

Revised Risk Assessments and the Insurance Industry

Carolyn Kousky

3.1 INTRODUCTION

Insurance plays an important role in the management of disaster risk.¹ First and foremost, it can protect individuals and businesses from financial losses that would be too severe for them to handle on their own. Insurance can also make funds available for rebuilding quickly after an event, helping to increase the resiliency of a community. By limiting the risk exposure of individuals or firms, insurance allows for certain business to occur, which may be too risky otherwise, whether it is the adoption by small farm-holders of a higher-yielding crop that is less resistant to drought, or the willingness of doctors to perform surgeries in which human error is possible. Insurance does not lower actual losses, but it is a way to manage remaining risk after all cost-effective risk-mitigation measures have been taken.²

Insuring disaster or catastrophe risks, as opposed to more well-behaved risks, such as automobile accidents, can be challenging, particularly if the insurance company does not fully understand the risk or if the risk changes significantly over time. This chapter examines catastrophe insurance with a particular focus on events that alter risk assessments in the insurance industry. This chapter addresses two overarching questions:

¹ I would like to thank Will Rafey for his research assistance. I would also like to thank Andy Castaldi and Robert Muir-Wood for helpful feedback on this chapter.

² It is possible that insurance premiums could be altered to encourage investment in risk reduction. As noted by Woo (1999), however, the market for insurance is inefficient and cyclical. In soft market conditions, when prices are low, it may discourage risk reduction, and when prices are high, many may simply forgo disaster insurance entirely. Insurance, then, is not likely to be the best tool for incentivizing hazard mitigation.

1. What types of events lead the (re)insurance industry to update risk assessments?
2. How do companies, consumers, and the government respond to updated risk assessments?

This chapter focuses, in general, on the United States, although many of the findings, particularly related to the private (re)insurance industry, will likely be globally applicable.

The next section of the chapter discusses the challenges of insuring disaster risks. Section 3.3 discusses the role and impact of disaster events on the insurance industry, even in the absence of changing risk assessments. Section 3.4 turns to the question of what types of events lead to a revision in risk estimates. Sections 3.5, 3.6, and 3.7 then outline the response to such changes by insurance companies, consumers, and the government. Section 3.8 concludes.

3.2 INSURING CATASTROPHES

The theory of insurance rests on the notion that the insured is risk averse and would pay more than the expected value of the loss to transfer the risk. Many authors have discussed the idealized conditions for insurability of a risk, or for risk transfer to an insurance company to occur (e.g. Swiss Re 2005; Charpentier 2008). For present purposes, I identify five conditions:

1. a degree of randomness to loss occurrences and their magnitude;
2. independent, thin-tailed, and quantifiable risks;
3. determinable losses;
4. no adverse selection or moral hazard; and
5. demand meets supply (the market clears).

First, losses must be unintentional and random – that is, not known with certainty. This requirement is perhaps obvious; insurance cannot be provided for events occurring with certainty or over which the insured has complete control. The second criterion allows for a benefit from pooling risks. Independent risks are those that are not correlated with each other. For example, when one person gets into a car accident, it does not make it more likely that their neighbors will, as well. Thin-tailed risks are those for which the probability of extremely large losses becomes negligible. With independent and thin-tailed risks, the law of large numbers and the central limit theorem ensure benefits to the insurance company from combining the risks of many insureds: the average claim converges to the expected value,

and the tails of the aggregation become thin (that is, normally distributed). As more policies are written, insurers can charge a rate closer to the expected loss (Cummins 2006). The third criterion is that losses must be measurable and verifiable for settlement of claims to occur. The fourth condition has to do with the information and incentives of the insured. Adverse selection occurs when the insured knows more about his or her risk than the insurance company, such that higher-risk individuals or firms are more likely to insure, but the company cannot price for this. Moral hazard occurs when insurance induces the insured to fail to take loss-reduction efforts or to intentionally cause a loss. Finally, insurance will not be sold if it cannot be offered at a price that is profitable for the insurance company and that insureds are willing and able to pay.

Violation of the second and fifth of these criteria³ can make insuring disaster risks challenging. With catastrophes, claims are often spatially correlated, such that all of the structures in a neighborhood may be damaged at once, as when an earthquake or hurricane occurs. Catastrophes are also characterized by fat-tailed losses. With fat-tailed loss distributions, the probability of an event declines slowly, relative to its severity. Put simply, very large losses are possible. Indeed, many natural catastrophes, from earthquakes to wildfires, are fat tailed (e.g. Schoenberg et al. 2003; Newman 2005; Holmes et al. 2008).

With correlated and fat-tailed risks, claims will be more volatile from year to year than for other lines of insurance, with companies on occasion experiencing very severe losses. With non-catastrophic risks, premiums received in a given year can largely cover losses experienced in that year. For catastrophic risks, on the other hand, insurance firms must solve an intertemporal smoothing problem of trying to match regular premium payments, insufficient in any given year to cover a large loss, with the need for enormous sums of capital in the catastrophe years (Jaffee and Russell 1997). Given this, firms are managed to keep the probability of insolvency below a certain level (so-called value-at-risk requirements)⁴ will be required to charge very large premiums to cover catastrophic risks because much more capital is needed to be able to pay claims when a disaster strikes. This can lead to rates that seem overly high in “good”

³ They could also violate the third criterion, as demonstrated by the wind–water controversy following Hurricane Katrina.

⁴ This type of management means that the firm ensures access to enough capital to cover up to a certain percentile of the aggregate loss distribution (thus guaranteeing solvency up to that point). Regulations in the EU (Solvency II), for example, have set the annual probability of insolvency at 0.5 percent.

years, but which are needed to account for the “bad” years. Take the case of Florida. From 1993 to 2003, the rate of return on net worth for homeowner insurers was 2.8 percent nationwide but a much larger 25 percent for Florida. When 2004 and 2005, two years with powerful storms, are included, the situation reverses dramatically, with the national return being -0.7 percent, and the return in Florida being a devastating -38.1 percent (Insurance Information Institute 2009).

There are multiple ways that insurance companies can meet capital-holding requirements, which are set either internally, by rating agencies, or by regulation. One is holding capital themselves. Another is the purchase of reinsurance. Reinsurance is essentially insurance for insurers and is a global market. Reinsurance can be expensive (much higher than expected losses), but it also stabilizes the potential losses of insurance companies and allows for increased capacity (Cummins et al. 2008). Reinsurance markets have been observed to cycle through hard and soft conditions (discussed further in the next section), which impacts prices. Reinsurance prices can also be driven by external international factors. Prices in reinsurance may then be passed through down to the purchaser of an insurance policy. In this way, the premiums for disaster policies can be influenced by reinsurance market conditions.

The higher rates that need to be charged to cover the need for high levels of capital to cover catastrophic lines could be so high as to lead to a breakdown in the insurance market. That is, there may be catastrophic risks that a company cannot insure at a price that insureds would either be willing or able to pay (Kousky and Cooke 2012). For instance, Munich Re executives have noted that they did not provide more reinsurance to companies with exposure to the 2011 Japanese earthquake because there was no demand at the price they deemed necessary (Munich Re 2012). (In Japan, the government established a reinsurance program for the residential earthquake insurance market due to the low market capacity and high cost (see Mahul and White 2013).) In such cases, homeowners and firms will either forgo insurance or the government may need to step in to provide coverage (see Section 3.7).

In addition, insuring risks is not a yes-no proposition. Risks exist along a continuum, from the easy-to-insure to the difficult. Automobiles are largely easy to insure.⁵ A private market for coverage from nuclear

⁵ Insurance companies also limit their risk (and moral hazard) in creative ways. For instance, in Germany, insurance companies have refused to pay for accidents caused by excessive speeding, and this has been upheld in court (Stahel 2003).

terrorist attacks is almost nonexistent because it could have unfathomable losses, and losses would be highly correlated across lines of insurance and with the broader economy. Most risks are somewhere in between, and insurance companies have multiple strategies for increasing their ability to cover a risk. For example, reinsurance companies can often diversify over greater geographic areas and over a wider range of perils, such that ceding some portion of risk to a reinsurer can allow a primary insurance company to offer more coverage. Or, if alternative risk-transfer instruments allow insurance companies to place some risk in the capital markets, it could help them access more capital in large loss years. Companies also limit their exposure in various ways to assume a portion of catastrophe risk that they can comfortably manage, such as increasing deductibles and copayments, enacting policy limits, carefully limiting underwriting, segmenting markets, or working cooperatively with government on hazard mitigation (Swiss Re 2005).

These strategies also suggest that the concept of insurability of risks is dynamic (Swiss Re 2005). New strategies can alter a firm's appetite for covering disaster risks, and broader economic and political conditions can also change insurability over time. In addition, new information on a risk could lead (re)insurers to reconsider the insurability of risks or the conditions under which risks could be covered. An extreme event could be one such source of new information (the main focus of this chapter), or it could come from improved science, updated risk modeling, or from changes in regulation and policy that influence the size of claims (notable for lines such as liability insurance). The rest of this chapter focuses on what types of events lead (re)insurers to alter their assessments of a risk, how they respond when this happens, and how consumers and governments respond.

3.3 THE ROLE OF DISASTER EVENTS IN THE INSURANCE INDUSTRY

The insurance industry is in the risk business. Insurance firms undertake detailed analysis and modeling of the perils they choose to cover. One event will thus not usually lead to any dramatic reassessment of risks, as long as it is seen as a draw from a reasonably well-characterized distribution. For instance, after the large 2011 tornado losses, State Farm stated: "catastrophe claims experience tends to be aberrational. We evaluate claims experience over longer periods of time than we do other types of claims experience" (Berkowitz 2012: n.p.). The question is when an event

makes an insurance company believe that it is indicative of a new, changing, or previously mischaracterized risk.

Following major disaster events, changes are often observed in the insurance market. Prices for insurance policies may increase, or insurance companies may alter coverage conditions. For example, hard markets – meaning that prices increase and supply is scarce – have been observed following many disasters, such as Hurricane Andrew in 1992, the Northridge Earthquake in 1994, and the September 11, 2001 terrorist attacks (Cummins 2006). More recent events have also seemed to trigger price increases. For example, following the terrible flooding in Thailand in 2011, which cost the industry over \$10 billion, companies raised rates around 20 percent and restricted flood coverage (Ng 2012).⁶

It is difficult to untangle the causes of these observed changes in the market, however, and insurance companies could increase premiums or decrease supply following a large event for multiple reasons that are *not* due to a revision in risk estimates. First, the disaster could coincide with other market changes. For example, a 2012 *Wall Street Journal* article highlighted increasing prices for homeowners insurance, but part of the reason was that insurers have seen a low return on their investments (Andriotis 2012), not because they revised their estimates of disaster risk following the large losses in 2011.

Also, although firms ensure access to more capital to cover catastrophic lines, a large event will deplete their surplus.⁷ Several studies suggest that companies may not be able to adequately smooth the payments of catastrophe losses over time because of institutional and political constraints, even when they are aware of the risk (Jaffee and Russell 1997). Due to the difficulty of preventing negative capital shocks in catastrophic lines, firms may raise rates after an event to recoup lost capital. In a sense, they spread the disaster costs over later years. Capital could be raised from several different sources. A visible disaster, however, may make it more difficult for insurance companies to raise external capital, either directly because of the shock to surplus (investors may not want their funds going to pay off debt) or because investors change their risk perceptions (Jaffee and Russell

⁶ Indeed, 2011 was a huge loss year for the industry globally. For example, the year reduced profits for Catlin, an insurance and reinsurance company, by 82 percent, leading it to increase prices on catastrophe lines by 9 percent for primary insurance and 17 percent for reinsurance in the United States and 12 percent for reinsurance elsewhere (Gray 2012).

⁷ The extent of the decline in surplus will depend, of course, in part on how much reinsurance they had purchased.

2003). Although theory suggests that investors' inability to evaluate risks can make it expensive to raise capital from them, thus providing one rationale for reinsurance purchases, reinsurers may also charge high prices and restrict supply post-disaster, for similar reasons discussed here (Froot and O'Connell 1997). This could cause a primary insurance company to raise premiums as a way to increase the capital it cannot obtain (or obtain as cheaply) from other sources. Depleted capital could also cause a firm to be downgraded by rating agencies, and the firm could then raise premiums or limit exposure in the highest-risk areas to reestablish a higher rating and maintain its financial position.

Yet another reason for the observed market changes after large disaster events may have to do with the politics of rate setting. Some have suggested that state regulators (discussed further below) tend to suppress disaster insurance premiums and, as such, insurance companies may use a major event as an excuse to raise prices, even if the event did not alter their risk perceptions (Kunreuther and Pauly 2005). Though difficult to observe, a scandal following Hurricane Andrew suggests that this may occur. Major newspapers reported that, while the storm was raging over Florida, a memo was circulated to American International Group (AIG) senior managers that the company could use the storm as an excuse to raise rates (Angbazo and Narayanan 1996). Text from the memo quoted by the *Los Angeles Times* suggests that AIG felt the industry could not absorb the loss without rate increases, and interview comments from AIG executives indicate that they felt the insurance was not priced high enough prior to Andrew (Mulligan 1992).

Finally, a disaster may also lead to changes in demand, as opposed to supply. If demand increases after an event as consumers reevaluate the risk or their need for insurance, higher prices could be observed in the market post-disaster (discussed further in Section 3.6). Unlike other industries, insurance often experiences an upward shock to demand concurrent with a downward shock to supply because large events can both increase demand and deplete insurance capital (Swiss Re 2005). This joint effect can lead to large price increases after events and can make price and quantity for disaster insurance very "spiky."

Disentangling all of the impacts of a disaster that are not due to risk-perception changes from the adjustments that occur when a catastrophe does alter the risk perception of insurers is difficult empirically, and very little work addresses this question. The next sections summarize what is known about this topic and offer some initial findings and hypotheses for future investigation.

3.4 WHAT EVENTS LEAD TO A CHANGE IN RISK PERCEPTIONS?

An extreme event could cause an insurance company to revise its estimation of the risk in any of three situations. The first is when the distribution of the risk is unknown, often due to very limited data on the risk. In this case, one extreme event carries more informational content for the insurance company, or leads to more updating, than when a large amount of data on a risk is available. The second situation is when the loss distribution is changing over time, such that an extreme event can be indicative of a change in the risk. The third is when an event identifies a new risk that had not been previously identified or incorporated into decision-making.

In practice, however, these need not be mutually exclusive categories. A risk may be unknown and changing over time, and new aspects of the risk may emerge post-event. Take the case of terrorism. The probability distribution of terrorism damages is clearly a distribution that is unknown. Getting an improved understanding of terrorism risk is also limited by lack of access to classified governmental information. The risk is continually changing over time as counterterrorism policies evolve, as terrorists shift their targets and intentions, and as both government security agencies and terrorists react to and anticipate each other. The changing nature of the risk can also lead to new aspects of the risk emerging, such as new types of attacks. It is thus no surprise that the attacks on September 11, 2001, provided new information that led to dramatic updates of terrorism risk by (re)insurance companies.

Insurance companies were quite aware of the risk of terrorism to the insurance lines they offered before 2001, having dealt with previous events both within and outside of the United States. Still, prior to September 11th, many firms simply had not considered an attack of the magnitude experienced. At the time of September 11th, it was the costliest insured event in history (coming in just behind Hurricane Andrew in 1992).⁸ As Warren Buffet wrote of General Re in his letter to shareholders in 2001: in “setting prices and also in evaluating aggregation of risk, we had either overlooked or dismissed the possibility of large-scale terrorism losses” (Buffet 2002, p. 8). Swiss Re revealed similar sentiments, noting that the September 11th attacks demonstrated a “staggering, previously inconceivable scale of threat scenarios and loss potentials” (Schaad 2002, p. 2).

⁸ It has since been surpassed by Hurricane Katrina, the 2011 Japanese earthquake, and Hurricane Sandy in terms of insured losses.

Academics and some government officials had discussed potentially catastrophic terrorism scenarios well before September 11, 2001, and yet insurance companies did not exclude such coverage from their contracts and appeared surprised by the magnitude of the losses, as noted by Buffet, Swiss Re, and others. In interviews of insurance officials, it was found that a total loss of the World Trade Center was simply not considered by most companies; their probable maximum loss⁹ may have included a plane taking out a few floors and a resulting fire, but not destruction of both towers (Ericson and Doyle 2004, pp. 216 and 221). The 1993 World Trade Center bombing was manageable for companies in terms of losses, and it seemed inconceivable that a much greater magnitude loss was possible. In addition, prior to September 11th, terrorist attacks were not uncommon on US interests overseas, but only 0.5 percent of all terrorist actions between 1991 and 1998 were in North America (Cummins and Lewis 2003). The September 11th attacks thus changed insurers' view of terrorism risk: it became something that could be more common within the United States, and attacks could be much larger in magnitude than had been previously believed.

September 11th also led to the identification of a new aspect of terrorism risk or a new type of risk. The event drove home for insurance companies that losses across lines of business could be highly correlated in a manner not previously appreciated (Ericson and Doyle 2004). The same single event caused losses in property, business interruption, liability, workers' compensation, aviation, life, and health insurance lines. Companies also realized after September 11th that a large claim-generating event could also lead to investment losses, further stressing the company, such that disaster events were not necessarily independent of market conditions. In his shareholder letter the year after the attacks, Buffet (2002, p. 7) stresses that insurance companies should "accept only those risks that they are able to properly evaluate" and "ceaselessly search for possible correlation among seemingly-unrelated risks." These correlations were made plain by September 11th.

A similar updating of risk perceptions occurred after Hurricane Katrina, when, again, the types of losses that can be sustained following a large event were surprising. Hurricane Katrina generated the highest level of insured losses in history. Insurance companies often rely on catastrophe models – probabilistic models of different perils that take

⁹ Probable maximum loss refers to the largest modeled loss for which the company is pricing.

into account a company's portfolio to estimate losses – when evaluating their pricing and underwriting. Three firms do the vast majority of such modeling: Risk Management Solutions (RMS), AIR, and EQECAT. These models generally underpredicted losses from Katrina. The storm led RMS modelers to realize that when disaster events are extreme, they can result in what RMS (RMS 2005, Foreword) called “super cats,” or events with such large amounts of damage that they “give rise to nonlinear loss amplification, correlation, and feedback.” Super cats result in impacts for many more lines of business and generate damage of types not previously modeled, such as infrastructure collapse, looting and crime, water contamination, prolonged business interruption, and delayed economic recovery (NAPCO LLC 2006). Adding these possibilities – along with a range of other lessons learned from Katrina – into the RMS model increased damage estimates by up to 125 percent (NAPCO LLC 2006). All firms recalibrated their models after the 2004 and 2005 seasons, increasing probable maximum losses by between 10 percent to over 100 percent (Fleckenstein 2006).

Hurricane Katrina also provided new information on how hurricane risks may be evolving over time from climate change. Before Katrina, the RMS hurricane model had relied on hurricane events over the past 100 years, using a representative selection of such storms to model losses. This did not account for any cyclical variations, such as El Niño and La Niña events, nor did it account for increasing sea-surface temperature. In a new 2006 model, RMS drew on a panel of scientific experts to instead take a forward-looking view of hurricane activity, determining that higher sea temperatures would lead to increased activity and incorporating the role of the Atlantic multi-decadal oscillation in affecting hurricane activity (NAPCO LLC 2006). This led to increases in modeled losses of about 40 percent for Florida and between 25 percent and 30 percent for the Mid-Atlantic.

This makes clear that insurers at times will be incorporating updated risk assessments by the risk modeling companies on which they rely. Beyond risk modelers, insurers also have to respond to updated requirements of rating agencies. After the 2004 and 2005 hurricane seasons, for example, rating agencies increased their capital requirements and adopted more rigorous stress testing for catastrophe lines, forcing insurers to raise more capital or reduce exposure in order to maintain their ratings (Fleckenstein 2006). This was in addition to insurers realizing after the series of storms that many homeowners were underinsured, leading to high claim payments even for partially damaged structures. When

companies increased their insurance to value checks, this led to an increase in exposure, which required a change in capital requirements. Combining all these factors created a shock to the market.

Large events can provide new information to insurers about a risk, particularly for risks that were poorly understood to begin with or those that are changing over time, or it can indicate risks not previously identified. The September 11th attacks and Hurricane Katrina are both examples of this type of risk updating by insurance companies. This suggests a model of learning about risks that is quite jumpy. In practice, catastrophic risks are continuously changing. Human populations and development patterns change over time; our technologies to mitigate hazards evolve; and other stresses, such as climate change or political conditions, shift. Although to some extent, all of these potential drivers are constantly modeled by the insurance industry, often it takes an extreme event to give deeper insight into the manner and magnitude of changes to risks.

On the other hand, however, insurance companies, though constantly evaluating risks and presumably more skilled at doing so than some other industries, may still be biased in their evaluation of risks, particularly after a very extreme event. They could overweight recent events, for example, or charge higher premiums when risks are unknown, a practice termed ambiguity aversion (Kunreuther et al. 2013). In addition, investor pressure after an extreme loss may induce insurance companies to overreact, or managers may otherwise be incentivized to react in this fashion.

3.5 INSURER REACTION TO CHANGING RISK PERCEPTIONS

When an extreme event causes an insurer to estimate a risk as higher than it previously did, the company may alter its pricing, coverage conditions, underwriting strategies, and/or capital management in response. Often, companies adjust all of these simultaneously, although this section discusses each in turn.

Large premium increases have been observed after many of the largest events the insurance industry has experienced. After the September 11th attacks, many companies revised their probable maximum loss to include the complete loss of the buildings they were insuring (Ericson and Doyle 2004, p. 221), which led to a large jump in prices. Reinsurance companies made similar revisions, and the supply of reinsurance for terrorism was dramatically curtailed after 9/11; what was available was priced at extremely high rates (CBO 2007), which had impacts on the pricing of primary insurance. Some primary companies raised rates dramatically, and others

refused to offer the coverage at all. As an example, one Midwestern airport saw its liability premium increase 280 percent in 2002, along with the exclusion of terrorism coverage (Swiss Re 2005).

Following a reassessment of the risk, companies also often change the conditions of coverage to make the risk more insurable. A notable example of this is hurricane deductibles, introduced after Hurricane Andrew. Following the storm, in many coastal states, companies introduced deductibles specific to either hurricanes or wind damage, often set as a percentage of the home, ranging from 1 percent to 5 percent (McChristian 2012). These have been a lasting legacy of the storm and expanded beyond Florida.

Other examples come from the 2011 tornadoes. Those events led some companies to seek broader geographic diversification in order to reduce the amount of exposure they had in tornado-prone areas, to increase deductibles, and to change pricing based on new factors, such as the age and quality of a home's roof (Berkowitz 2012). The *Wall Street Journal* noted that Allstate, for example, was introducing a new policy in Kansas and Oklahoma that would not pay the full cost of roof replacement (Andriotis 2012).

If companies revise their estimates of the risk upward sufficiently, they may believe that they need to lessen the amount of exposure to the risk in their overall portfolios. In the extreme, companies may abandon a location or line of business altogether. As already mentioned, after September 11th, many (re)insurers dramatically restricted the supply of terrorism coverage. It was widely reported in the months after the attack that commercial terrorism coverage was unavailable, even at very high prices (Swiss Re 2005). A 2002 Swiss Re publication noted that, in response to the attacks, "the insurance industry is compelled to fundamentally review its risk acceptance position, and to reduce and limit coverages granted to avoid unmanageable exposures in the future. In fact, the question whether terrorism risk is insurable at all must be fundamentally reviewed" (Schaad 2002, p. 5).

Insurance companies also pulled back along the Gulf Coast after Hurricane Katrina, although not as severely as was seen in the terrorism market after September 11th. The trimming of hurricane exposure, however, has continued over many years since Katrina, suggesting that companies fundamentally do not consider the risk to be improving. In February 2010, for instance, Farmer's announced that it would drop more than 10,000 policyholders in the coastal counties of Alabama, joining Allstate, Alfa Mutual, and State Farm in shedding policies in Baldwin and Mobile counties (Amy 2010).

Reducing coverage is not independent of the prices firms can charge. In 2007, State Farm stopped writing new homeowners policies in Florida (Stroud 2012). Part of the difficulty was a struggle over rates. Florida was preventing State Farm from raising rates to the level the company thought was needed. Negotiations with the state followed, and, in December 2009, State Farm agreed to drop 125,000 high-risk policies instead of exiting the state entirely, and Florida allowed the company to raise its rates by 14.8 percent (Fineout 2010).

A pullback of insurance companies after the Northridge earthquake led to a crisis in California. Following the earthquake, insurance companies paid out \$15 billion in claims but had collected only \$3.4 billion in earthquake premiums in the preceding 25 years (GAO 2007). The Northridge Earthquake generated far higher claims than insurers had deemed plausible. Claims analysis revealed a large amount of underinsurance, appurtenant structures that were more vulnerable and represented a greater share of property value than had been assumed, and zip-code level data that masked important heterogeneity (RMS 2004). Concerned about their ability to charge risk-based rates and the challenge in diversifying their earthquake risk, insurance companies began shedding their earthquake exposure throughout the state. California state law, however, required that insurance companies offer earthquake coverage if they wrote residential coverage, so companies began to quit writing all residential coverage. The California Department of Insurance estimated that in the summer of 1996, 95 percent of the homeowners insurance market in the state had stopped or dramatically limited the sale of new policies (CEA 2010). This triggered a housing crisis that led the state to intervene (discussed below).

Finally, insurance companies may alter the management of their capital. They may increase reserves, for instance, or purchase more reinsurance. Following Hurricane Andrew and the Northridge Earthquake, strategies were developed to transfer risk to the capital markets, such as through catastrophe bonds (Kunreuther and Michel-Kerjan 2005). This opened up a new source of capital to firms; for many reasons, the market remains small, although it is growing.

Some amount of “risk contagion” is also apparent. In other words, when a bad disaster of one type occurs, prices go up for other disaster lines as well. For example, the prices for earthquake coverage increased after Hurricane Katrina, and the price of catastrophe bonds for natural disasters increased after the September 11th terrorist attacks (Froot 2008). This could be due to the general decreases in surplus. It could also be, however,

that as insurance companies revise their risk estimates of one catastrophe line, it prompts them to reconsider their evaluations of other catastrophe risks as well. Hurricane Katrina prompted a reexamination of the catastrophe models, as discussed earlier, and whereas some changes were unique to windstorms, some were broadly applicable to a range of catastrophes, leading to price increases on other catastrophic lines, like earthquake coverage (Adviser 2006).

What happens after the immediate post-disaster changes? In some cases, changes may be temporary. Insurance companies may find new tools to help insure the risk and access new pools of capital to expand their underwriting. As prices increase and quantity is restricted, it can attract new capital to the market, helping to reestablish lower prices and more availability. Terrorism coverage has improved since September 11th, although this is partly due to federal legislation, as discussed below. It may also be due to improved modeling of terrorism losses, such as the model developed by RMS (RMS 2008).

In other cases, however, the new assessments of the risk may be such that the market changes after the event are permanent. For example, since Katrina, companies have continued to push for higher prices along the coast and have continued to tightly manage their exposure to hurricane losses. Katrina suggested not only that companies had fundamentally underestimated potential hurricane losses, but also that the risk may be worsening.

It is also worth remembering that insurance companies cannot perfectly predict changing risks and cannot possibly guard against every catastrophe scenario. Rare events that stress the industry will always occur. For example, one executive noted that, although EU regulations (Solvency II) require insurance companies to reserve for the one-in-200-year event, that means that, with 100 large insurance companies, roughly one will go bankrupt every two years (Munich Re 2012).

3.6 CONSUMER REACTION TO CHANGING RISK PERCEPTIONS

An extreme event may not only lead insurance companies to update their risk assessments, but also cause consumers to update their risk perceptions. If individuals assess a risk as higher after an extreme event than they did before, it may lead them to change their insurance purchases. Findings from behavioral economics suggest that individuals can often be poor evaluators of risks, using mental shortcuts and rules of thumb (Kahneman et al. 1982). For example, after an

event, individuals often assess the risk as higher because it is now salient for them. This has been termed the availability heuristic (Tversky and Kahneman 1973). When this happens, it could increase insurance demand. This increase in demand could come at the same time the market is hardening, exacerbating the changes post-disaster in both the price and quantity of available insurance coverage.

Supporting these theoretical arguments, several studies have found empirical evidence that individuals are often more likely to purchase insurance in the wake of a disaster. Browne and Hoyt (2000) find that flood insurance purchases at a state-level increase when flood damages the previous year are higher. Looking only at flood insurance purchases in Florida, Michel-Kerjan and Kousky (2010) find that, after the 2004 hurricanes, the number of policies-in-force statewide jumped 6 percent, compared to increases of only 1 percent to 2 percent in other years. They also find that more homeowners in areas hit by the hurricanes lowered their deductibles and chose the maximum coverage level.

September 11th also had impacts on insurance demand. A month after the attacks, CNN reported a 30 percent spike in the purchase of travel insurance, even though the total number of travelers was still below pre-attack levels (Max 2001). As another example, following the Deepwater Horizon oil spill, firms engaged in drilling began to demand greater levels of insurance coverage (Booz Allen Hamilton 2010). Finally, some empirical evidence suggests that catastrophes lead to greater purchases of life insurance (Fier and Carson 2010). Demand can also fall as salience declines. There is some indication that, as the time since the last earthquake increases in California, more people drop earthquake insurance (Wilkinson 2009).

3.7 GOVERNMENT REACTION TO CHANGING RISK PERCEPTIONS

The government has intervened in insurance markets in the United States at both a state and federal level following extreme events. Government intervention is often motivated by a perception that the insurance market has broken down, with private companies choosing not to offer coverage for a risk or only at prices that are beyond what many consumers can afford. Governments can intervene in insurance markets in a number of ways. The insurance industry is regulated at the state level by insurance commissioners. Commissioners oversee licensing of insurance companies (and thus a firm's ability to sell insurance within a state), pricing, solvency,

underwriting, marketing, and claims handling, among other things. Beyond regulation, many states have created their own insurance programs for consumers who cannot find a policy in the private market. Finally, the federal government also runs several (re)insurance programs. This section discusses these various interventions.

After an extreme event, state insurance commissioners often work to prevent steep price increases or the exit of firms in an attempt to protect consumers. Following Hurricane Andrew, insurance regulators in Florida prohibited dramatic rate increases and only let companies gradually increase prices over a decade, and the state legislature passed a moratorium on policy cancellations (Klein 2009). Part of this, however, was due to the AIG controversy mentioned earlier. In response to it, the Florida insurance commissioner froze AIG premiums and warned all companies that unjustified rate increases would not be permitted (Angbazo and Narayanan 1996). The state also put in place a three-year moratorium that limited how quickly firms could reduce their market share in the state (McChristian 2012). Following Hurricane Katrina, the state allowed an initial wave of price increases that were generally highest in coastal areas but then began disapproving them in 2006 (Klein 2009). Other states have taken similar measures. After Katrina, the Louisiana Department of Insurance prohibited cancellation or nonrenewal of residential dwelling and commercial property insurance for structures damaged by Hurricane Katrina or Rita until 60 days after all repair and reconstruction had been completed (Klein 2009).

More dramatically, states have set up their own insurance programs after observing a severe hardening of the insurance market (Kousky 2011). These state programs, often called residual market mechanisms, are created for residents who cannot find policies in the voluntary market. They take a variety of forms, including state FAIR (Fair Access to Insurance Requirements) plans,¹⁰ state wind pools or “beach plans” that provide wind-only coverage in certain high-risk areas, hybrid programs that write both hazard-specific policies and complete dwelling coverage, an earthquake program in California, and a reinsurance fund in Florida. Many programs have eligibility requirements intended to ensure that policies are

¹⁰ Following riots and civil disorder in many urban areas, federal legislation in 1968 made federal riot insurance available to states that enacted FAIR plans that offer homeowner coverage to residents who cannot find policies in the voluntary market. Initially, these plans offered coverage only for fire, but many have expanded, and some even offer wind coverage.

purchased only as a last resort. Almost all of these programs were adopted in reaction to an extreme event and insurer reactions to that event.¹¹

The CEA is a good example. It was established following the housing crisis triggered by the Northridge earthquake. Insurance companies can comply with the state mandate to offer earthquake coverage with residential dwelling coverage by participating in the CEA. Upon joining the CEA, insurers make a capital contribution and are able to be assessed after an event if available capital and reinsurance do not cover all claims. The CEA began operating in late 1996; within a year, almost all insurance companies were again operating in the state (CEA 2010). The CEA is the largest earthquake insurer in California. Historically, the coverage offered was quite limited, with low caps and high deductibles. Recently, however, the CEA has introduced new policies with broader coverage and more choice. Still, take-up rates for earthquake coverage are only around 10%, leaving many homeowners vulnerable to earthquake losses.

The CEA is well prepared to cover claims from a severe earthquake, but other state programs are not. Florida's insurance program, initially created after Hurricane Andrew, has been a source of controversy, for example, with many observers noting that its pricing is too low, such that it will be unable to pay claims from a severe hurricane,¹² and artificially low prices could cause perverse incentives that may not occur in a private market. The state has taken steps recently to raise rates and improve the standing of the program.

State intervention could be used as a temporary measure to relieve market hardening after a disaster. Hawaii's program exemplifies this possibility. The program was established in 1992 after Hurricane Iniki. By 2000, private insurance companies were writing their own policies in Hawaii, and the state program has not written any new policies over the last decade. Such short-term intervention is useful when the private market

¹¹ For instance, Louisiana Citizens and the Alabama Beach Pool were created in response to Hurricane Camille, Hawaii's fund was created after Hurricane Iniki, the Texas Windstorm Insurance Association was created following Hurricane Celia, the precursor to Florida Citizens was created following Hurricane Andrew, and the California Earthquake Authority was created after the Northridge earthquake.

¹² When reserves are not enough to cover claims, the program would be funded by post-event assessments on policyholders in the program. Following policyholder assessments, all property and casualty insurance companies in the state would be assessed, and finally an emergency assessment on all property and casualty policies. This distributes the risk beyond only the at-risk homeowners in the program. Recouping these assessments would take time, however, making the program reliant on issuing post-event bonds.

simply needs time to revise strategies and rebuild capital. It will not be possible if the private market fundamentally reassesses a risk as uninsurable. Florida Citizens, for example, is the largest insurer in the state; it will probably remain a fixture of the Florida insurance market. Indeed, many state programs have grown in recent years and play a vital role that is unlikely to be replaced completely by the private market in the near future.

The federal government has also created its own insurance programs. Building in part on a widespread perception that flood insurance was unavailable in the private market, Congress created the National Flood Insurance Program (NFIP) in 1968. Now housed in the Federal Emergency Management Agency (FEMA), the program makes flood coverage, up to certain limits, available to residents of participating communities that adopt baseline floodplain management regulations. Purchase of a flood insurance policy is mandatory for homeowners in a FEMA-mapped 100-year floodplain with a mortgage from a federally backed or regulated lender.

To encourage the purchase of insurance, the NFIP historically discounted the premiums of some policies. This prevented it from building a catastrophe reserve or purchasing reinsurance, and the losses of Hurricane Katrina sent the program deeply into debt to the US Treasury. Characteristic of a catastrophic risk, the NFIP paid out more in claims after Katrina than it had over the life of the program to that point. This debt generated many discussions on reform of the program, which culminated in the passage of the Biggert-Waters Flood Insurance Reform Act of 2012 and the Homeowners Flood Insurance Affordability Act of 2014. Under these laws, rates for some previously discounted policies are now increasing. This, coupled with new hazard mapping in some locations, has raised concerns over the affordability of flood insurance (Kousky and Kunreuther 2013), a tension that is found in many government insurance programs. Political pressure for lower rates often exists, but subsidizing costs could theoretically lead to an overinvestment in risky locations and underinvestments in hazard mitigation.

Most recently, the federal government has intervened in the terrorism insurance market.¹³ As mentioned above, reinsurance companies began excluding terrorism coverage in 2002 renewals. This prompted 45 states

¹³ Other countries have intervened in the terrorism insurance market. France, for instance, developed a terrorism insurance pool with a state guarantee after September 11th. French law from the mid-1980s made coverage for terrorism risks mandatory and, as such, the government had to intervene when the reinsurance market collapsed after the attacks. Britain already had a pooling scheme with a government backstop developed after terrorism incidents in London in the early 1990s.

to allow primary insurers to exclude terrorism coverage in policies as they came up for renewal (Brown et al. 2004). Terrorism coverage, with a few exceptions, was not available, and commentators warned of negative impacts on the economy. Some also argued that the federal government could be more effective at the intertemporal diversification required for terrorism risks and that the federal government had a hand in managing terrorism risk and thus should intervene in the market.

The federal government responded by passing the Terrorism Risk Insurance Act (TRIA) in fall 2002. It created a federal backstop for terrorism insurance for US property-casualty insurers. Under the act, the federal government covers certain declared terrorism losses for insurance companies above a deductible and up to a limit (the insurance companies also have a coinsurance amount). The firms pay nothing up front, but the government has the option to recoup costs *ex post* with a surcharge on commercial insurance policies that cannot exceed 3 percent. TRIA was intended to be temporary, with the thought that the private market would recover, but it has been extended multiple times.

The legislation mandated that firms make terrorism coverage available in exchange for the federal government assuming some of the risk. This did lead to more supply after its passage. And some evidence indicates that many insurers would not offer terrorism coverage if TRIA were not in place. Cummins (2006) notes that in 2004, 90 percent of insurers wrote coverage that was covered by TRIA, but only 40 percent wrote coverage for terrorism acts that TRIA did not reinsure. This law did not cap prices, however, and many companies appear to have gone without terrorism coverage rather than pay high prices. That said, premiums for terrorism coverage have fallen and demand for primary terrorism coverage has increased substantially since TRIA's passage (CBO 2007). Take-up for terrorism insurance was 27 percent in 2003 but grew to 61 percent in 2009 (Marsh 2010). This is despite the fact that the 2005 extension increased the deductibles and coinsurance borne by primary insurers. Although the purchase of reinsurance by primary insurance companies has increased, it is only a quarter of primary insurers' deductible under TRIA and thus still quite limited (CBO 2007).

The question of when and how governments should intervene in insurance markets is a difficult one. If the price increases and declines in availability of insurance post-disaster are influenced largely by a negative shock to capital, the market should re-equilibrate after a short period of time as capital is restored. Government intervention, however, is often more lasting

than initially intended, and in these cases may be counterproductive. Recent events, however, have led insurance companies to rethink the insurability of some catastrophic lines, such as terrorism and hurricane coverage, sending prices upward and available quantities downward. Governments often see their role as maintaining both availability and affordability of insurance coverage. As we have seen, however, catastrophe risks are expensive to insure. Often government intervention in the name of affordability simply transfers the costs to others. The overall question of who should cover the costs of catastrophic events is a difficult one worthy of more public discussion and quite beyond the scope of this chapter.

3.8 CONCLUSION

The insurance industry and the modeling companies that support it often have some of the best evaluations of risk available. Even in the absence of full information about a risk, such as when risks are unknown, uncertain, or are evolving over time, (re)insurance companies often still offer coverage. Although done at a price insurance companies feel can justify assumption of the risk, this provides needed risk management for many homeowners and firms. For unknown and changing loss distributions, however, extreme events can provide important new information on the nature of the peril. When this occurs, insurance firms will reevaluate their pricing, exposure, underwriting policies, and capital management. Severe events that lead to this type of risk updating, however, also often lead to updating on the part of consumers and governments. This chapter has traced how all three sectors may respond when they assess a risk as higher than they did previously. This may simply lead to temporary adjustments, or it can cause new equilibrium conditions in the market or permanent government interventions.

References

- Advisen (2006). Earthquake: The Other Insurance Crisis. Advisen Ltd. www.cybersure.com/Documents/The_Other_Crisis.pdf.
- Amy, J. (2010). "Farmers insurance to drop wind coverage from 10,000 coastal policyholders." *Al.com* (Birmingham, AL). http://blog.al.com/live/2010/02/farmers_insurance_group_to_dro.html.
- Andriotis, A. M. (2012). "Home Insurance Goes Through the Roof." *The Wall Street Journal Market Watch*, March 9. <http://blogs.marketwatch.com/realtimeadvice/2012/03/09/home-insurance-goes-through-the-roof/>.

- Angbazo, L. A. and R. Narayanan (1996). "Catastrophic Shocks in the Property-Liability Insurance Industry: Evidence on Regulatory and Contagion Effects." *The Journal of Risk and Insurance* 63(4): 619-37.
- Berkowitz, B. (2012). "Insurers Forced to Rethink Tornado Coverage." *Chicago Tribune*, March 7. www.reuters.com/article/us-insurance-tornadoes-idUSTRE826IX320120307.
- Booz Allen Hamilton (2010). The Offshore Oil and Gas Industry Report in Insurance – Part One, Report funded by the Department of Energy's National Energy Technology Laboratory.
- Brown, J. R., J. D. Cummins, C. M. Lewis and R. Wei (2004). "An Empirical Analysis of the Economic Impact of Federal Terrorism Reinsurance." *Journal of Monetary Economics* 51: 861-98.
- Browne, M. J. and R. E. Hoyt (2000). "The Demand for Flood Insurance: Empirical Evidence." *Journal of Risk and Uncertainty* 20(3): 291-306.
- Buffet, W. E. (2002). Letter to Shareholders. Berkshire Hathaway Inc. 2001 Annual Report.
- CBO (2007). *Federal Reinsurance for Terrorism Risks: Issues in Reauthorization*. Washington, DC, Congressional Budget Office.
- CEA (2010). Annual Report to the Legislature and Insurance Commissioner on Program and Operations. Sacramento, CA, California Earthquake Authority.
- Charpentier, A. (2008). "Insurability of Climate Risks." *The Geneva Papers* 33: 91-109.
- Cummins, J. D. (2006). "Should the Government Provide Insurance for Catastrophes?" *Federal Reserve Bank of St. Louis Review* July/August: 337-56.
- Cummins, J. D. and C. M. Lewis (2003). "Catastrophic Events, Parameter Uncertainty and the Breakdown of Implicit Long-Term Contracting: The Case of Terrorism Insurance." *The Journal of Risk and Uncertainty* 26(2/3): 153-78.
- Cummins, J. D., G. Dionne, R. Gagne and A. Nouira (2008). *The Costs and Benefits of Reinsurance*. CIRRELT-2008-26. Montreal, Université de Montréal, Interuniversity Research Centre on Enterprise Networks, Logistics, and Transportation.
- Ericson, R. V. and A. Doyle (2004). *Uncertain Business: Risk, Insurance, and the Limits of Knowledge*. Toronto, University of Toronto Press.
- Fier, S. G. and J. M. Carson (2010). Catastrophes and the Demand for Life Insurance. Working Paper, available at SSRN: <http://ssrn.com/abstract=1333755>.

- Fineout, G. (2010). "Truce Reached with State Farm Florida; Citizens Property Insurance Corp. Could Grow Due to Deal." *Florida Underwriter*. 27(1): 24. <https://insurancenewsnet.com/oarticle/Truce-Reached-With-State-Farm-Florida-Citizens-Property-Insurance-Corp-Could-a-152331>.
- Fleckenstein, M. (2006). Rating Agency Recalibrations. In *The Review: Cedant's Guide to Renewals 2006*. London: Informa UK Limited: 40–43.
- Froot, K. A. (2008). "The Intermediation of Financial Risks: Evolution in the Catastrophe Reinsurance Market." *Risk Management and Insurance Review* 11(2): 281–94.
- Froot, K. A. and P. G. J. O'Connell (1997). On the Pricing of Intermediated Risks: Theory and Application to Catastrophe Reinsurance. NBER Working Paper 6011. Cambridge, MA, National Bureau of Economic Research.
- GAO (2007). *Public Policy Options for Changing the Federal Role in Natural Catastrophe Insurance*. Washington, DC, United States Government Accountability Office
- Gray, A. (2012). "Catlin Warns of Disaster Insurance Rates." *Financial Times*, February 9.
- Holmes, T. P., R. J. Huggett, Jr. and A. L. Westerling (2008). Statistical Analysis of Large Wildfires. In *The Economics of Forest Disturbances: Wildfires, Storms, and Invasive Species*, edited by T. P. Holmes, J. P. Prestemon and K. L. Abt. Springer Science: 59–77.
- Insurance Information Institute (2009). *Catastrophes: Insurance Issues. Issues Updates*. New York, NY, Insurance Information Institute.
- Jaffee, D. M. and T. Russell (1997). "Catastrophe Insurance, Capital Markets, and Uninsurable Risks." *The Journal of Risk and Insurance* 64(2): 205–30.
- Jaffee, D. M. and T. Russell (2003). Markets Under Stress: The Case of Extreme Event Insurance. In *Economics for an Imperfect World: Essays in Honor of Joseph E. Stiglitz*, edited by R. Arnott, B. Greenwald, R. Kanbur and B. Nalebuff. Cambridge, MA, MIT Press: 35–52.
- Kahneman, D., P. Slovic and A. Tversky, eds. (1982). *Judgment under Uncertainty: Heuristics and Biases*. Cambridge, UK, Cambridge University Press.
- Klein, R. W. (2005). *A Regulator's Introduction to the Insurance Industry*. Kansas City, MO, National Association of Insurance Commissioners.
- Klein, R. W. (2009). *Hurricane Risk and the Regulation of Property Insurance Markets*. Atlanta, GA, Center for RMI Research, Georgia State University.

- Kousky, C. (2011). "Managing the Risk of Natural Catastrophes: The Role and Functioning of State Insurance Programs." *Review of Environmental Economics and Policy* 5(1): 153–71.
- Kousky, C. and R. Cooke (2012). "Explaining the Failure to Insure Catastrophic Risks." *The Geneva Papers* 37: 206–27.
- Kousky, C. and H. Kunreuther (2013). Addressing Affordability in the National Flood Insurance Program. RFF Issue Brief 13-02. Washington, DC, Resources for the Future.
- Kunreuther, H. and E. Michel-Kerjan (2005). *Insurability of (Mega-) Terrorism Risk: Challenges and Perspectives. Terrorism Risk: Insurance in OECD Countries*. Organisation for Economic Co-operation and Development. Paris, France, OECD Publishing.
- Kunreuther, H. and M. Pauly (2005). *Insurance Decision-Making and Market Behavior. Foundation and Trends in Microeconomics*, vol 1, no 2. Hanover, MA, Now Publishers, Inc.: 63–127.
- Kunreuther, H. C., M. V. Pauly and S. McMorrow (2013). *Insurance & Behavioral Economics: Improving Decisions in the Most Misunderstood Industry*. New York, NY, Cambridge University Press.
- Mahul, O. and E. White (2013). Earthquake Risk Insurance. Knowledge Note 6-2: The economics of disaster risk, risk management, and risk financing, Washington, DC, World Bank. <https://openknowledge.worldbank.org/bitstream/handle/10986/16149/793930BRIodr0000Box377374BooPublico.pdf?sequence=1>.
- Marsh (2010). *The Marsh Report: Terrorism Risk Insurance 2010*. New York, NY, Marsh.
- Max, S. (2001). "Is Travel Insurance Worth It?" CNN, October 9. http://money.cnn.com/2001/10/09/insurance/travel_insurance/.
- McChristian, L. (2012). *Hurricane Andrew and Insurance: The Enduring Impact of an Historic Storm*. Tampa, FL, Insurance Information Institute.
- Michel-Kerjan, E. and C. Kousky (2010). "Come Rain or Shine: Evidence on Flood Insurance Purchases in Florida." *Journal of Risk and Insurance* 77(2): 369–97.
- Mulligan, T. S. (1992). "Florida Agency Orders Freeze on Insurer's Rates." *Los Angeles Times*, September 10. http://articles.latimes.com/1992-09-10/business/fi-453_1_hurricane-andrew.
- Munich Re (2012). "This Is Totally Different from Anything We Have Ever Experienced". *Topics Geo* 2011: 12–19.
- NAPCO LLC (2006). *The Impact of Changes to the RMS U.S. Hurricane Catastrophe Model*. Iselin, NJ, NAPCO LLC.
- Newman, M. E. J. (2005). "Power Laws, Pareto Distributions and Zipf's Law." *Contemporary Physics* 46(5): 323–51.

- Ng, J. (2012). "Insurance to Cost More in Areas Hit by Natural Disasters." *Asia One: The Business Times*, February 5. <http://news.asiaone.com/print/News/AsiaOne%2BNews/Business/Story/A1Story20120203-325702.html>.
- RMS (2004). *Northridge Earthquake 10-Year Retrospective*. Newark, CA, Risk Management Solutions.
- RMS (2005). *Hurricane Katrina: Profile of a Super Cat: Lessons and Implications for Catastrophe Risk Management*. Newark, CA, Risk Management Solutions.
- RMS (2008). *Terrorism Risk: 7-Year Retrospective, 7-Year Future Perspective*. Newark, CS, Risk Management Solutions.
- Schaad, W. (2002). *Terrorism – Dealing With the New Spectre*. Zurich, Swiss Reinsurance Company.
- Schoenberg, F. P., R. Peng and J. Woods (2003). "On the Distribution of Wildfire Sizes." *Environmetrics* 14(6): 583–92.
- Stahel, W. R. (2003). "The Role of Insurability and Insurance." *The Geneva Papers on Risk and Insurance* 28(3): 374–81.
- Stroud, M. (2012). "As Weather Gets Biblical, Insurers Go Missing." *Reuters*, April 11. www.reuters.com/article/us-insurance-disasters-idUSBRE83911S20120411.
- Swiss Re (2005). *Innovating to Insure the Uninsurable*. *Sigma*. Zurich, Swiss Reinsurance Company.
- Tversky, A. and D. Kahneman (1973). "Availability: A Heuristic for Judging Frequency and Probability." *Cognitive Psychology* 5: 207–32.
- Wilkinson, C. (2009). *The California Earthquake Authority*. New York, NY, Insurance Information Institute.
- Woo, G. (1999). *The Mathematics of Natural Catastrophes*. London, Imperial College Press.