.[11]

As a result, this proposal would reduce the aggregate exposure of society to disaster losses and improve efficiency with respect to the way in which disaster claims are financed. Of course, the proposal does require an expansion of primary-insurance coverage for natural hazards. As such, this proposal would be most effective if linked to an expansion in financing capacity for upper layers of disaster risk—an issue to which we now turn.

2.4.2 An Industry-Level Excess-of-Loss Contract

The second market problem identified in section 2.2 above is the absence of any market mechanism for spreading large, idiosyncratic, and spatially correlated disaster claims intertemporally. As noted above, traditional property insurance diversifies claims through a pooling of risk, where the risk pool is held by a low-cost intermediary that specializes in assessing, monitoring, and pricing insurance risks. Once risks in an insurance pool become correlated, however, the value of insurance as a risk-diversification and financing mechanism is diminished.

For relatively high-probability, low-severity events, property insurance is a classic insurance risk. However, when natural disasters create widespread

11. A study by Duff and Phelps found that mortgage-backed security pools exposed to earthquake losses in California had special hazard-loss provisions equal to approximately 1 percent of the pool, four times the expected losses from the highest loan-to-value categories in those pools (Mandel and Hayssen 1995).

property damage within a region, claims on the pool are highly correlated, and the insurance mechanism breaks down. In this case, the risk of insolvency for the insurance company rises, the premium that homeowners are willing to pay for given a coverage level falls (premiums are discounted to reflect the solvency risk of the insurer), and the premiums that the insurance companies need to earn to capitalize against large losses increase. As a result, the insurance sector is thrown into disequilibrium.

An obvious avenue by means of which insurance intermediaries can reduce their exposure to natural disaster risk is the $19 trillion capital market. Theoretically, as a low-cost transactor in the market, insurance companies are in a good position to diversify any residual exposures from their insurance portfolio by taking positions in capital market securities. Unfortunately, the development of capital market securities remains in its infancy, leaving a financing gap for insurance companies. As a result, members of the insurance industry have raised the possibility of federal intervention in the provision of disaster insurance.

Lewis and Murdock (1996) argue that the federal government is in a unique position to utilize its ability to diversify claims intertemporally by designing a new risk-management mechanism for diversifying disaster risks intertemporally. However, taking a market-enhancing view of government policy, they argue against proposals for federalizing the provision of disaster insurance or reinsurance. Consistent with Priest (1996), they find that the federal government would have a comparative disadvantage in assessing disaster-risk exposures for individual properties or companies.

Instead, they offer a market-based proposal where the federal government would attempt to expand private-insurance capacity through the creation of a federal excess-of-loss reinsurance mechanism narrowly targeted to the missing market for the intertemporal diversification of large disaster losses. Specifically, the federal government would sell tradable per occurrence excess-of-loss (XOL) reinsurance contracts for insured disaster losses in the United States in the range of $25–$50 billion. These contracts, which are equivalent to call-spread options written on an industry index of disaster losses, would be auctioned to qualified insurance companies and would carry a maturity of one year.

The XOL program would be based on industry losses to minimize the moral hazard associated with providing company-specific reinsurance. Further, the program would be actuarially sound and would be designed to complement existing private-sector insurance and reinsurance mechanisms by covering only layers of reinsurance currently unavailable in the private market and by incorporating a cost-of-capital adjustment to offset the federal government's lower borrowing costs. As such, the program is designed to allow the "crowding out" of the federal government by private-sector institutions instead of the classic crowding out of the private sector by the government. Lewis and Mur-

dock (1996) argue further that, by offering an efficient, nonredundant security, the XOL proposal actually enhances the ability of the private market to develop new financial instruments for financing lower levels of disaster risk in the private market. (For more information on the pricing of XOL contracts, see Cummins, Lewis, and Phillips [1997, chap. 3 in this volume].)

An important aspect of the excess-of-loss program not discussed in Lewis and Murdock (1996) is the institutional benefits that the program would bring to the private market. The natural question emerging from the debate over capital market disaster instruments is why the market has failed to fill this need for intertemporal risk diversification. We believe that a large portion of the answer to this question revolves around (*a*) the great deal of uncertainty that capital market institutions and institutional investors have concerning the evaluation of disaster risks, (*b*) the lack of standardization in measuring disaster risk or structuring catastrophe securities, (*c*) the lack of an institutional structure for a capital market in catastrophe risk, and (*d*) the high degree of risk aversion exhibited by investors when faced with a financial payoff that provides a high risk-adjusted return but carries a small probability of a large loss.

The model for the industry structure that would evolve with the XOL program is fundamentally different from the current industry model. At present, reinsurance companies provide reinsurance to a pool of primary insurance firms—diversifying the risk geographically. Since the occurrence of large disasters is highly idiosyncratic (and has a high variance), however, reinsurance companies cannot adequately diversify catastrophic disaster risk through insurance pooling and remain exposed to large losses. As a result, reinsurance companies limit their exposure to catastrophic risk by limiting supply, raising the price of catastrophe covers, or requiring a cross-selling of other products.

With the XOL mechanism, reinsurers would still assemble national pools of risk by providing an appropriate mix of reinsurance to primary insurers. However, the XOL program would provide reinsurers with a mechanism for transferring the responsibility of intertemporally smoothing large disaster claims to the federal government and, ultimately, to competing private market providers of similar instruments. As such, reinsurers could loosen supply constraints on the amount (or price) of catastrophe reinsurance being offered in the market. Then, as the reinsurers accumulated larger, national insurance pools, the correlation between their disaster exposure and the industry's exposure would rise, increasing the value of XOL-type contracts and encouraging the establishment of private-label XOL structures.

As noted above, however, the proper functioning of an XOL market requires a number of investments in institutional infrastructure before the market can flourish. First, someone must make the investment to create an audited value (on agreed-on terms and parameter assumptions) for total industry losses arising from a natural disaster and the probability of disaster events. Second, some agent must credibly provide a sufficient number of XOL contracts to allow the

reinsurance and insurance industry to cede a significant portion of the upper-end catastrophe risk. Third, the reinsurance industry and the national primary insurers must make substantial adjustments to their internal policies and procedures and risk-management tools to support the purchase of XOL-type contracts.

For the industry, these last two issues present the classic "chicken-or-egg" problem. The reinsurance industry is not going to make large investments to integrate XOL contracts into their business system unless there is a credible multiyear commitment to supplying these XOL contracts. However, without the reinsurers making this investment, there will be insufficient demand to justify the investments required by potential suppliers of these contracts.

The temporary provision of these contracts by the federal government "solves" this coordination problem. First, the XOL contract will establish the standards on which all future XOL contracts (public or private) can be based. Second, the federal government commits to providing a sufficiently large supply of XOL contracts to allow reinsurers to justify the investment in changing their business systems. As the demand for these contracts is realized, however, the government continues to short the market for these contracts, allowing the private sector to serve a growing fraction of the market. Ultimately, the private sector will crowd out the federal government, and the XOL program will be ceded to the private sector.

Reinsurance companies and capital market firms could take a much more active role in providing this coverage today. However, private capital may be reluctant to flow into a market before the appropriate investments are made to establish institutions and standards for providing information on how to structure securities on the basis of this new asset class. The advantage of the XOL program is that it helps establish these institutions. The program can also serve as a conduit for information on assessing natural disaster risks in general. Then, once the market structure and standardization is accomplished, the private sector can simply "crowd out" the federal presence in the market.

Finally, the excess-of-loss program provides an immediate expansion in the capacity of the reinsurance and insurance markets, greatly reducing the exposure overhang felt by insurers in the wake of reassessing their disaster-risk exposures. As such, the program would relax the solvency concerns of policyholders and investors, which will aid the market in reaching a new equilibrium. Without such an expansion in capacity, it is possible that concerns over counterparty solvency will prevent the development of any private market institutions in this area.

2.5 Conclusion

In reviewing the existing state of catastrophic risk management in the United States, this paper examined whether *market-enhancing* public policy can be used to improve the financing of disaster risk in the United States. On

the basis of weaknesses identified within the current system, the paper suggests that at least two public policy options being discussed publicly have the potential to generate improvements in the way in which the United States manages disaster risk: (*a*) requiring homeowners to purchase all-hazards disaster insurance as a condition of receiving a federally related mortgage and (*b*) establishing a federal reinsurance mechanism, as proposed by Lewis and Murdock (1996), that allows insurers and reinsurers to purchase protection against large industry losses from catastrophic disasters.

The objective of the all-hazards-insurance-purchase requirement is to establish a direct link between individuals' decisions to create disaster exposure and the recognition of the costs associated with that exposure—that is, to increase the internalization of disaster risk. The objective of the federal reinsurance facility is to provide an immediate expansion in the capacity of the insurance industry to finance existing disaster exposure while providing the institutional investments that will foster the development of more active private-sector mechanisms for financing these disaster risks.

However, it is important to recognize that any real solution to the natural disaster insurance problem in the United States requires a comprehensive set of policy reforms that address all aspects of disaster policy, including hazard mitigation, tax policy, and the removal of any inefficiencies or inappropriate incentives in the state or federal regulatory structure. In this context, the public policy framework developed in this paper will be a useful tool for analyzing the merits of alternative disaster-reform proposals.

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Comment

Peter Diamond

This is an interesting paper, which does a good job of bringing existing theory to bear on these problems. I want to go over the same ground, organizing the material differently, and connecting with additional parts of the literature, especially the second-best literature.

The paper identifies two potential public policy issues, one relating to the behavior of individual propertyowners, the other to the behavior of insurers

Peter Diamond is professor of economics at the Massachusetts Institute of Technology and a research associate of the National Bureau of Economic Research.

and reinsurers. The paper argues that we can successfully disconnect these two problems, thinking about them separately. I agree, but, as has already been mentioned by Steve Goldberg, some ways of approaching insurance provision will make worse the problems with the behavior of individual insurees. I will consider the two problems separately, assuming such a disconnect.

Individual behaviors include decisions involving new construction (where to build, how to build), existing construction (whether to retrofit, whether to replace), and insurance (whether to smooth income across states of nature). There are three models of individual behavior presented in different places in the paper. Model A has rational consumers responding to incentives, such as the tax deductibility of large losses and disaster relief, that induce some inefficiency. Model B has rational consumers suffering from inadequate information (presumably resulting from a high cost of obtaining that information) and therefore making some decisions that are inefficient relative to a richer information set. Model C has irrational consumers in one of a variety of forms, such as those having very high implicit discount rates (coming from myopia, not just facing higher interest rates because of capital market imperfections) and those ignoring or undervaluing risks.

If all consumers satisfied model A, then the focus would be on the incentives, recognizing the second-best issue that, with asymmetrical information, it is impossible either to provide insurance or to redistribute income without some distortions. The focus would be on finding the balance between providing more insurance and more redistribution and inducing larger deadweight burdens. While I do believe that many people are responsive to these incentives, I do not think that this is the whole story.

If all consumers satisfied model B, then the focus would be on providing information. However, I think that the evidence is overwhelming that many people do not successfully incorporate risk information into their decisions without experiences that affect responses. This has been explored extensively in the work of Kunreuther (e.g., Kunreuther et al.). My first exposure to this was a presentation by two psychiatrists discussing decisions on smoking (Tamerin and Resnik 1972). In addition to laying out a perspective on individual decision making, they cited the result that, "among the medical specialties, the most successful in quitting smoking are internists and radiologists, who have repeated contact with the disease consequences of smoking, and those with poor records are psychiatrists, who have the least direct contact with the sequellae" (p. 82). Note that the presence of irrationality in assessing risks is compounded by a "winner's curse," the tendency for those with the least concern about the risks to value new construction most highly.

In order to address the issues raised by model C, we need to consider some forms of compulsion. Note also that, as long as we are not addressing all the issues raised by model C, we will have a need for institutional structures that will have to balance helping those satisfying model C with those satisfying

model A, whose behavior is distorted by these measures. Note also that the issue arises, not only in high-risk areas, but also in low-risk areas and for problems with uniform risks. For example, a recurrence of a major earthquake in New England, as occurred in the eighteenth century, would cause major damage. So too would the impact of a meteor, such as the one that created the massive crater in Arizona. How society should respond to the occurrence of such events, which are "unpredicted" as far as insurance preparation goes, depends on one's view of society. With the American ethos, there is a strong sense that the government should help in such settings.

The proposed compulsion analyzed in the paper is mandating insurance for new construction. The paper does not indicate whether this is just in areas considered high risk or in all parts of the country. Part of the motivation for this approach is to allow time for insurance capacity to grow along with mandated coverage. The paper assumes that such a mandate would result in efficient price signals to builders. But this seems overly optimistic to me. There will be insurance-price variation with mitigation efforts, but the level may not be efficient. Some of this insurance cost will be bundled with the other costs of buying new housing. Some of it may generate market power and thus redistribution from home buyers. That in turn may be dissipated in overentry. A parallel with closing costs may be appropriate, with limited market discipline on levels. The paper contrasts assumed efficient pricing with the shortcomings of building codes, recognizing both the problems of high uniformity in codes and the tendency to underenforce some of them. Once one also recognizes inefficiencies in pricing, we may be in a setting best approached in the prices versus quantities framework of Weitzman (1974). Indeed, since we will have codes no matter what we do about pricing, it may be best to think about having both tools in effect and to consider how to coordinate them.

Another problem with Lewis and Murdock's approach is that it grandfathers existing construction. Given the presumed undervaluation of mitigation expenditures by the market, this results in an overvaluation of existing housing. This results in an inefficient incentive to build on vacant land rather than replace existing structures. How this relates to renovation depends on the rules covering grandfathering. A natural solution to this problem is to expand the mandate for insurance to existing buildings slowly. This can be done at transaction time, as, for example, is being done in Massachusetts relative to septic systems. Of course, this has a distortionary effect on transactions. Another approach might be to have an analogue to the draft lottery, picking counties at random and extending the mandate slowly throughout the country. That would produce a dream instrument for econometricians.

We might also consider more use of tort liability of builders along the lines of products liability, although such an approach will not solve this problem by itself.

I turn now to the second problem—that of the behavior of insurers and re-

insurers. The discussion considers the cost of reserves—basically a cost of liquidity. Implicit in some discussions is an assumption that the social cost of liquidity differs from its private cost. This may well be the case, but we do not have good equilibrium models of liquidity, models with capital market imperfections, with which to evaluate the implications of this perspective for insurance. There are two implications of low reserves—an insolvency risk for insurees and guaranty funds and a slow growth of capacity after a catastrophe and therefore a limited availability of insurance during such an adjustment period, as has been examined in the work of Gron (1990). Again, we would need a model of capital market imperfections to examine how to respond to this problem. Intertemporal sharing of risks involves substituting consumption in one year for that in a later year, something that takes place through changes in the level of investment. The link between this and reserves runs primarily through atemporal distribution of risks. Analysis of this issue may parallel that of the national debt, where the intertemporal effects come from the effect of alternative decisions affecting the national debt on investment decisions.

There are two ways to go for tapping into conditional funds in order to speed the growth of capacity after a catastrophe. One is to have conditional payments (a form of insurance), and the other is to have conditional loans (a form of committed lines of credit). Which approach would do better at tapping additional sources of funds I do not know, but it would be good to analyze this formally. On the one hand, lines of credit involve putting less at risk by the new sources of funds. On the other hand, it may take having more at risk to create the incentives to get involved in supplying this market.

As a matter of equilibrium, it is also important to recognize that increasing the availability of conditional funds is likely to reduce the level of insurance-company reserves, so one needs to evaluate the net effect relative to whatever other incentives are associated with increasing such fund availability.

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Comment

Paolo M. Pellegrini

I read the Lewis and Murdock paper with great interest. My comments are in the spirit of stimulating further thought and research as they reflect limited data and analysis.

First, I would like to offer some introductory thoughts about the two proposals contained in the paper. Concerning Lewis and Murdock's first proposal, mandatory disaster insurance for new homes, I agree with their view that home buyers in disaster-prone areas need guidance to internalize risk. At a minimum, some form of disaster-hazard disclosure should be required. I doubt whether mandatory insurance is socially or politically viable. However, it would not be unreasonable to condition federal postdisaster assistance to ex ante insurance requirements. Also, the tax deductibility of disaster-insurance premiums could be a powerful incentive for individuals to make responsible risk-management decisions.

Concerning the second proposal in Lewis and Murdock, a federal government excess-of-loss (XOL) program, I believe that such a program is neither justified nor effective. The industry's $200 billion capital is subject to volatility far greater than its catastrophe exposure in the $25 billion excess of $25 billion layer covered by the proposed XOL program. Moreover, such exposure is unlikely to be significantly correlated to the industry's other sources of volatility, and, therefore, removing it would not reduce the industry's overall volatility by any noticeable amount.[1] Individual companies that do need catastrophe protection, perhaps as a result of sound strategies based on geographic focus, would benefit only marginally from the XOL program because, as discussed in Major (chap. 10 in this volume), index-based hedges (such as the XOL program would be) present unacceptable basis risk.

The insurance industry and the capital markets can address the nation's property-catastrophe risk-transfer needs without the direct involvement of the federal government. The only policy initiative that I would support is the transfer of regulatory authority from the states to the federal government. State insurance departments lack the degree of coordination required to regulate the inherently suprastate process of redistributing property-catastrophe risk. Con-

Paolo M. Pellegrini is president of Global Risk Advisors LLC, a New York firm that advises utility and insurance clients with respect to corporate finance and risk management. Until May 1998, Mr. Pellegrini served as president of Select Reinsurance Ltd., a Bermuda property-catastrophe reinsurance company.

1. As a hypothetical example, let us assume that the insurance industry's annual results have a standard deviation equal to 15 percent of the industry's $200 billion capital, or $30 billion (this is comparable to the volatility of the S&P 500 and lower than the volatility of many individual insurance stocks). By some estimates, the annual losses associated with the XOL program (the XOL losses) have an expected value of $125 million and a standard deviation of $1.25 billion. Assuming no correlation between XOL losses and industry results excluding XOL losses, the industry standard deviation excluding XOL losses would be $29.97 billion. Assuming a 50 percent correlation (a figure far above any reasonable expectation), the industry standard deviation excluding XOL losses would still be $29.66 billion.

sequently, they tend to impose market-inefficient constraints on insurance companies' risk selection and pricing as well as on their financial and investment policies.

I offer the following explanatory model for the current property-catastrophe-insurance- and reinsurance-capacity shortfall.

Because of regulatory constraints, primary insurers cannot control their risk exposure directly, through selective underwriting. Although they could control their risk exposure indirectly, through reinsurance, they cannot pass through the cost of reinsurance to policyholders. Therefore, they are forced to resort to market exit as their primary risk-management tool.

Reinsurers face their own constraints, as they lack opportunities to diversify geographically their concentrated exposures to zones such as Florida and California. Consequently, they can offer incremental coverage in such zones only at prices that primary insurers can hardly afford.[2] Lewis and Murdock advocate intertemporal diversification as a possible solution.[3] A much simpler solution is diversification through investments.[4] The obvious impediment to such a solution is that regulators and rating agencies would not allow it. Even more important, the syndicated, "consensus-pricing" structure of the property-catastrophe-reinsurance market would not allow it.

Despite much effort, the capital markets have failed to fill the gap so far. There is no obvious explanation. Perhaps the securities offered are too risky for the fixed-income buyers and too anemic for the hedge funds, the two primary marketing targets to date. Perhaps they are simply not attractive, given the market's current perception of potential risk and return. With respect to risk, investors are skeptical about the predictive power of simulation models, given their poor performance in events such as the Los Angeles Earthquake. With respect to return, investors perceive a capped upside that will not affect overall portfolio results substantially. Consequently, they are reluctant to make the intellectual investment required to understand the new securities. Although most industry observers agree that securitization will ultimately succeed, the timetable is unclear.

The following are possible suggestions to reduce dislocation in the property-catastrophe-insurance and -reinsurance markets.

2. As a hypothetical example, let us assume that a reinsurance company has a cost of capital of 25 percent, provided that the standard deviation of its return on capital not exceed 20 percent. Let us assume further that it can underwrite treaties with the same limit in n zones not subject to a common peril. In addition, let us assume that each treaty has an expected value and a standard deviation of losses equal to 3 and 12 percent of the treaty limit, respectively, and that investments yield a risk-free rate of 5 percent. The break-even rate on line (i.e., premium divided by limit) would be 15 percent for $n = 1$, 11.5 percent for $n = 2$, 9.0 percent for $n = 4$, and 7.2 percent for $n = 8$.

3. Assuming that losses in different years are independent of each other, underwriting n years (for a fixed multiyear premium) would have the same diversification effect as underwriting n zones.

4. Using the same assumptions as were used in n. 2 above, except for an investment yield of 20 percent with a standard deviation of 15 percent, the break-even rate on line for $n = 1$ would be 7.5 instead of 15 percent.

Since federal postdisaster assistance is a given, property-catastrophe insurance should be regulated by the federal government with the objective of reducing unintended cost shifting and cross-subsidization. Clearly, this is not an option that is available in the near future.

Most of what can be done immediately involves reinsurance and securitization, which are regulated only indirectly by individual states.

Reinsurers have already accomplished a lot in terms of underwriting methods and standards. However, there could be beneficial changes. The property-catastrophe reinsurance market should move beyond the syndicated, consensus-pricing format to accelerate further the process of underwriting-quality improvement. Even today, few treaties are underwritten on the basis of the best information already available, namely street address data, because few reinsurers have the capability to analyze such data. If individual reinsurers were able to underwrite treaties in their entirety, the pressure on the technology laggards would be much greater.

In addition, reinsurers should satisfy the risk/return equation, not by chasing marginally priced, nonaccumulating business, but by changing financing and investment policy. If a reinsurer's volatility is 15 or 20 percent as a result of underwriting property-catastrophe business, its cost of capital will be commensurate, perhaps also 15 or 20 percent or higher. A 5 percent yield on investments financed with equity creates enormous deadweight cost and imposes rate-on-line hurdles that cannot be sustained by the ceding companies. A focus on business with a low expected loss ratio, even at the expense of geographic diversification, is a superior strategy, provided that the reinsurer (1) maintains a conservative ratio of premiums and underwriting exposure to capital and (2) allocates its assets to higher-return, even though higher-volatility, investments.

The role of the capital markets needs to be reevaluated in the light of the experience of the last three years. Clearly, unlike securitization, the capital raising efforts on behalf of the Bermuda property-catastrophe-reinsurance specialists were an unqualified success.

The issue of whether there is a need for additional reinsurance capital is a conundrum. Reinsurers complain about their inability to write enough adequately priced business, an indication that there is too much capital. Yet insurers complain about their inability to buy enough reasonably priced coverage, an indication that there is too little capital.

The implication of my previous comments is that there is too much capital available to underwrite diversifiable risks and too little to underwrite undiversifiable risks. Investor-return requirements to underwrite undiversifiable risks, however, will be comparable to those for privately placed risky assets.

Therefore, the immediate focus of capital markets intermediaries should be to raise equity for a new class of highly capitalized, single-cedent reinsurers, able to achieve return enhancement and risk diversification internally, through a more aggressive investment policy.

The competitive advantages of these new entities are significant. They will be able to address any insurance risk, regardless of accumulation, and at any time (as opposed to the standard inception dates of 1 January, 1 April, and 1 July). They will be able to perform superior underwriting due diligence and, therefore, price risk more accurately. They will be able to offer transparent security—the reinsured will know as much about the reinsurer as the reinsurer itself (today, the security of property-catastrophe reinsurers, or the lack thereof, is difficult to assess).

Over time, single-cedent reinsurers could become increasingly debt financed, driving down the cost of capital and risk-transfer pricing to the theoretical level that would be demanded by risk-neutral investors, that is, expected value of losses with no premium for volatility. Initially, however, they will reap excess returns comparable to those reportedly enjoyed by Berkshire Hathaway in connection with its treaty with the California Earthquake Authority.[5]

5. According to some estimates, the California Earthquake Authority and Berkshire Hathaway have entered into a treaty providing, on an annual equivalent basis, for a rate on line of approximately 10 percent, against losses with an expected value of between 0.5 and 1 percent and a standard deviation of between 2.5 and 5 percent (the standard deviation estimate reflects the four-year intertemporal diversification inherent in the treaty).