
Should Society Deal with the Earthquake Problem?

Howard Kunreuther, Neil Doherty, and Anne Kleffner

Everyone in California knows that it is just a matter of time before a part of the state is hit by a severe earthquake. The Loma Prieta earthquake, which interrupted the World Series of 1989 and caused approximately \$10 billion in property losses in the San Francisco Bay area, was a grim reminder of the damage that such disasters can cause. An earthquake similar to the one that rocked San Francisco in 1906 is predicted to cause considerably more damage than the 1989 quake.

There are two complementary ways that residents and businesses in those hazard-prone areas can reduce the effect of a catastrophic earthquake on their property. They can adopt mitigation measures, such as anchoring their house to the foundation, which will reduce property losses in the event of a severe quake. In addition, they can reduce their recovery costs from a disaster by purchasing private insurance. To date those measures are voluntary since the attitude that we have taken in society is that people should recognize the dan-

gers facing them and then adopt cost-effective protective measures.

Relatively few residents have taken loss mitigation measures, even after severe earthquakes. Many of those actions are cost-effective in saving lives, reducing injuries, and lowering property damage from future earthquakes. Most residents in California are also uninsured against shaking damage even though everyone has been informed by his homeowners' insurance company that earthquake insurance is available. Although insurance companies are required to offer earthquake insurance to policyholders who have homeowners' coverage, agents are reluctant to promote it widely. With their existing portfolio, insurers are concerned that a catastrophic quake will wreak financial havoc on their balance sheets and may lead to insolvency.

There is an additional interested party with a stake in the impact of a catastrophic quake on its welfare—the vast majority of the population not located in earthquake-prone areas. If the past is any guide to the future, then all taxpayers will help to pay for the uninsured losses of victims through some form of disaster assistance or low-interest loans. State government and municipalities affected by the quake will also have to turn to the federal government for assistance if a large number of public structures are damaged or

Howard Kunreuther is the Riklis Professor of Decision Sciences at the Wharton School of the University of Pennsylvania. Neil Doherty is a professor of insurance at the Wharton School. Anne Kleffner is an associate professor of insurance at the University of Calgary.

destroyed. Those facilities are normally uninsured, and many have not adopted mitigation measures unless required by state or local building codes.

There are alternative ways of dealing with the earthquake problem that account for the decision processes of the affected interested parties. Homeowners facing a natural disaster often conclude that “it will not happen to me” or that the probability of the event is so low that it is not worth worrying about the consequences. In addition, they may utilize very short time horizons on which to base their decisions so that they do not capture the full benefits of adopting loss-reduction measures to their house. Insurers, on the other hand, focus on the impact of a catastrophic earthquake. They recognize that the chance of such an event may be very small, but they know that if it should happen, they may be forced to declare insolvency.

This article documents empirical evidence on the decision processes of homeowners and insurers with respect to the earthquake hazard and proposes a program that may be more efficient and equitable than the status quo.

Homeowners’ Protective Behavior Regarding Earthquakes

Loss-Reduction Measures. Few homeowners have taken steps to reduce the losses from future earthquakes, even though the costs of many mitigation measures are relatively small and their expected benefits can be substantial. In a 1974 survey of more than 1,000 California homeowners in earthquake-prone areas, only 12 percent indicated that they had adopted any protective measures to reduce earthquake damage. Fifteen years later the situation had not changed, although seismologists had predicted a number of serious quakes and the media devoted considerable discussion about steps homeowners could take to reduce losses from a future earthquake.

In a 1989 survey of 3,500 homeowners in four California counties subject to earthquake damage, 5 to 9 percent of the respondents reported adopting measures to reduce losses. A follow-up survey of residents affected by the Loma Prieta earthquake revealed that few residents invested in any type of loss-reduction measures, and those who did made only minor changes, such as bolting furniture to walls and floors. The principal reason given for not adopting loss-reduction measures

was that they were overly expensive relative to the expected benefits that could be gained from the investment. In some cases homeowners’ calculations of benefits may have been based on very short time horizons so that some cost-effective measures would not be adopted.

To lessen the effect of a catastrophic earthquake residents and businesses can adopt mitigation measures to reduce property losses and purchase private insurance to reduce recovery costs.

To understand this point, consider the following example adapted from a study conducted at the Wharton Risk Management and Decision Processes Center for the Federal Emergency Management Agency. That study used data from a report by Gallagher Associates to the California Department of Insurance that concluded that over 25 percent of the dwellings built before 1940 moved from their foundations as a result of the 1983 Coalinga earthquake in central California. It costs between \$1,000 and \$2,000 to brace a one-story house so that it will not move from its concrete foundation. In return the homeowner can expect savings of between \$25,000 and \$30,000 if his house would otherwise have moved from its foundation as a result of a future earthquake.

Suppose that we use the midpoints of those two estimates—a cost of \$1,500 and an expected benefit of \$27,500—to evaluate the attractiveness of that loss-reduction measure. Suppose a family with a pre-1940 house estimates that if there is a recurrence of an earthquake as powerful as the Coalinga earthquake near its residence, there is a 25 percent chance that the house will move off its foundation. If the family believes that the annual chance of such an earthquake is one in twenty-five, then under the assumption that the quake occurs at the beginning of the year, the expected benefits from that loss-reduction measure will be \$275 ($.25 \times .04 \times \$27,500$). If one is short-sighted and only focuses on the expected benefit for the next year, then the \$1,500 expense of bracing the foundation will not be justified in the homeowner’s mind. Table 1 depicts the critical probability levels above which the family will want to invest in the \$1,500 to brace its house. On the basis of a

Table 1: Critical Annual Probability Level of Future Earthquake to Justify Bracing Pre-1940 One-Story House

Cost of Measure: \$1,500

Benefit of Measure: \$27,500

Chances of House's Being Damaged by Earthquake If It Occurs in Area: .25

Time Horizon in Years	Critical Probability of Future Earthquake
1	.218
2	.111
3	.076
4	.058
5	.047
10	.026
25	.014

one-year time horizon the only way that bracing the foundation would be attractive to the family is if it estimated the probability of a future earthquake to be greater than 218 in one thousand.

On the other hand, suppose one computes the expected benefits of bracing the foundation over a multiyear period. Then the annual probability of a future earthquake will be lower to justify investing funds in that loss-reduction measure. Suppose that one uses a 4 percent discount rate to compute the net present value. If the family expects to live in its house for at least ten years, then if the family perceives the annual probability to be twenty-six in one thousand or higher, it should want to adopt the loss-reduction measure.

Earthquake Insurance. Until very recently, few homeowners have had an interest in voluntarily purchasing earthquake insurance. In 1976 less than 5 percent of homeowners residing in California had bought coverage although it had been

Most consumers view insurance as an investment so that they want to get something back in return for their premium. It is hard to convince individuals that the best return on a policy is no return at all.

available since 1916. Two recent developments have stimulated the demand by homeowners for earthquake insurance today. At the beginning of

1985 a statute by the California state legislature went into effect that required insurance companies to inform all policyholders with homeowners' coverage that they could add the earthquake peril to their policy for an additional charge. In addition, there have been forecasts by seismologists that an earthquake of catastrophic proportion is likely to occur somewhere in California by the end of this century.

Still only 20 percent of homeowners across California purchased earthquake insurance voluntarily in 1990. On the other hand, there are counties in the state where insurance demand today is relatively high. For example, in Santa Clara County, the area most directly rocked by the Loma Prieta earthquake, a 1991 survey of homeowners by Risa Palm and her colleagues at the University of Colorado revealed that 51 percent of the respondents had earthquake insurance—an increase of 11 percent over the number insured before the 1989 quake.

In other areas of the country, the demand for earthquake coverage has been considerably lower or nonexistent. In the region near the Missouri-Kentucky-Tennessee border where the New Madrid fault is located, there was little interest in earthquake insurance until Iben Browning predicted that a severe earthquake in New Madrid would occur in December 1990. His forecast created quite a sensation with the media since an 1812 earthquake in that area is still one of the most severe quakes in recorded history. Insurance companies, such as State Farm, reported a surge in demand for earthquake policies before the predicted date of the quake, but that demand decreased once 1990 passed. Nevertheless, most homeowners who purchased earthquake insurance as a result of their prediction have retained their coverage to date. If past experience is a guide, one may expect cancellations in future years if no earthquake occurs.

There are several reasons for the general lack of interest in earthquake coverage. In regions of the country that face earthquake risks but have experienced very little seismic activity, it is natural for residents to feel that an earthquake will not happen during their lifetime. They then worry about one less thing. In addition, it means that they do not have to think about expending funds for coverage where they perceive the chances of collecting on a policy to be very small. Most consumers view insurance as an *investment* so that they want to

get something back in return for their premium. It is hard to convince individuals that the best return on a policy is no return at all.

For those homeowners who have evaluated the potential damage to their structure from a severe earthquake, some may feel that insurance is not a very good deal. For example, in California most residential dwellings are wood-frame structures, which are likely to suffer relatively minor losses from shaking. With the standard 10 percent deductible on an earthquake policy, those homeowners are unlikely to collect much, if anything, from earthquake coverage. Fire damage from an earthquake will be covered by a homeowners' policy, which financial institutions require as a condition for obtaining a mortgage. The fact that homeowners can collect on fire damage claims whether or not they have earthquake insurance is of additional concern to the insurance industry.

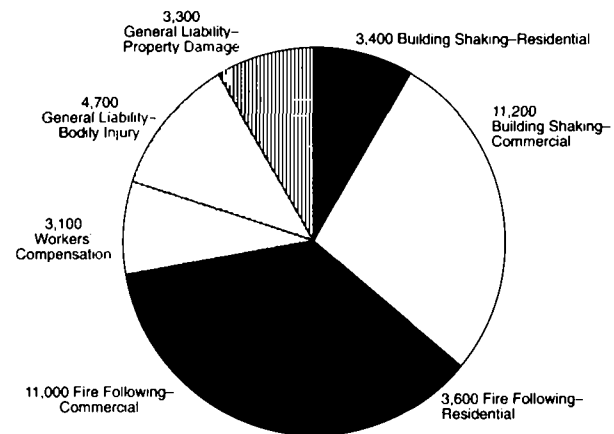
Insurance Industry Concerns Regarding Earthquake Losses

Insurance companies are not particularly worried about the long-run financial impact to them of earthquakes of moderate severity, even those of the magnitude of the 1989 Loma Prieta earthquake, where the direct insured losses were estimated at \$902 million. Most companies have enough surplus on hand to cover losses from those disasters without adversely affecting their balance sheet.

Should a very severe earthquake occur in a populated area of California, the story is likely to be completely different. Consider a disaster of the same force (8.3 on the Richter scale) and geographic location as the 1906 San Francisco earthquake. Should such a quake occur tomorrow with similar secondary losses such as fire damage, the event will be classified as a catastrophic earthquake. Our analysis of a catastrophic earthquake will relate to that specific hypothetical quake.

The insured losses from such a catastrophic earthquake, which include shaking, fire, general liability, and workers' compensation, are estimated to be \$40.3 billion. Figure 1 reveals that most of the insurance claims will be due to damage that has not been directly caused by structural shaking. More specifically, over \$14 billion of losses will be due to fire following the earthquake, \$3 billion for workers' compensation payments, and \$8 billion for claims under general liability policies. Such indirect losses are covered by fire,

Figure 1: Estimated Total Insurance Industry Losses for a Recurrence of the 1906 San Francisco Earthquake (\$ millions)

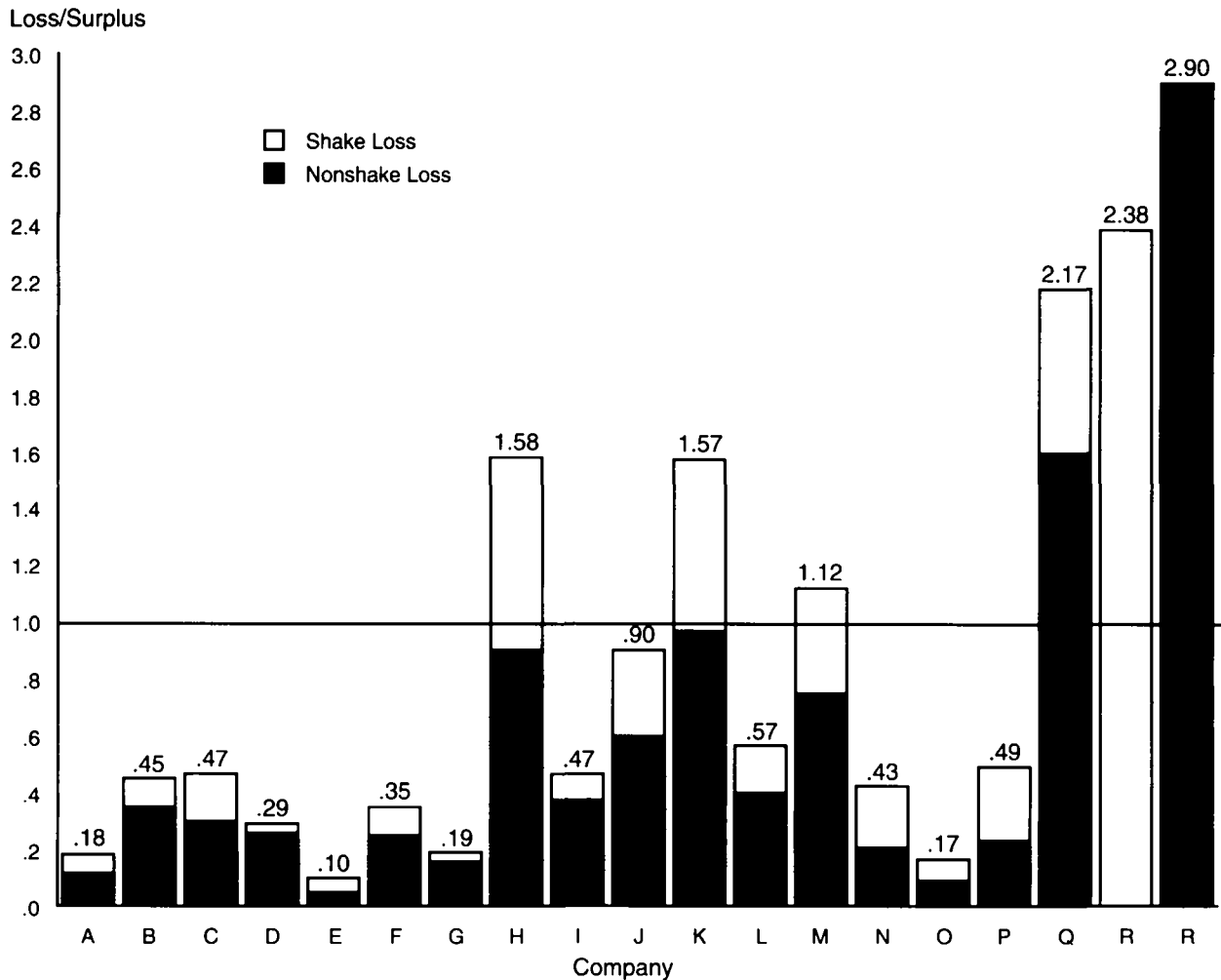


workers' compensation, and liability policies and require dedicated earthquake coverage. Earthquake insurance policies cover shaking damage, but only \$14.6 billion in claims would be due to the shaking of buildings. Thus, if there was no "shake damage" in force today, the insured losses from other policies—fire, workers' compensation, and general liability—would still be \$25.7 billion.

Most insurance companies have enough surplus on hand to cover losses from earthquakes of moderate severity without adversely affecting their balance sheet.

The financial strength of insurers is measured by their surplus or equity. The surplus provides a safety net in case the aggregate losses from different policies turn out to be larger than expected. The total surplus of the insurance industry in 1990 was about \$130 billion, significantly greater than the damage from the catastrophic earthquake described above. Hence, at an aggregate level, that damage does not appear to be crippling to the insurance industry.

Drawing such a conclusion from those data is somewhat risky and imprudent. For one thing, it assumes that the catastrophic earthquake does *not* coincide with other major catastrophes such as windstorms or hurricanes in the current time

Figure 2: Shake and Nonshake Loss as a Percent of Surplus

frame. Even if there were no other abnormally large losses, the depletion of surplus will affect the ability of all insurers to write their current book

The financial strength of insurers is measured by their surplus or equity. The surplus provides a safety net in case the aggregate losses from different policies turn out to be larger than expected. The depletion of surplus will affect the ability of all insurers to write their current book of business.

of business, except for those who are able to raise new capital from the market—a process that takes time. Regulators are always concerned when a company's surplus is reduced and hence may require some insurers to cut back on the coverage they offer. That means that consumers and businesses will find it more difficult to purchase coverage that they now consider standard, or they will find that they have to pay much higher rates for identical coverage.

The aggregate figure also does not reveal anything about the effect of a catastrophic earthquake on individual insurers. Some firms will be able to absorb their losses, while others will become insolvent. Our findings in another study of a sample of eighteen different sized insurers provide

insight into those distributional effects. Seven of the insurers (labeled A through G) had a surplus at the end of 1990 that was greater than \$2 billion, five (labeled H through L) had a surplus between \$1 billion and \$2 billion, and six (labeled M through R) had a surplus less than \$1 billion. Those companies accounted for 36 percent of the total surplus of the insurance industry and 41 percent of the total net premiums written.

As a first cut in our analysis, we used public information from A.M. Best Co. to estimate how much each insurer in the sample would be obligated to pay on policies sold directly to individuals and firms who suffered damage from a catastrophic earthquake. Our analysis *excluded* any consideration of reinsurance policies bought from or sold to other firms. Figure 2 depicts the amount of insured shake and nonshake losses from a catastrophic earthquake for the eighteen firms in the sample. All of the firms had losses before reinsurance that were greater than 10 percent of their surplus. Such a situation would be a cause of regulatory concern to the California Department of Insurance.

None of the seven largest firms would be insolvent from a catastrophic earthquake, but five of the eleven smaller firms would suffer losses greater than their surplus. Unless their reinsurance could cover enough of those losses, those firms would be declared insolvent. Even if they had not sold a single earthquake insurance policy, two of the firms (Q and R) would still be insolvent owing to their *nonshake* losses, and two others (H and K) would be on the verge of insolvency.

All primary insurers use the reinsurance market to protect themselves against the possibility of a catastrophic loss from events such as a catastrophic earthquake. A reinsurer effectively buys a portion of the claim should such an event occur. A reinsurance program may provide an insurer with a layer of protection of between \$50 million and \$150 million for losses from a single catastrophe. That means that the primary insurer would cover the first \$50 million in claims and that the reinsurer would cover the next \$100 million. If total insured losses were above \$150 million, the primary insurer would absorb the additional amounts unless another layer of reinsurance was purchased.

Data on reinsurance in force for insurers is not in the public domain, except in aggregate form. Therefore, we distributed a questionnaire to the eighteen firms in the sample to determine the

amount of catastrophe reinsurance in force. Fourteen companies responded to the survey. Although that sample is relatively small, the data paint a consistent picture across all fourteen insurers: private reinsurance will not significantly change the story from the one described above. We show that in Figure 3. Three (H, M, and R) of the five firms that we predicted would be insolvent from a catastrophic earthquake responded to the survey; all of them would still be in the same unenviable position, even if the reinsurers paid all their claims.

Today reinsurers show little interest in offering more protection against natural hazards such as earthquakes simply because they believe that the premium they feel they can justify will expose them to excessive risk.

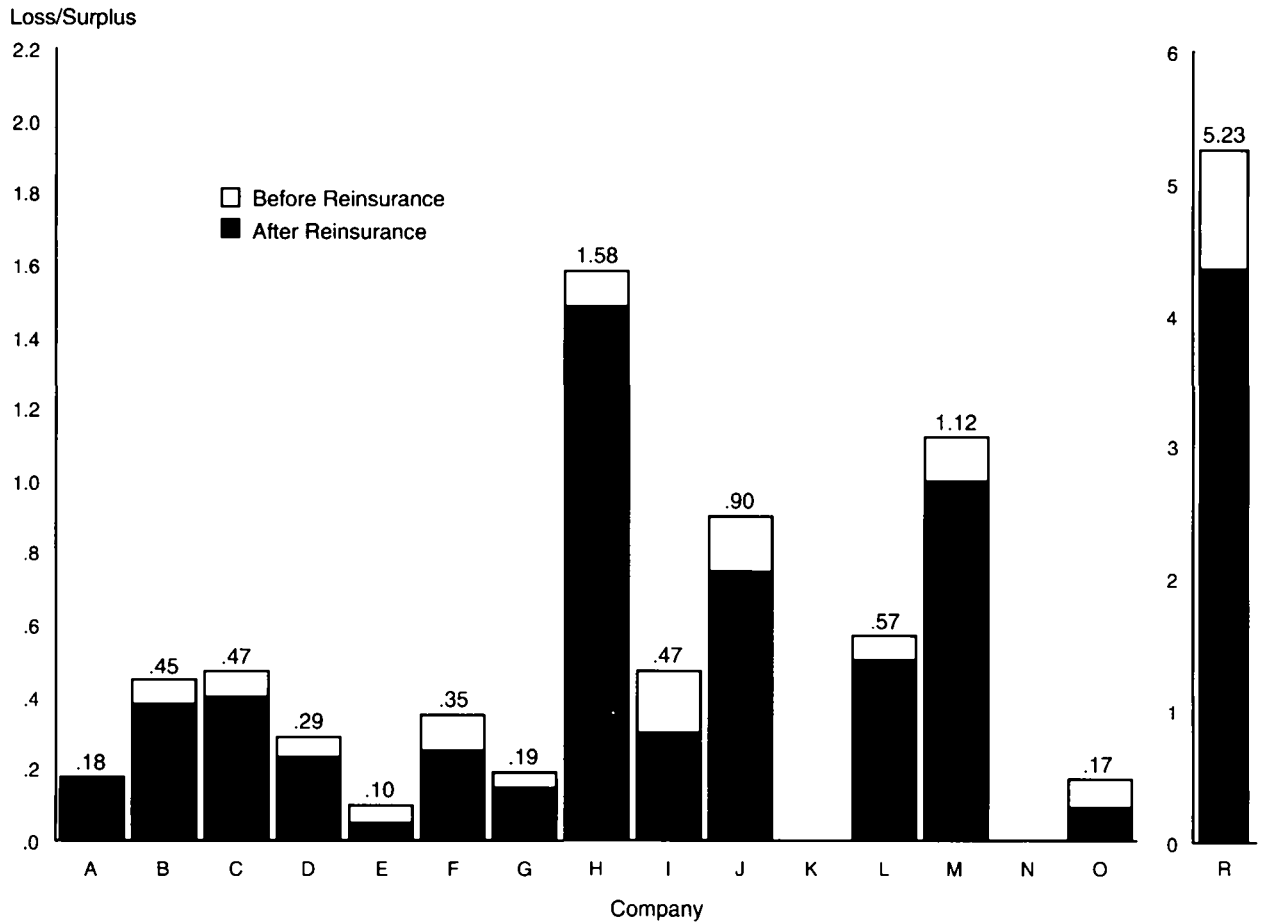
Private reinsurers face the same problem that the primary insurers do when it comes to a catastrophic earthquake. They know that in the case of such an event they will be required to make full payment on their reinsurance coverage. In the example presented above, the reinsurer is likely to pay \$100 million to the private insurer simply because the earthquake damage is large. The premium that reinsurers believe they can charge for such coverage will likely be relatively small since the event has such a low probability of occurring.

Today reinsurers show little interest in offering more protection against natural hazards such as earthquakes simply because they believe that the premium they feel they can justify will expose them to excessive risk. They prefer not to provide coverage at an exorbitantly high premium but would rather indicate that they do not have enough capacity to provide any additional protection against earthquakes.

A Proposed Program

The empirical data on the attitudes of homeowners and insurers toward earthquake losses presents an interesting contrast. While homeowners prefer not to think about the consequences of a severe earthquake to themselves and their property, insurers are focusing their attention on the

Figure 3: Loss as a Percent of Surplus before and after Reinsurance



Note: Companies K, N, P, and Q did not report their catastrophe reinsurance in force.

potentially catastrophic losses that may lead to insolvency. Neither side wants to deal with the hazard for entirely different reasons.

Banks and financial institutions should have an interest in requiring mitigation measures and earthquake insurance, but to date they have not mandated those protective measures as a condition for a mortgage. Each bank may fear that if it imposes those restrictions, the homeowner will seek a loan elsewhere. In such a case it may be advantageous for all banks to be required to have an appropriate building code on all their mortgages. Otherwise, no individual bank will adopt that requirement for fear that the competition will not.

Need for Building Codes. Building codes for loss-reduction measures that pass an expected benefit-cost test are desirable for both new and

existing structures. The liberal federal assistance to disaster victims and the possible bankruptcy of businesses and homeowners impose costs on the general taxpayer that can be reduced by adopting building codes. A study by Robert Litan and Fred Krimgold details the types of building codes for specific structures that can be justified when one makes a conservative estimate of the expected benefits from reductions in property damage.

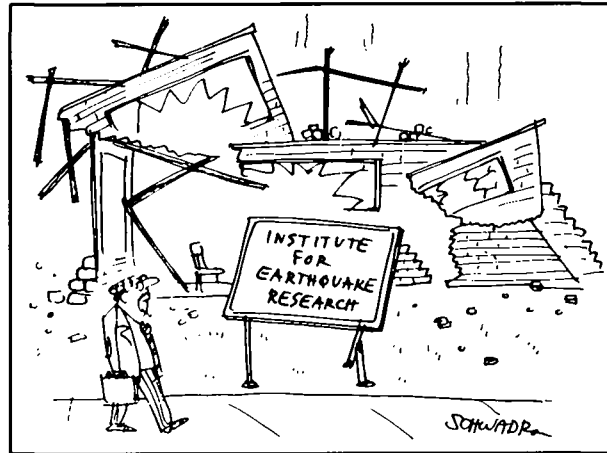
Linda Cohen and Roger Noll advanced an additional rationale for building codes. The structural soundness of a building may have social value over and above its economic value. Should a set of buildings collapse in an earthquake, it may create economic dislocations and other social costs over and above the replacement value of the buildings. Those will not be taken into account when the owners decide whether to improve the structure.

Of course, there are a set of equity questions as to who should pay for improvements in structures, particularly existing ones. Most of the poorly constructed buildings are owned by low-income families, who are least able to afford those additional expenses. Low-interest loans or special subsidies to those groups may be necessary to enable them to fortify their structures. With respect to new construction, the developer and the contractor will decide on designing building structures to meet the code, and their decision will be reflected in the price of the structure.

Advantages of Required Insurance. Currently homeowners, private insurers, and financial institutions do not enthusiastically promote earthquake coverage on residential structures. While an insurer may not view the offering of earthquake coverage to a business as an attractive investment, most businesses desiring this protection are able to obtain it as part of their entire insurance package.

While we recognize that many mitigation measures may not be cost-effective, insurance can have an important role to play in encouraging contractors and homeowners to adopt mitigation measures that have positive net benefits and are not included in existing building codes. If premiums are based on risk, then those who adopt such measures can be charged lower premiums. If the premium reduction is large enough, it should encourage homeowners to adopt the measure. If the premium reduction is relatively small, then homeowners may not find that benefit to be very attractive for the same reason that they did not want to invest in the mitigation measure in the first place—myopic behavior. The large up-front cost looms much larger than the cumulative premium reductions over a period of years.

One way to counteract that effect is for the state or federal government agency to provide homeowners with long-term loans for mitigation. Loan repayments would coincide in timing with insurance premiums. If the benefits of the loss-reduction measure are great enough, the loan repayments will be more than counteracted by lower insurance premiums. California took steps in that direction when it created the Residential Earthquake Recovery Fund, which became effective in January 1992. Each of the 6.5 million residential policies and 500,000 mobile home policies



have a surcharge of between \$12 and \$60 imposed to cover possible damage of up to \$15,000 to the structure from a future earthquake. First reports

If victims of an earthquake are protected by insurance, that obviates the political pressure for liberal assistance following a disaster.

from insurance companies indicate that 85 percent of customers are paying surcharges. Mitigation will be encouraged through low-interest loans and reduced surcharges to properties that are retrofitted to withstand earthquake damage.

From the insurance industry's vantage point, there is a great advantage in requiring all homeowners to purchase earthquake insurance. Such a measure diversifies the risk so that there will be a larger premium base to cover the losses from a particular disaster. If rates are not set carefully to reflect risks, however, policyholders may feel as if they are paying a "tax" rather than a premium.

In addition, the insurance industry would be able to set rates on the earthquake coverage to reflect their hidden losses after an earthquake from causes such as fire and general liability. Those exposures are difficult to rate for the earthquake risk. Japan has addressed that problem by having insurers pay for shake and nonshake losses only if the policyholders have earthquake coverage. It is highly unlikely that private insurers in the United States would be encouraged or allowed to imitate the Japanese earthquake insurance policy by eliminating those hidden exposures from their existing coverage.

If victims of an earthquake are protected by insurance, that also obviates the political pressure for liberal assistance following a disaster. The prospect of disaster relief not only discourages loss-reduction measures, but also raises questions of equity. Should the victims or the general taxpayer pay for disaster losses? Disaster relief also increases the possibility of fraud, since funds might be used for nondisaster expenses. The San Fernando earthquake of 1971 is a case in point. At that time the federal government provided relief through the Small Business Administration and offered a forgiveness grant as part of its policy to aid victims. In effect, an individual could borrow \$3,000 but had to repay only \$500 at a 3 percent annual rate so that the general taxpayer helped subsidize recovery. A survey by the *Los Angeles Times* revealed that many homeowners were given funds to repair damage *not* caused by the earthquake, did their own work even though their loans were based on a contractor's doing it, and frequently received more money than they needed for repairs.

The Case for Federal Involvement. Given the inability of private reinsurers to provide sufficient protection against losses from a catastrophic earthquake, we propose the creation of a federal reinsurance agency. In other words, the federal government would act as a reinsurer of last resort. Private insurers would pay premiums to the agency in return for protection of losses over and above a certain magnitude, just as they would to a private reinsurer.

Given the inability of private reinsurers to provide sufficient protection against losses from a catastrophic quake, we propose the creation of a federal reinsurance agency.

If there is no severe earthquake over the next few years, the agency would build up a base of reserves to cover future losses. If a catastrophic earthquake were to occur next year, the agency would have to be authorized to cover those losses even though the premiums they would have received fell short of their claims. That is what insurance and reinsurance are all about. A related

proposal has been advocated by the Earthquake Project, a consortium of private insurance companies. It has proposed a federal insurance and reinsurance program for catastrophic losses that requires the insurance industry to pay back any excess of losses over premium.

Since the federal government would be officially involved with earthquake disasters, it should be able to avoid the large amounts of disaster assistance that it has previously provided. The government would have the authority to require earthquake insurance on all federally insured mortgages, a step that might encourage other financial institutions to follow suit on their private loans. In addition, it could withhold funds and disaster assistance from earthquake-prone communities unless they instituted specific building codes and regulations for both public facilities and private structures. The National Flood Insurance Program set a precedent for that type of federal involvement when legislation was passed in 1973 that specified those type of sanctions.

In summary, we advocate a combination of incentives, insurance requirements through financial institutions, and building code standards with federal reinsurance coverage for catastrophic earthquakes. Such a program promises to reduce private and social costs from future disasters and to make for a more efficient and equitable recovery process after the next earthquake occurs.

Selected Readings

- Cohen, L. and Noll, R. "The Economics of Building Codes to Resist Seismic Structures." *Public Policy* (Winter 1981).
- Doherty, N., Kleffner, A., and Kunreuther, H. "The Impact of a Catastrophic Earthquake on Insurance Markets." Report prepared for the Federal Emergency Management Agency. Washington, D.C.: 1991.
- Kunreuther, H. and Kleffner, A. "Should Earthquake Mitigation Measures Be Voluntary or Required?" *Journal of Regulatory Economics* (forthcoming).
- Litan, R., Krimgold, F., Clark, K., and Khadlikar, J. "Physical Damage and Human Loss: The Economic Impact of Earthquake Mitigation Measures." Report prepared for the Earthquake Project. Washington, D.C.: 1992.