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The Economics of Catastrophes

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Abstract

Catastrophes can profitably be thought of as economic events. This essay begins by considering the consumption of catastrophes, stressing the way that we disseminate information about them, and respond, possibly on a nonrational basis. Catastrophes are produced through a combination of actions by nature and humans. Due to inappropriate incentives, human actions often exacerbate outcomes. This is particularly true in "micromotive" situations, such as the AIDS epidemic, where actions by many players produce a collectively bad outcome. Mechanisms to prevent or ameliorate catastrophes—liability, insurance, and government regulation—are considered.

Key words: catastrophe, risks, incentives, micromotives, flood

Kobe, Japan suffered a disastrous earthquake in January 1995. Property damage was estimated at $30 billion. Most of this property loss will be borne in Japan, since it spreads little risk internationally. More than 5,000 people were killed, more than 25,000 injured. In purely financial terms—attaching values to life and limb that are implicit in decisions within affluent nations—this loss exceeds the loss of property. Catastrophes of this sort are major economic events.

This essay examines the economics of catastrophes, looking first to the issues of their consumption and production. Catastrophes are consumed directly by their victims, and somewhat less directly by those who through risk-pooling arrangements share in the victims' losses. Indirectly, information about catastrophes in news reports and concern about their possibility affect both welfare and actions of uninvolved others.

Most catastrophes are produced jointly by nature and humans. Nature provides the earthquake; humans build the inappropriate structures, and crowd them together so that fires are disastrous. Nature creates the AIDS virus, but humans engage in the sexual practices that promote its spread. The adverse consequences of catastrophes are increased when decision makers are given insufficient incentives to promote safety, or when institutional arrangements are such that our compensation or amelioration efforts are far out of line.

Catastrophes are by definition extreme events. As such, they tend to escape the attention of economists, who are most comfortable with large data sets, well-behaved functions, and readily understood phenomena. A central theme of this analysis is that catastrophes, like most economic phenomena, are both produced and consumed. Their distinctive feature is that they come as a big bundle.

An adequate economics of catastrophes should also help us as we seek ways to prevent and ameliorate them. The final portion of our analysis considers liability, insurance, and government regulation as instruments for prevention and amelioration, and concludes with some policy recommendations.

1. The consumption of catastrophes

To the individual, the loss of a loved one or possibly even a job is a catastrophe, an overwhelming loss. Everyday thousands of individuals die, thousands lose their employment; yet we do not count such events as social catastrophes: the events are not cognitively linked together. By contrast, when 130 people were lost in the crash of a USAIR plane approaching Pittsburgh in the summer of 1994, that was a catastrophe, but the 1,000 or so people who died in auto crashes that week were not.[1] This is the catastrophe mentality, whereby large concentrated losses are overcounted relative to dispersed losses. More generally, with catastrophes, perceptions are critical in defining losses and determining how individuals and society cope with them.

At least to some extent, the catastrophe is in the consumption. Thus, in the fall of 1994, Americans and Italians suffered a grievous loss when Nicholas Green, a boy of seven years, was killed by bandit's bullet as he and his vacationing family drove along an Italian highway. His family donated his organs to medically needy Italians, and the media spread the story around the world. Thus, good news, an act of extreme generosity, created a catastrophe from an event that would normally receive little attention.

From the 1950s through the 1980s, the greatest impending catastrophe was that of nuclear war between the United States and the Soviet Union. Many opinion leaders told us that the probability of a conflagration that would kill tens of millions of individuals was significant, certainly on the order of 1% per year. The clock of the *Bulletin of Atomic Scientists* chronicled just how close we were to "midnight." In the heart of the Cuban missile crisis, President Kennedy estimated the probability of a thermonuclear exchange at 1 in 3. But nuclear war did not come. Maybe it was luck, though many experts on nuclear weapons had always placed the probability well below the common perception.[2] Nuclear war would be the quintessential man-made catastrophe, with virtually no triggering event from the natural world. Interestingly, none of our usual mechanisms for mitigating catastrophes, such as insurance or a liability system, would have worked.[3]

The threat of nuclear war may still have been a catastrophe, however, if it caused considerable worry. In the past, few individuals spent much time worrying about an asteroid hitting the planet, but many more do now that Jupiter had its collision episode in the summer of 1994.[4] The AIDS epidemic kills 47,000 Americans in a typical year (Philipson and Posner, 1993), but causes significant anxiety to millions of others, not to mention losses of sympathy and empathy. And there are further costs—though some gains as well—due to changes in behavior to avoid AIDS.

Catastrophes cannot merely be measured by body counts or by resources lost. How these losses are publicized matters.[5] How many of us suffered an extra twinge of anxiety recently as we read about the flesh-eating killer bacterium that in rare cases quickly eats

away at the body? Yet this particular danger has been with us for years, just not much publicized.

When our concern is the consumption of catastrophes, it is worthwhile to distinguish between consumption effects before and after the event. The latter include direct losses to the victims, sharing of losses when there are implicit or explicit insurance pools (as say citizens share the burden when government disaster relief is granted), and losses of empathy incurred by those who are not financially involved. Haunting memories may also play a role. Before-the-event losses, to which we turn first, are primarily involved with consuming risk information; they are comprised of anxiety and the loss of peace of mind.

1.1. Catastrophes and information

Neither humans nor society deal effectively with information, particularly probabilistic information. That is, their decisions stray far from what the prescriptive science of decision analysis would recommend (see Kahneman, Slovic, and Tversky, 1982). This is a major reason why we do not deal effectively with catastrophes, which are low-probability events entailing large losses. If the probabilities of catastrophe are not appropriately assessed and if those values are not disseminated and acted upon, we must expect poor outcomes.[6]

To the extent that individuals consume the probabilities, rather than the outcomes, then substantial underperception is desirable. For example, if people merely worry about floods and can do nothing to prevent them or to reduce their costs, then it is best to alleviate their worries. However, underperception leads to inappropriate actions when preventive measures could be taken.[7] Kunreuther reveals the sorry story of the distribution of insurance.[8] Citizens fail to buy insurance, often even when its purchase is subsidized and falls well below actuarial value. Or, they purchase it shortly after a salient catastrophe, only to let it lapse soon thereafter. Absent insurance against the loss of resources, the costs of catastrophes are magnified, since individuals are risk averse and costs are concentrated. Publicizing the specter of catastrophe, if it increased insurance purchases, could improve welfare.

Viscusi gives us a somewhat more hopeful story. He shows that in the amounts which they demand for compensating wage differentials for risk, individuals do make sense of the probabilities of health loss from asbestos exposure. Their decisions yield implicit values for life that are comparable with previous findings. In this demonstration, Viscusi provides one more strut to an impressive structure that he has built over the years, showing that individuals can respond reasonably to risk information.

But there is a disturbing side to the Viscusi findings, and other work on asbestos. While Viscusi and the studies he cites carefully distinguish among risk levels that vary by more than a level of 1,000 among different groups of exposed individuals and between different types of asbestos, such distinctions are rarely drawn effectively in policy deliberations. Collective processes may exacerbate individual tendencies toward poor decision making

on probabilities.[9] Identifiable expenditures to remove a risk may be particularly tempting. Many financially strapped schools, for example, have found it necessary to remove at great cost asbestos imposing little risk because of political pressure from parents.

In more dramatic cases, vast sums have been spent to avoid hazards that impose minimal risks. Three Mile Island may be the best recent example in U.S. history. Although the leak of radiation was not sufficient to cause one expected additional case of cancer, this accident played a significant role in condemning the U.S. nuclear industry for at least a couple of decades; only widespread concern about global warming could potentially reverse this situation. Yet, all along, coal-based electricity generation has been far more hazardous to our health than nuclear power. The disaster at Chernobyl was a significant accident entailing substantial losses; it has had a chilling effect on nuclear power efforts in many parts of the world, though most experts had long believed that the plant was highly dangerous, while nuclear power plants in the West were quite safe.

The demise of new nuclear installations in the United States is assuredly due to the catastrophe mentality. Large concentrated losses get substantially overweighted. Coal-based electricity generation, by contrast, may be more lethal,[10] but the deaths which it induces due to air pollution are dispersed, and rarely can be traced back directly to the production process.[11]

1.2. Reputational externalities

Risks create reputational externalities. Thus, Chernobyl damns all nuclear power plants. To be sure, individuals should draw inferences from the occurrence of like events. USAIR, given five recent accidents, probably is more dangerous than other airlines. But a nonstop USAIR flight is probably safer than a one-stop flight on a competitor, and much safer than a journey that includes significant additional auto travel.

Sometimes the spread of risk information is useful. Thus, when prominent women have suffered and told about breast cancer, the level of self-inspections and mammograms goes up substantially. This is worthwhile, because, if breast cancer is caught early, it is dealt with more successfully. The increase in anxiety is outweighed by the number of early detections. But if not much can be done, or if the probabilities are grossly exaggerated, or if the occurrence of one disaster has little bearing on others that are superficially similar, then the publicity may be counterproductive. For example, a single act of hijacking has in the past led to the cancellation of many thousands of long-planned visits to Europe, whereas the risks associated with hijacking have never been as severe as the risks of heart attack from lugging a suitcase, or the fatalities from the substitute domestic auto trip.

Sometimes reputational externalities can dramatically shift the allocation of resources, even removing products from the market. This is what has happened with intrauterine devices (IUDs) in the United States. After extensive litigation over the Dalkon Shield, settled at large expense to the defendants, for which A.H. Robins had a compensation fund of $3 billion,[12] all other makers of IUDs in the United States removed their products from the market, despite the fact that there was no evidence of excess risk. It simply was not worth the effort to continue to defend the product.[13]

Policy debate now swirls around the use of chlorine-based compounds in the United States, important in the production of plastics, pharmaceuticals, and other chemicals. Greenpeace has targeted all chemical use of chlorine, and is seeking to capitalize on the inability of the public and/or Congress to draw appropriate distinctions between a few demonstrated cases of significant environmental risk associated with chlorine-containing substances, and a vast range of products where no dangers have been or are likely to be identified. To the uninitiated—including important decision makers—the reputational externalities are strong.

1.3. Scenario thinking

Kunreuther shows that individuals often insure against some risks, such as fire, but not against others, such as water damage.[14] The phenomenon of protecting against some risks but not others is quite common; it derives from scenario thinking. Scenario thinking occurs when individuals judge their risk exposure on a case-by-case basis rather than cumulating over cases to see in the aggregate how likely they are to be injured, whether physically or financially. Consider an individual who might lose her house due to a flood (F) or a hurricane (H). Between them there is a 1% probability, with the hurricane accounting for 7/10 of it. The individual is given two options. With A, all risk from the flood is eliminated, with B each of the two risks is cut by 40%. The ultimate probabilities are as follows:

Initial risks	(A) Eliminate risk from flood	(B) Cut both risks by 40%
F=.003 H=.007	F=0 H=.007	F=.0018 H=.0042

Option B is superior, because it offers a .994 chance of being safe, while option A offers only a .993 chance. I suspect, however, that many people would choose option A, since it totally eliminates one possible scenario.[15] A range of work in decision theory shows that individuals respond disproportionately to efforts that reduce risks to zero.[16] If scenario thinking is prevalent, that is, if individuals will respond disproportionately to eliminating risk for one scenario, and underrespond to changes in conditions in scenarios where some damage will occur no matter what, then singly and collectively they are likely to make poor decisions.

Many communities have installed levees that protect against modestly high waters but can lead to larger catastrophes in substantial flood conditions. Suppose that, if there is a flood, there is one chance in three that the waters will be 12 or more feet above normal, with two in three that it will be below that level. Without protection, there will be a loss of 100 when the water reaches 12 feet, but only 30 with the lower waters. One can build a levee for protection from 12 feet of water, but if the waters are higher, the levee will be breached, and the damage will be more severe than it would have been without protection. A second option is amelioration; one can secure some wetlands for flood protection, and this would reduce damage in either case. Possible values for this situation might be:

Losses from flooding

	No Protection	Levee protection	Wetlands amelioration
<12 feet	20	0	15
≥12 feet	100	150	80
Expected Value	47	50	37

If individuals fall prey to scenario thinking, they might well opt for protection, even though amelioration has a higher expected value.[17]

The tendency of individuals to underassess probabilistic reductions that do not bring a bad outcome to zero was recently illustrated by the reaction of AIDS activists to the cancellation of a highly imperfect AIDS vaccine, one that offered perhaps 40% protection against the disease. The activist community concurred in the cancellation of trials, waiting for a superior vaccine, though most decision analysts would have been delighted with the protection which the inferior vaccine would offer "along the way."[18] Not flying when there are terrorist incidents, though driving would impose far higher risks, is another example of scenario thinking.

Scenario thinking is just a special case of framing, which dramatically affects thinking about catastrophes. The way a decision is presented can dramatically affect the answers that are given. Peter Diamond recently constructed a potentially telling experiment related to saving wildlife injured in a catastrophe.[19] First, using willingness to pay, he inquires about an individual's utility function for the number of birds in an area. Then he suggest that a number of birds may be at risk, and asks the value to saving more of them. The experiment has not yet been run, but experts in the field expect to find diminishing marginal returns in both cases. Yet these two patterns are inconsistent, since the former implies concave utility for the number of birds, and the latter convex.

1.4. Celebrity catastrophes

Catastrophes are an informational event; they are consumed by many individuals who themselves do not directly suffer. In general, we should expect that their utility is diminished, since catastrophes represent losses, and most people are more empathetic than sadistic. When the catastrophe is relatively small and the publicity great, the collective losses to external consumers of the news may even dwarf the collective losses to the individuals affected.

When the bulk of the loss from a catastrophe is due to its external rather than direct consumption, we call it a celebrity catastrophe. The catastrophe's celebrity is the major cause of loss. Perhaps the most dramatic example which the United States has seen recently is the murder of Nicole Simpson and Ronald Goldman, and the accompanying difficulties of O.J. Simpson. In contrast with typical murders, of which there are unfortunately thousands each year, the utility consequences to the citizenry at large from this event have been monumental.

A celebrity catastrophe need not rob bystanders of utility value. Though there is widespread agreement that the Simpson situation is a tragedy, it has clearly provided extraordinary entertainment value for millions. The focus of much of the daily media on tragic events—murders, accidents, rapes—suggests that citizens do derive some positive utility from learning about such situations, though they may sympathize with the victim. Catastrophes that have purposeful human perpetrators and affect few direct sufferers seem to be the ones that are most likely to yield positive utility value to external consumers. Thus British tabloids collect and publish real-world tales that belong in the movies of Alfred Hitchcock, and sell many papers.

Hurricanes and earthquakes, oil spills and asbestos contamination do not fall in this category. In what follows, I focus on celebrity catastrophes that do not elicit pleasurable voyeurism, that is, catastrophes that provide negative external utility. The magnitudes of such catastrophes are difficult for individuals to assess. Consider three recent American catastrophes, the Yellowstone fires, the Mississippi—Missouri Rivers flooding, and the Southern California earthquake. All citizens had their utilities diminished by these events, but, summing across individuals, it is unlikely that the degree of diminution of nonaffected parties was even roughly proportional to the aggregate losses suffered by the victims.

Several methods have been developed to evaluate these external losses. One highly controversial approach is called the contingent valuation method, where individuals are asked—often in quite sophisticated fashion—how much they would pay to have avoided some catastrophe. The evidence suggests that such answers are unreliable. One of the most startling effects is called the embedding effect. If we ask about an oil spill, say, we may get roughly the same valuation for avoiding killing 1,000 birds, as 2,000 birds plus 2,000 otters, as opposed to all the wildlife killed in oil spills over a five-year period. Though the first losses are a strict and small subset of the second, and so for the second and third, the values given in response to questionnaires differ but little.

The embedding effect suggests that small catastrophes that are widely publicized have a far higher ratio of external to internal cost than large catastrophes reaping equal publicity. For example, in the summer of 1994, the murder of a single unknown priest in Haiti received widespread publicity in the United States, and consequently had more influence on U.S. foreign policy than the massacre of hundreds of thousands of individuals in Rwanda. Yet, the massive 1994 typhoons in China, doing billions of dollars in damage and leading to the deaths of 4,300, were hardly noticed.[20]

Economists may bemoan the significance of external consumption of celebrity catastrophes, and journalists may shout mea culpa. However, barring any change in our media system, we should recognize that the impact of a catastrophe includes not just the direct losses, but the costs that are felt by people who are not directly affected, including a loss of security, and the actions which they take in response. The importance of external factors also has implications for policy, in how we publicize catastrophes, and how we propose to deal with them. If rational action toward catastrophes is our goal, we should seek an objective and evenhanded mechanism for measuring losses to diminish the whiplash effects of valuations by unaffected parties.

1.5. Risks to lives

Many catastrophes—the 1994 Estonian Steamship Authority ferry (formerly Swedish ferry) accident that took 800 lives is a good example—primarily involve loss of life. Let us assume, contrary to reality, that we could deal with such risks efficiently. How much should we spend at the margin to avoid which risks of death? Viscusi (1994) tells us that workers receive from $3 to $7 million in compensating differentials for risk to their lives, and employs $5 million in his subsequent discussion. However, Viscusi considers situations where one or two lives may be lost at a time. Are lives lost in a catastrophe worth a different amount?

To those who die, a catastrophe is no worse than any other accident; to those who simply read about it, it is. Let us first think of the individual who might be subject to a loss of life. Say you are going from San Francisco to Santa Barbara and have the choice between a small commuter plane that seats eight and a regular aircraft seating 150. If the latter goes down, it will be a catastrophe that will make headlines and be recorded in almanacs. But from your perspective, the only consideration—assuming that comfort and cost are the same—is the probability of death. It does not matter who goes down with you.

From a policy perspective, looking solely to the victims, we should make the same marginal efforts per person to save people from mass murderers and large airplane crashes as we do from single murders and small plane fatalities. Economies of scales may dictate that we make more efforts inspecting airlines than small commuter craft, but not that we implicitly value a large bunch of deaths more highly than the same number that happen in small groups.

But what of the welfare of others, those who weep for the dead and suffer when they read the paper? There are two cross-cutting effects. If deaths are concentrated among individuals caring about each other, as say they might be from a tidal wave, or an aircraft carrying families, rather than isolated business people, then those who would have been most gravely injured by the death of another are likely to be killed as well. If the whole of an isolated village, say 200 people, is wiped out by the tidal wave, there will be no grieving spouses and children. How much worse would it have been to lose one person from each of 200 villages?

But what of the people, unconnected or marginally connected to those who die, who also grieve? If there are 200 isolated fatal events, many of them will escape public notice, whereas 200 concentrated deaths will be a widely perceived tragedy. If our concern is the empathetic costs of external observers, we want to know not just whether the 200-death incident is more likely to be reported, but how much more likely it is to be reported.[21] To an outside observer, is one 200-death accident more devastating than 70 accidents that each take one life? And will observers deduce that there are many more isolated deaths than the 70 observed?

Whatever the perceptions of outsiders, whatever the intensity of their preferences, how much should they count? If such values of the unaffected were really important, we should tax the world at large to make airplanes safer for the relatively rich people who ride them. And if outsiders really suffered, perhaps newspapers would not publicize tragedies so fully.

2. The production of catastrophes

Some catastrophes are due to nature's bolts from the blue; others are partly caused or exacerbated by human action. Tokyo and San Francisco are both located in earthquake zones, and human activity keeps adding to the value that may be destroyed when the Big One comes. Now we know that many recently built structures that collapsed in the 1995 Kobe quake had been inappropriately constructed. The floods along the Mississippi and Missouri Rivers in the summer of 1993 were created at least in part by human settlements up and down the rivers that had dramatically reduced the area of wetlands that could absorb excess waters, and some allege by extensive anti-flood works. The Estonian ferry accident was assuredly due to extreme seas and winds in the Baltic. But human error had failed to identify and transmit information about metal fatigue and an inappropriate door design.

The economics literature is filled with discussions of situations where inadequate or inappropriate incentives lead to undesirable outcomes. Indeed, the central concern of the principal/agent literature—see Pratt and Zeckhauser (1985)—is to get incentives structured so that the agent, say a manufacturer setting safety levels, takes appropriate actions for the principals, its customers. In the externalities context, appropriate incentives get the agent (generator) to internalize the costs which he imposes on the principals (recipients). In this context, catastrophes are situations in which one party imposes risk on many parties.

To understand how to cope effectively with catastrophes, we must understand their source. Even for nature's solo catastrophes, mortals can take ameliorating actions. Insurance policies can spread risks, and human activities can be located to diminish the losses say from hurricanes or earthquakes.[22]

When a combination of natural and human actions helps to create physical losses, we can write

$$L = f(N,H), \tag{1}$$

where physical losses are represented by L, N is nature's action, and H are the actions of humans.

How these physical losses translate into costs to particular parties is discussed under the headings liability and insurance below. The efficiency goal in coping with catastrophes should be to minimize the sum of all losses which they entail. We categorize those costs in two categories:

$$\begin{aligned}\text{Cost of a catastrophe} = {} & \text{cost of losses from catastrophe} \\ & + \text{cost of actions to reduce those losses}\end{aligned}$$

The first category includes the value of the resources lost, including lives, valued at the willingness-to-pay (WTP) of parties to avoid such losses. Holding total losses constant, spreading losses, say through insurance, would reduce WTP, because risk aversion will play less of a role. The second category includes preventive measures to avoid catastro-

phes, expenditures after the catastrophe to ameliorate damage, plus any increase or decrease in future catastrophes due to the way the current one is handled.

Say that, if society did nothing, we would suffer $80 billion in discounted expected health and environmental costs from Superfund sites. A hypothetical $100 billion cleanup would reduce those costs to $20 billion. This action would turn an $80 billion catastrophe into one costing $120 billion. Proper prioritization and choice of cleanup expenditures might lead to $30 billion expenditure and $30 billion in remaining costs. The third alternative should be chosen.[23]

We now turn to a classification of catastrophes paying particular heed to the actions of humans. For the first two categories, human actions play a minimal role.

2.1. Mere catastrophes

On September 7, 1994, a USAIR plane went down killing 130 people. This is a catastrophe, to be sure, but it is a mere catastrophe. The magnitude of the resources involved are not so great as to shift the marginal utility of money. To date, no one has shown that the crash occurred, because decision makers invested far too little in safety. In addition, the nature of the accident is such that it is appropriate to spend little on remediation, and little will be spent.

A mere catastrophe occurs when there is a big loss of value, but insurance appropriately spreads the risk. A mere catastrophe also requires that incentives be roughly appropriate for decisions relating to risks. Thus, a hurricane that wipes out a number of houses in an insured community is a mere catastrophe if the homeowners just recover the value of their lost property.

2.2. Magnitude catastrophes

In many cases the losses associated with catastrophes are concentrated on a limited number of parties. For example, the damage from the Chinese typhoon of 1994 was borne almost exclusively by the residents of China; and given the primitive insurance markets in that state, probably predominantly by residents in the affected regions.[24]

Finance experts have developed the useful concepts of generic and diversifiable risk. Diversifiable risks are large for an individual, but small relative to the overall economy. Generic risks are so large as to affect all individuals, assuming that they are spread. Nuclear war, a worldwide recession, or, conceivably, global warming are all generic risks. A magnitude catastrophe results when a risk that in theory is diversifiable is not spread sufficiently; risk aversion magnifies the costs of losses.

2.3. Amelioration catastrophes

When a catastrophe happens, we take measures to ameliorate its consequences—sometimes with great inefficiency. Our measures may be excessive or insufficient relative to the

situation at hand. For example, numerous analyses suggest that our expenditures on Superfund are dramatically too great given the risks involved. In many circumstances, we are eliminating risks at a cost in excess of $50 or $100 million per life saved. Spent elsewhere, these resources could save far more lives; we are paying far more than the implicit price for a life for the safety secured.

Sometimes the government creates the amelioration catastrophe. Viscusi raises this possibility for our policies toward asbestos: if, due to government regulation, we pay far more to remove asbestos than it is worth for the health risk avoided, that multiplies the original catastrophe.

Additional losses may also be incurred in the cleanup process. After a substantial disaster, say an earthquake or hurricane, some chaos must be expected. But when massive corruption or inefficiency creeps into the cleanup process, that increases the magnitude of the catastrophe.

Disaster cleanups are often occasions when prices rise precipitously. This is desirable to the extent that it draws in additional resources—for example, when additional workmen flowed into Miami after the hurricane—or redirects resources to their highest valued use—say repairing a church roof before a residential roof. But if there is little elasticity, hence little resource reallocation, accompanied by substantial increases in price, the perception of exploitation may play an unhealthy role in rupturing the social fabric.

Catastrophes present an intriguing time-money tradeoff. To rebuild roads and bridges more swiftly is assuredly more expensive, but it also removes unpriced costs from the community, say the inability to commute swiftly. Anecdotal reports suggest that the recovery from the recent earthquake in southern California went faster than expected. Extra overtime pay may be a good investment, as a means to speed the elimination of costs.

2.4. Claiming catastrophes

Even when only a few parties are involved, decision makers are willing to sacrifice significant value to all parties taken together to increase their own claims over resources in a potential catastrophe. Circumstances may well render transaction costs for an efficient deal prohibitive. That is, the losers may be unable to compensate the gainers not to undertake the value-wasting activities. Socially wasteful value-claiming activity is particularly likely when there is enmity between the parties. Such activities are the source of some strikes and many wars.

Claiming catastrophes arise when a party is willing to sacrifice significant total value to claim value from others. It would seem that Bosnia and Rwanda fall into this category. We need not inquire whether an extreme version of claiming catastrophes is at work, namely, some parties taking absolute pleasure from the diminished utility of others. (Such a situation should be contrasted with situations where A hurts B, because he fears that otherwise B will hurt him—though that situation as well may lead to catastrophe.)

2.5. Incentive catastrophes

Some catastrophes are produced because decision makers have insufficient or incorrect incentives to spend resources. If an unscrupulous employer can escape some of the costs of a workplace catastrophe which he may impose, then he may take the risk and skimp on safety. He is more likely to get away with this—say, than with offering lousy working conditions. Lousy working conditions are observable every day, whereas an inadequate safety level may be a probability of .001 that should have been .0001. Whichever level is chosen, the feared event is unlikely to be observed. Sometimes there will be solid indicators of safety—a sophisticated fire control system in a factory—but often not.

Catastrophic events usually call for investigations. After the fact, vast safety inadequacies are frequently identified. This is not all Monday morning quarterbacking. The decision maker may have been ignorant of the risks, or his incentives to ameliorate them may have been insufficient.

Assuredly, insufficient attention to risks in the past has created the toxic wastes cleanup problem which the United States now faces. Up until the past decade, the government was a principal culprit, failing to handle nuclear wastes appropriately as it constructed bombs. Efforts to deal with the government's dump sites are likely to cost more than $100 billion. Government agencies in decades past simply did not take into account the cleanup costs that they were imposing on the future; they were given no incentive to do so.

The private sector has its own toxic waste problem stemming from the past. Many firms simply dumped hazardous materials. They were not being monitored, and there were few, if any, penalties in place. Moreover, there is no indication that firms' stock prices of a generation ago reflected remediation costs that the firm would be incurring in the 1980s and 1990s.[25] Even when rules against toxic waste became much stricter, clandestine illegal dumping by some disreputable parties was still a problem. In sum, the incentives for proper disposal were not in place.

2.6. Ex post versus ex ante catastrophes

As Viscusi writes in this issue, asbestos has caused a significant number of deaths. Had we known the danger at the time, say from 1930 to 1970, we would have used far less asbestos. But was our decision to use that material poorly chosen? Given the risk awareness in that period, was it not reasonable to employ asbestos?

When after the fact a product proves to pose a risk far greater than had been perceived, we tend to have a selective process of sifting information. First, we are likely to think of only a few of the products that would have been removed from the market if we had discontinued using everything as risky as asbestos was then thought to be. Thus, for asbestos, we might think of all forms of insulation. But what about foodstuffs, pharmaceuticals, metals for household products? Second, we are likely to be able to identify the individuals who were already highlighting risks associated with the product. Even successful drugs usually have a past record of scientific reports of adverse reactions, which are eventually outweighed by a wealth of positive data.

The stock market provides an outstanding example of society's ability to retrospectively identify levels of risk. Newspapers regularly provide explanations of stock market movements that allegedly were available ex ante. For example, "the market fell because it was nervous about employment numbers that were coming out after the close." But surely the likely nervousness would have been known the day before. So if the market were expected to fall, it would have fallen already. Powerful aspects of self-delusion are built into Monday morning quarterbacking, whether the dangers relate to financial markets, toxic substances, or a failed double-reverse.

Shortly after the October 1987 crash, we saw the retrospection phenomenon in its greatest glory. Dozens of analysts pointed out all of the signs of why the market had been way too high, was precarious, etc. Few of them, however, had acted on their own insights. Catastrophic risks often fall into this category. Experts and laymen alike skillfully point out that we should have known.

Errors such as the use of asbestos up to the 1950s or, for that matter, the poorly designed and metal-fatigued door of the Estonian ferry are part of the price of living in a modern industrial society. We should not be too hard on ourselves in saying that we should have known. We must distinguish between reasonable decisions leading to bad outcomes, and bad decisions.[26]

3. Micromotives and the many-imposer catastrophe

While many catastrophes are the result of bad luck and bad decision making by a few actors, other human-assisted catastrophes seem to arise without any decision makers. In these situations, many individuals contribute to a risk, none playing a significant role in the overall outcome. This situation is discussed much less frequenlty than the one-imposer situation. AIDS may be the most salient example of a many-imposer situation. Since the impact on the general society is so great relative to the impact on self, self-interestedly rational choices may lead to highly nonoptimal outcomes—catastrophes that are too large and too often.

In his volume *Micromotives and Macrobehavior,* Thomas Schelling explores a range of situations where individual choices aggregate to produce collective outcomes that no one wants. Such an outcome might be traffic congestion rather than clear roads, an excess degree of segregation in an open-minded community, or an epidemic.

Some catastrophes result from, or are ameliorated or exacerbated by, the actions of great numbers of individuals. I do not discuss economic catastrophes, such as recessions or depressions, though they fall in this category,[27] rather, my concern is with catastrophes involving the loss of life, such as the flight of Rwandan refugees, or resources, such as a rapidly spreading fire amidst closely placed homes, none of which is sufficiently fire retardant. These catastrophes could have been substantially diminished if individuals had behaved differently.

The AIDS epidemic, like many epidemics, provides an excellent example. Let us assume that, in a sexually active population, the only choice is whether or not to wear a condom, where wearing entails a personal cost in both pleasure and dollars. Figure 1

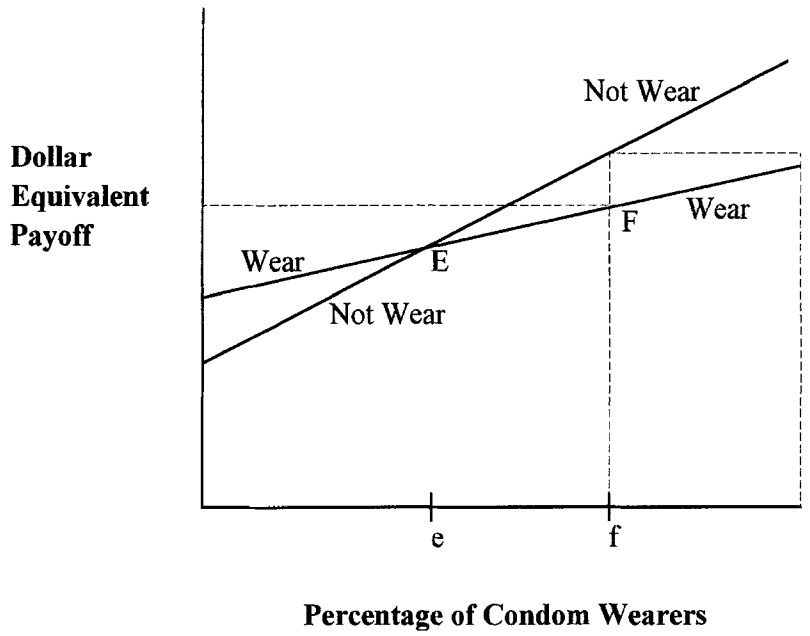

Figure 1. Use of condoms and AIDS.

shows the possible situation, where individuals are concerned both with disease and cost.[28] Equilibrium is reached at point. *E,* where the payoffs to wearing and not wearing are equal, and *e*% of the population uses condoms.[29] But total benefit is maximized at *F* with more condom wearers, namely, *f*%. This is where the sum of the dashed rectangles representing total payoffs to the wearers (left rectangle) and not wearers (right rectangle) is maximized. But the *f*% outcome cannot be sustained, since "not wearing" offers a higher payoff at that point.

The flight of the Hutus to Zaire is another catastrophe that resulted from the misalignment of micromotives with collective welfare. Every refugee who flees is rationally avoiding physical danger, but is imposing an extra drain on the limited food supply across the border.[30] Staying would benefit those who flee, and by maintaining food production and a presence in Rwanda itself, quite possibly stayers. The AIDS and Rwandan refugee catastrophes derive from situations where self-interested individuals may produce a catastrophic outcome that none of them wants. In some circumstances, some combination of ill will or irresponsible behavior on the part of many may produce a catastrophe. Breakdowns of civic order may fall in this category; so might massacres.

The curves above deal with situations where all participants are similarly situated. Frequently, a few instigators or an evil leader play a critical role, but, nevertheless, if the large numbers of others changed their behavior, the catastrophe could be avoided. Reports of the original massacres of Tutsis in Rwanda, for example, suggest that many of the killers undertook their actions, because they felt they couldn't resist, given the collective pressures to show solidarity through atrocity. In the riots of South Central L.A., some

heroes did stop beatings and lootings, but from the standpoint of the community, their numbers were too few. To understand how such catastrophes can be caused by micromotives, we should take as given the choices of the instigator or leaders. If enough of the masses refuse or resist, all may be better off.

From a moral standpoint, the greatest human catastrophes happen when human action purposefully hurts others. Such situations are awful when individually felt antagonisms by themselves are sufficient to promote such harm. They may be more tragic still, in that they might well have been avoidable, if the perpetrators were predominantly "going along."[31]

Economists, confronting micromotive situations, frequently propose that efficiency could be achieved if we merely charged each individual the externality that he imposed. This "solution" seems far too pat and unrealistic in light of such catastrophes as AIDS, or the succession of catastrophes in Rwanda.

3.1. Micromotive catastrophes as probabilistic phenomena

Many micromotive catastrophes are probabilistic, where ex ante there was a small chance of a highly adverse outcome. Let us simplify, and assume that the catastrophe is of a single magnitude, M, and that it occurs with probability p. Thus, the disease might or might not reach the proportions of a sustainable epidemic, racial antagonisms might or might not erupt into a race war, the Mississippi might or might not dramatically overflow its banks.

Let us consider a stylized version of the river-flood example. Individual landowners or cities can take actions, such as filling in marshes for real estate developments or building protective levees, that make the flood more likely.[32] Let us say that there are n decision makers with a binary choice, where a 1 promotes the flood probability, and a 0 does not. With m players choosing 1, we have $p = P(m)$.

Even if p or $P(m)$ were directly observable, we would have a severe incentives problem if the number of decision makers is large. Say there are ten equal-sized decision makers on the river. By choosing 1, they would reap any increase in expected benefits, but would bear only 1/10 of the extra costs. Too much risk would be taken, too many 1's would be chosen. Figure 2 shows the average and marginal costs of being an m, judged from the standpoint of the individual taking the action. Here $M = 100$. Say the benefit of choosing a 1 is constant at 1.[33] Then we will have six players choosing a 1 in equilibrium. Note that there will be a race to choose, since the six who choose 1 get a higher payoff than the four who choose 0. What is efficient, however, is to have only one person choose 1. Beyond that, for a gain of 1, there is a greater than a .01 chance of loss of 100.

Given such a situation, assuming rational choice, an absolute increase in the $P(m)$ function may be desirable, because it may deter some risk-imposing behavior, lead to a lower level of risk, and improve overall welfare. For example, if there were a critical mass point, a point at which the probability of the catastrophe rose rapidly, this would curtail risk-imposing behavior beyond that point. Tilting a portion of the $P(m)$ curve upwards could reduce the equilibrium probability of a catastrophe.

Of course, some ways of raising the curves could make matters worse. The general point, however, is that, to cut off risk-imposing behavior in the uncoordinated equilibrium,

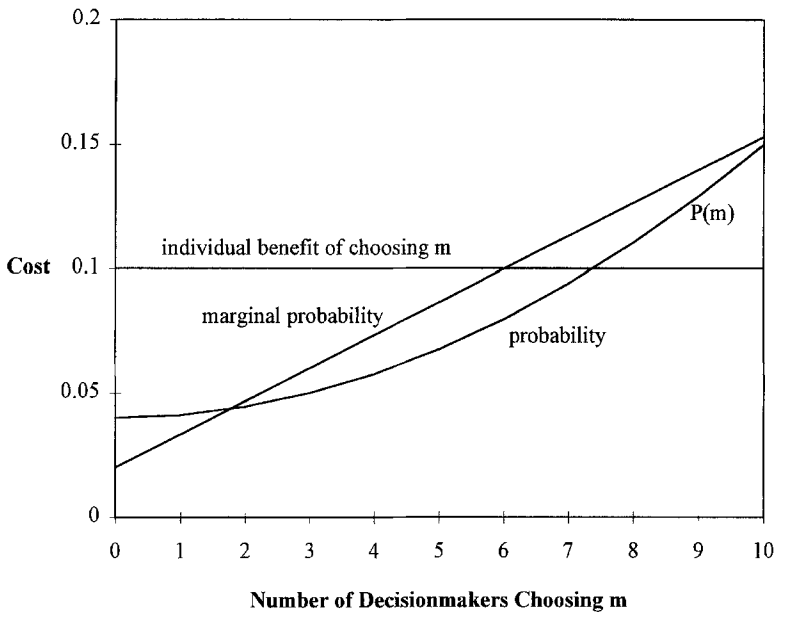

Figure 2. Self-interest and flood probability.

we need to have the *marginal* cost sufficiently high at some point. Any increases in the $P(m)$ curve offer a gain in deterrence but a loss in terms of increased risks created by the actions which we fail to deter.

Many catastrophes in the real world do not advertise how their probability will respond to alternative actions. Often, as with asbestos in the early years, we may even be unaware that there is a risk. Sometimes the political process tends to suppress the recognition of risk-imposing actions, as with the excess levee construction on the Mississippi. But even when risks are recognized, as when excessive crowding of buildings or their construction with highly flammable materials increases the potential for a massive conflagration, no decision maker can make a reasonable assessment of the costs that she imposes. As a consequence, even if there really is a critical point at which the probability of catastrophe begins to rise swiftly, it is unlikely to be recognized. (Ignorance is also a problem with unitary decision makers; ferries sometimes sink, because they are somewhat overloaded.)

To avoid micromotive catastrophes, it is desirable to have some party take responsibility for limiting the actions of individuals that increase common risks. One natural candidate is the government, which presumably takes into account the welfare of all parties, and is often called upon to deal with externalities. If some private party owns or can take responsibility for the resource at risk, and if it has appropriate policing or taxing powers, it can also create the appropriate incentives. Thus, a college polices its students, preventing, say, dangerous drug-taking activities, and an airline has ample incentive to ensure that its passengers are not intoxicated or carrying a weapon. Insurers have a natural incentive to control their policyholder's risks, and can charge less for fire insurance, say, if a

sprinkler system is installed. But insurers do not have incentives to attend to externality risks; only if an insurance company provided most or all of the insurance for a particular resource at risk could it be relied upon to induce appropriate behavior. A company that insured all the houses in the neighborhood would charge both the direct and externality costs associated with excessively flammable dwellings. There are two difficulties in relying on insurance companies for such activities: first, insurers wish to diversify; and second, if a large insurer were covering most individuals subject to a risk, a new insurer could underprice it be selling a single policy and ignoring the externality risk.

The potential victims of a catastrophe have an incentive to control the externality risk, whether they will suffer directly, or whether they are insured, but will reap benefits of risk reduction through lower premiums. If transaction costs are low enough, such individuals can act collectively to reduce their risks. Thus, fraternities limit bad behaviors by their members, and city governments establish fire codes for buildings.

4. Approaches to preventing and ameliorating catastrophes

There are two major economic problems in dealing with potential catastrophes: reducing their magnitude, and spreading the risk of whatever losses do result. Equation (1) represented physical losses from catastrophes as a function of natural occurrences and human actions. But the costs of such losses, $L = f(N,H)$, in terms of loss of human utility, will depend on how effectively they are spread and how they affect future decisions. Risk spreading is desirable, because individuals are risk averse with respect to losses. A catastrophe imposing $1 billion in damage in the U.S. would cause much misery if it caused 100,000 people to lose $10,000 each. But it would be of fairly minor consequence if each American lost merely $4.

The way in which we pay for catastrophes will affect incentives for future preventive actions. For example, if the injuring party is charged much less than the costs that it imposes, its future actions will be too reckless. By contrast, if it is charged more than the damages created, it will be too cautious. Society as a whole will sacrifice resources in either case.

Represent the degree of risk spreading created by the instruments for dealing with castastrophes as S, and the incentives which they create for the future as I. Then we can represent the cost, C, of a loss due to catastrophe as

$$C = g(L,S,I). \tag{2}$$

In measuring this cost, we are summing across individuals, employing certainty equivalent values, since costs are probabilistic. If risk spreading is costless, the greater is S the smaller will be losses. If we think of I as the magnitude of the incentive to avoid future catastrophes, C will diminish with increases in I, reaching a minimum when I is set equal to the cost of the current catastrophe, just the right value. If I is set higher than this value, then costs will be increasing.

The two major private-sector responses to catastrophes, liability and insurance, change the incidence of catastrophic losses, and hence incentives. Liability is primarily oriented to situations where a second party brings damages to a first. Insurance allows individuals to protect themselves. The primary purposes of these two mechanisms are, respectively, to promote equity, by making the risk-imposer pay, and to spread risk. If well designed, they also promote efficient risk decisions. Insurance, which in isolation attenuates incentives to control losses, will promote efficient decisions if premiums are appropriately calibrated to the insured's behavior and experience.

Government safety regulation complements these two mechanisms in an effort to achieve efficient risk levels. Jobe (1994) assesses the effectiveness of the insurance and reinsurance markets in spreading the risks of hurricane losses. He identifies tax and accounting rules that impede the effectiveness of these markets, suggesting that public (tax), nonprofit (accounting standards), and private efforts do not coordinate well. Neither liability nor insurance is ideal, either in theory or in practice, and government regulation, assuredly, cannot make up for their deficiences.[34] Other articles in this issue provide ample evidence for their failings in practice; this article focuses primarily on theoretical shortcomings.

4.1. Liability

The efficiency principle behind liability is simple. If A is a potential damager of B's property, then we should charge A for any actual damage to B's property, so that A will have a proper incentive to take B's welfare into account. In practice, transaction costs impose a major difficulty. For example, less than half of the Superfund expenditures to date have gone to actual cleanup; legal and consultant fees have taken a larger bite of the pie. Weiler et al. (1993) have examined the medical malpractice arena, and find that only a small percentage of the individuals who are injured receive any compensation. In addition, in virtually every liability situation, there is significant difficulty in establishing who is responsible.

But let us say that we lived in a world where, once a case came to court, it would be possible to determine costlessly precisely what happened. Still, appropriate incentives would not emerge from current practices. For example, say Jones, who lives downstream from Smith Chemicals, converts from raising and harvesting timber (presumed to be resistant to chemicals) to growing flowers. If the chemical plant is sloppy with waste disposal, and leaks chemicals that kill the flowers, we would all feel that Smith should pay whatever damages are incurred. However, such a solution is in some sense inefficient, since too many decision makers who live in the neighborhood of chemical plants will choose horticulture over lumbering.

This problem is not so serious where physical injury to a human takes place—there are strong incentives to avoid such accidents. But when resource losses alone are involved, the problem may be severe. Too many people will fish where the oil tankers go by, knowing that if there is a spill they will be compensated. The committed student of Coase will argue, "no problem." If transaction costs are low, we need merely ask the potential injurer

to bribe potential victims in advance of any accident to take actions that will reduce damages. Unfortunately, the transaction costs are almost certain to be large. First, many transactions will be necessary: dozens of firms and thousands of individuals may reside downstream from the chemical plant or may fish the waters on the tanker route. Second, unless the potential injurer can virtually establish property rights over the entire area of possible injury, new individuals will arrive and risk injury. Bribing 1,000 fishermen not to fish in a particular area will merely make room for another 1,000 fishermen. The difficulties for truckers of chemicals, who would have to negotiate with everyone along their path, would be insurmountable.

In general, therefore, we have found it beneficial to contract with parties after damages have occurred, which substantially reduces transaction costs, but raises costs in other areas. A primary difficulty is that although every case creates a precedent, the parties to the lawsuit will have insufficient concern for the future. This difficulty is particularly true of catastrophes, which are rare events that are unlikely to involve the same parties in the future. It is unlikely that either Exxon or the Alaskan fishermen will be involved in a catastrophe equivalent to the Exxon–Valdez spill in the foreseeable future, yet what has been decided in this case will have profound effects on oil-shipping practices in the future. Moreover, catastrophes generate passionate feelings in adjudicators, not just the parties involved, which will tend to impede the search for efficient solutions.

Let us say that Exxon's total costs for the spill turn out to be $8 billion. Assume further, contrary to reality, that any firm shipping oil in the future would be charged an equivalent amount for an equivalent accident. If the damages were truly $8 billion, then appropriate decisions about double-hulled tankers, routings, spare captains, and the like would be made in the future. But if the true costs were far lower (or higher), then other shippers would take excessive (or insufficient) precautions. It is difficult to assume that the damages which Exxon paid were accurate, since, until the decision was made, there was a reasonable prospect—as Jimmy the Greek would present the odds—that the award would be far higher or far lower. Indeed, $15 billion, the amount which the plaintiffs demanded, was a distinct possibility; yet, there is some evidence that the long-term ecological damage to Prince William Sound was negligible.

Contracting over payments surrounding catastrophes—low-probability, high-consequence events—is much less efficient than contracting over more normal losses. For example, if a dress manufacturer fails to deliver to a department store, the ability to determine losses is much simpler; and if there is a long-term relationship between the two, and the costs of the one missed shipment are small relative to ongoing benefits, then both have an incentive to get the price right.[35]

The Exxon–Valdez fishermen situation is far different than the supplier-store situation. The former event will not be repeated. Moreover, the oil spill decision affects other parties. If the damages are set too high, then future oil shipments will be conducted in too safe a manner. There will be too few spills, and the cost of oil and its derivative products will be too high. The citizens of San Francisco, who benefit from Alaskan oil, will pay too high a price in the future. These consumers were not represented in the Exxon litigation; with the store and dress supplier, all relevant parties are included.

The more repeat transactions there are with the same group, the more confident we can be that safety levels will be established efficiently through litigation. Thus, we might expect inefficiency with breast implant compensation, but not with compensating differentials for workplace injuries. With workplace safety, the unions, the courts, the workers in general will have an incentive against setting unrealistic awards, since such injuries are a common event. Women who suffer (or are believed to suffer) ill effects from breast implants are unlikely future victims, and are unlikely to receive future benefits from the manufacturers, as employees do from their firms.

After a workplace catastrophe, however, our assurance that appropriate attention will be paid to future incentives, or that the outcome will be what would have been decided ex ante, vanishes. The public in general and the jury in particular are likely to be exposed to information outside the courtroom setting. There may be a tendency to believe that an accident injuring one or a few people could happen inadvertently, but assuredly not a catastrophe. The individuals involved, say the workers at the plant or indeed a whole union, may recognize that the losses to be compensated in this accident will outweigh discounted expected losses as we look into the future. No holds will be barred in terms of seeking compensation and neglecting efficiency implications.

Consider, for example, the Bhopal tragedy, which raised the question of what level of damages should be paid to the Indian victims. Think of this from the Indian perspective. Does it not make sense for a U.S. firm to pay as much for an Indian life as it would for an American life?[36] The case, which received so much attention, also has the effect of signaling to the world the way in which Indians value their own lives. The 2,000 odd people who were killed are a great number relative to the number who are likely to be killed in foreign-owned Indian workplaces in the near future. Even assuming that all foreign investors would take the Bhopal price as indicative of what they would have to pay in the future, it would be worth jacking up that price. The actual charge to Union Carbide was $470 million, even though it was never convincingly demonstrated that sloppiness by Union Carbide was responsible for the accident.

In summary, quite apart from transaction costs, the parties to a situation where one may injure another are likely to behave best if they are in a repeated transaction where any losses will be small relative to future benefits. When a low-probability catastrophe occurs, all bets are off. Although such a catastrophe may not have major future implications for the contracting parties, it may have substantial efficiency implications for other participants in roughly parallel circumstances. Excessive payments or charges relative to the catastrophe may lead to excessive safety efforts in the future, and insufficient damages may lead to insufficient safety efforts. The period after a catastrophe is not a good time for sound minds and clear heads to prevail, yet it is difficult to contract in advance as to what charges will be paid. Sinfield (1994) traces the history of asbestos liability claims. He finds that the liability system has worked poorly. In effect, he asserts, the rules of the game were changed after the fact in favor of plaintiffs and against defendants, and hence their insurers. The changes were achieved through the actions of an emboldened and aggressive plaintiff's bar, supported by unions and an activist judiciary. He finds that political passions play a major role in affecting how human adjudictors distribute the costs of catas-

trophes.[37] Not surprisingly, the experience has been far different with hurricanes, where it is hard to point at "guilty" human parties.

There is a second possible consequence if excessive charges may be imposed when an unusual catastrophe arises. Resources may pass from strong to weak hands, in an effort to make the risk-imposing entity judgment-proof. Thus, it would not be surprising to discover that some small entities ship oil on behalf of the major oil companies. The saved liability and damage costs will reduce the cost of shipping. (There is clear evidence that the damages in the Exxon–Valdez case were established in relation to Exxon's annual profits.)

4.2. Insurance

In theory, insurance can provide appropriate incentives for parties to reduce costs to themselves through actuarially fair rates for any risks that are covered. In insuring buildings for fire insurance, therefore, brick construction will cost less than wood, and a sprinkler system will reduce costs. Kunreuther argues that such actuarial pricing is far from fully effective. The author, for example, has 80-year-old knob-and-tube wiring in his house. He has received conflicting assessments on the safety of such wiring. Presumably, his insurance company has reliable information on this score, but it takes no account of it in setting his fire insurance rates.[38]

Fair actuarial pricing for catastrophes is much more difficult than it is for small accidents. Insurers have a great deal of experience with events that happen dozens of times a year in a workplace, but relatively little with events that happen once in 100 years. There is no prior reason to assume that the latter are proportional to the former, or indeed that the measures that are best equipped to curtail the former will also curtail the latter. In dealing with catastrophes, insurers are handicapped, because they just do not have the experience.[39]

A decade ago, economists would have discussed at length how Lloyd's of London looks across a great range of possible catastrophic losses and manages to set roughly appropriate rates through a competitive process. Given the substantial risk aversion of the insureds, moreover, even a substantial premium for taking risk and dealing with adverse selection meant that desirable insurance would still be written. There are many explanations for Lloyd's difficulties, but one is undoubtedly the firm's failure to anticipate the common risk of a litigation explosion.

Insurance that is adequate when purely physical risks must be gauged is unlikely to be adequate when one-time political risks must be judged, such as the risk that legislatures and courts will dramatically increase the amounts and frequency of awards. One solution to this problem would be to cap insurance payouts, but this would eliminate one of the major benefits of insurance, protection from extreme losses.

Witnessing Lloyd's struggle for survival, and reading the evidence provided by articles in this issue, which identify the possible problem of insurance company solvency in case of major catastrophes, and the incomplete workings of reinsurance markets, one is left to

conclude that in many instances insurance may not be the appropriate instrument for protecting us against catastrophe.

4.3. Government safety regulation

Government safety regulations often complement the liability and insurance systems to provide protection against catastrophe. Thus, when we are worried about earthquake or hurricane damage, building codes that require appropriate structures may be part of the solution. The asbestos crisis has been substantially affected by government regulations requiring its removal. To curb the AIDS epidemic, the government may close down bathhouses, or other locales where the disease is spread.

Any such measures reveal that either the liability and insurance systems are not working fully effectively, or that the government is not well-suited to allow them to work. That is, the government cannot idly stand by while people are dying, even if that would be the right policy. Economists are quick to debate when government regulations are superior to liability systems, and whether appropriate government measures for safety should involve standard setting or taxation.

This discussion may be appropriate when the subject is clean air or water pollution, but it is barely germane to the regulation of low-probability catastrophic risks. Viscusi (1994) reports that EPA and OSHA asbestos standards implicitly values lives at $144.8 and $124.1 million, "one of the least cost-effective risk regulations ever issued by a government risk regulation agency." Given the potential for such out-of-line regulations, the critical issue in choosing one's mode of intervention may not be whether it is a standard or a tax, say, but rather the tool's order of magnitude. Even if we agree that an ideal tax would be superior, it is important that it be set at the right level, not 1/10 of or ten times its optimal level.

5. Some policy recommendations

Most catastrophes arise from the complementary actions of humans and nature. Nature may shake the earth or release the virus, but human action puts buildings in the wrong places and spreads the disease. Our efforts to ameliorate catastrophes are often woefully misguided. Insurance is often inadequate—only 3% of the homeowners in the prefecture where Kobe is located had insurance.[40] Misaligned incentives may induce decision makers to take excessive risks. Government regulations respond to political pressures, not just to concerns for the appropriate expenditure of resources; they may be far too lax or stringent. And human decision makers have great difficulty in interpreting the small probabilities and large consequences that are associated with catastrophes.

Since catastrophes are distinctive—an earthquake is hardly an epidemic—different policy tools are required for each type. But some lessons may apply to a range of situations where extreme losses threaten. A few are outlined below.

1. Identify big threats. Celebrity status, chance occurrences, and media sensationalism are not the appropriate way to identify potential catastrophes. It would be better to conduct more forums, such as this one, securing input from experts and citizens to identify catastrophes on an ex ante basis—recognizing that many potential catastrophes will never occur.

For large threats, it seems worthwhile to undertake some minimal planning. For example, let us assume that the costs of a Big One in Tokyo, equivalent to the Great Kanto earthquake of 1923, could be $1.2 trillion, a sum that simply dwarfs what we have lost in all large earthquakes to date (Shah, 1994). Appropriate planning might determine what protections, if any, there should be against Japan's selling its foreign assets and bringing the proceeds home. Such prohibitions, incidentally, might be beneficial for Japan, if they prevented a fire sale of massive proportions.

Right now, global climate change is by far the hottest environmental topic. There is a realistic prospect that some international agreement will be reached in the coming years that requires many countries to sacrifice annual amounts equal to, say, 2% of GNP.[41] This amount too will dwarf what we are currently spending to deal with catastrophes. Is global warming a threat that merits expenditures of that magnitude?

2. Limit collections to efficient compensation. We argue above that there are many terrible events where utility losses are great, but where the marginal utility of money is not substantially affected. The death of a child is such an event. In such cases, a rational individual should not insure against the event, since his ability to turn money into utility has, if anything, diminished.

Transaction costs would be far lower, and compensation more efficient, if courts were not allowed to pay for pain and suffering or for wrongful death. Individuals who might be killed should have their own insurance (or its equivalent, such as workmen's compensation).[42]

3. Force government regulation to be guided by risk-benefit analysis. Given that insurance and liability systems do not work perfectly, we much expect that government regulation will be an adjunct to these systems. Yet the evidence suggests that government risk regulation is often grossly inefficient. The implicit values of lives saved across risks regularly vary by a factor of 1,000. Presently, we have controversial presidential orders on the books that permit the Office of Management and Budget (OMB) to provide some guidance to regulatory agencies for computing risk and benefit levels; exactly what is required is hotly debated in the courts; and the outcome to date is certainly unsatisfactory. Congress, in part seeking to avoid blame, generally passes regulatory responsibility to the agencies, at best sketching broad guidelines. This is understandable, and probably cannot be reversed. But Congress could pass broad legislation requiring that agencies adhere to risk-benefit guidelines, and that OMB impose consistency across agencies.

4. Design systems that search for the least consequences from cognitive error and agency loss. Individuals have a difficult time making decisions under uncertainty, and they do particularly poorly when making such decisions on behalf of others. Congress, insurance companies, and the liability system fail to create satisfactory outcomes. This should be recognized, and we should attempt to design systems for compensating for catastrophes that do as best we can in a second-best world. Government regulation should not substitute for imperfect private sector decision making just because that latter will be imperfect; the government will be imperfect, too.

5. Get the levels right in our portfolio of safety-promoting instruments. We are most familiar with the problem of widely divergent standards in the context of government regulation. However, the Weiler et al.'s (1993) evidence with malpractice and the Exxon case suggest that the liability system may work poorly, and Kunreuther provides depressing evidence on the efficacy of insurance. Rather than debating the relative merits of these three techniques, we should seek to design a system that capitalizes on the strength of each. Our present system of dealing with catastrophes has been a process of separate evolution in each of three areas, with nothing like natural selection to ensure that the evolutionary processes were desirable, either separately or taken together.

Individual catastrophes, involving massive losses of life and resources, grab vast policy attention and frequently elicit reflex policy response. Reforms in individual arenas, say in the liability system, come only in response to crises, such as the vast escalation in insurance rates which we witnessed in the 1980s.

Policy toward catastrophes should be formulated in a dispassionate manner, starting with a careful look at the relevant empirical facts concerning the range of possible catastrophes. Epidemics, toxic substances, and hurricanes will always be with us, but the costs which they incur, both directly and in coping, can be reduced with effective policies for insurance, the liability system, and government regulation.

Acknowledgments

Participants in the Stanford Conference on Social Policy Toward Catastrophic Risk and KSG colleagues provided useful comments. MIT Economics offered hospitality. NSF provided research support.

Notes

1. For discussion of biases in perception of catastrophic risks, see Fischhoff et al. (1981). The role of media coverage in generating these misperceptions is documented by Renn et al. (1992).
2. Thomas Schelling, a recognized authority on nuclear war, and conflict more generally, suggests that in the 1960s his friends who were experts in this field probably assigned a 5% chance to nuclear war over a

20-year period. By 1970, this had fallen to 1%, and by 1980, it had become even lower. "In the early 1980s, numbers like 10^{-4} might have been reasonable" (Personal communication, September 8, 1994).

Part of the divergence may be explained by difficulties which individuals have in assessing probabilities, particularly small probabilities. See Kahneman et al. (1982) and, for particular applications to risk, Zeckhauser and Viscusi (1990).

3. The author worked for an insurance company in the early 1960s. At his company, it was understood that there would be no payoffs to policies in case of a significant war, due to the loss of the asset base, but it was concluded not to write such a clause into insurance contracts.
4. Scientists have estimated our risk of death by a "doomsday rock" as being 1/6000 (See the *New York Times*, 1991). Given that they are scientists with an interest in this scenario, this estimate may be excessive.
5. How losses are divided up also matters, a subject to which we turn to below.
6. Breyer (1993) cites evidence showing that experts' rankings and civilians' rankings of environmental threats are substantially at variance.
7. Some organized religions, for example, elaborate hellish contingent futures as a means of changing current bad behaviors.
8. See Kunreuther et al. (1978). In Kunreuther (1994), he complements his important past work that documents incisively the difficulties individuals have in making wise insurance purchase decisions.
9. Full disclosure requires the author to reveal that he once spent $2,000 to remove tiny amounts of asbestos from his basement, though it might well have been safer to wrap it.
10. EPA estimates that the monetary loss equivalent value of the SO_2 mortality deaths from coal-fired power plants are enormous (See U.S. Environmental Protection Agency, 1988).
11. Interestingly, countries such as Japan and France have managed to continue and expand their nuclear programs.
12. *Wall Street Journal*. (1989).
13. Excessive transaction costs hurt plaintiffs as well. It is estimated that the average share of compensation that plaintiffs devote to legal fees in the typical tort liability case is 30% (See Kakalik and Pace, 1986).
14. He ultimately recommends that we develop "all-hazard" insurance. Beleaguered Californians—who have suffered riots, earthquakes, and floods in recent years—would surely agree.
15. See Kahneman and Tversky (1979), for a discussion of the perceived virtues of pushing probabilities to zero.
16. The Russian Roulette example asks a bachelor how much he would pay of his lifetime income to get rid of one bullet out of two in a six-barreled gun, assuming that he would have to spin once and aim at his temple. It then asks how much he would pay to eliminate one out of one bullets. The answer given to the second question is generally greater. In theory, the first should be greater, since there is already some probability of death, in which case money is worth less.
17. The choice of such an action would be consistent with prospect theory, which finds that individuals are risk seeking with respect to losses (Kahneman and Tversky, 1979).
18. To the extent that there is some herd immunity, a 40% effective vaccine might offer much more than a 40% reduction in new cases of the disease. On the other hand, the vaccine might lead to riskier behavior, hence more negative externalities. If this response is strong, the vaccine could even diminish welfare.
19. Personal communication (September 1994).
20. Weather catastrophes in China are potentially relevant to the global warming debate. The most likely weapon against such warming is to dramatically curtail carbon emissions. China, with her vast coal supplies and burgeoning growth rate, will be a major source of carbon emissions absent a considered policy to curb them. International financial inducements would promote such curbs, as would weather catastrophes, assuming that the latter are linked (as many suspect) to global warming.
21. A bunching of fatal commuter aircraft crashes in the fall of 1994 secured attention and policy concern, which suggests that public notice is important, and that perception of losses does not necessarily increase more than proportionally with the number of deaths.
22. Preston (1994) studies the outbreak of a fatal, extremely contagious monkey virus in a laboratory near Washington, D.C. Fortunately, it was not able to infect humans. Preston attributes a significant threat of

unknown viruses creating widespread fatalities, AIDS being but one example, to human actions disturbing the natural ecosystems where such viruses were confined.

23. Hamilton and Viscusi (1994) demonstrate that current Superfund targeting is woefully inefficient. For example, most of the expenditures go to sites where there are no current residents, but where there is a concern that future residents will come in. In most cases, it would be far cheaper to exclude future residents. Targeting to sites where there are current residents, the authors find would dramatically increase benefits for any level of expenditure.
24. There have been nine typhoons in China this year, in contrast to the usual five or six. The damage has been $17.4 billion; 4,300 people have died (*Los Angeles Times*, 1994). These massive disasters have received virtually no attention in the United States.
25. Some of these costs ultimately got shared by other firms which used the same site, perhaps many years later, or purchased the dumping firm unaware of its past.
26. Some bad outcomes, of course, are due to bad decisions. Our failure to address smoking risk until the mid-1960s, despite ample information demonstrating dangers, is a case in point.
27. A recession might easily be avoided if all citizens would behave as if boom times were underway. Sometimes an action by government (such as federal deposit insurance to avoid bank runs) or an external party may help stave off a disaster. In other circumstances, such actions may shift equilibria. Presumably the latter was the purpose of the U.S. bond guarantee following the Mexican peso crash of December 1994: to restore investor confidence, make a reasonable equilibrium a focal point, hoping thereby to prevent a financial collapse.
28. The diagram is drawn for the case $W(x) = 350 + 25x$, and $NW(x) = 300 + 125x$, where x is the percentage of condom wearers, and W and NW are functions giving payoffs to wearers and not wearers.
29. To simplify, I do not distinguish between sexes, worry about people wearing condoms sometimes but not other times, etc. As drawn, the wearers derive small benefit as the percentage of other wearers increases, say because condoms offer imperfect protection. The result would be fundamentally the same if the "wear" curve were horizontal.
30. In this particular instance, there is even the question of whether most of the Hutu refugees would not have been better off staying home, given the forbearance of the new regime.
31. Some might argue that satisfying antagonisms by harming others, though hardly justifiable, does provide some benefit.
32. The early assessment that levees may have promoted the 1993 flood has been questioned. "During large events such as occurred in 1993, levees have minor overall effects on floodstage but may have significant localized effects" (Interagency Floodplain Management Review Committee, 1994, p. 50).
33. This seems reasonable for the real estate development choice, since the risk of flood does not dramatically affect value. However, the benefit of the levee increases in direct proportion to the probability of a flood. The diagram is drawn for the function $p = p(m) = .028 + .02m^2$.
34. The government sometimes acts as a direct insurer, particularly when it is believed that private insurance markets will fail. Government has fundamental deficiencies as an insurer, however. For example, as we saw in the savings and loan debacle, political pressures tend to prevent it from charging premiums on the basis of risk characteristics, or from blowing the whistle on high-risk practices.
35. Indeed, in many ongoing relationships, nothing is charged for disappointing performance within a range. A regular customer at a restaurant may complain that the beef was a little tough tonight, but he would not think of demanding compensation. Nevertheless, the restaurateur may offer compensation, say free after dinner drinks. A satisfactory theory of trust, as yet unwritten, could explain why long-term relationships do not generally employ compensatory charges for disappointments along the way.
36. The usual compensation in such situations is the deceased's present value of lost earnings net of consumption. This works out to roughly 40% of discounted present earnings, and would have given a comparatively low value for individuals with the average earnings of Indians (W. Kip Viscusi, personal communication, October 1994).
37. It could be argued that politics remedies a previously unjust situation. But, even then, if decision makers have relied on preexisting rules, both inefficiencies and injustices will be created by changing the rules.
38. In recent years, the pricing of auto insurance has attracted a considerable amount of attention. Part of the

issue has been the overall rate level, and massive givebacks have been imposed in New Jersey and California. A second issue has been the cost to high-risk groups. Massachusetts, under the leadership of Insurance Commissioner James Stone, imposed a system of rather substantial cross-subsidies in the 1970s. It is not surprising that former Commissioner Stone now runs a highly successful casualty insurance company, capitalizing on his company's ability to sell disproportionately to people whose rates are higher than their experience would predict.

39. The three insurance lines that had the greatest financial difficulty in the mid-1980s were environmental, product liability, and medical malpractice. Each of these experienced events that altered the normal loss pattern, and the companies had not allowed for these changes because of their reliance on classical statistical assessments for rate setting.
40. *New York Times*, (1995). The explanation was: "Earthquake insurance is rare because of high premiums."
41. It is generally expected that substantial portions of these expenditures will consist of payments by developed countries to get developing countries to take environmentally beneficial actions. Yet most developing countries appear to be more vulnerable to warming, given their already high temperatures, their susceptibility to heat-related (e.g., insect-borne) diseases, and their heavy reliance on outdoor agriculture (Thomas Schelling, personal communication, October 15, 1994).
42. Under present circumstances, where wrongful death looks at future earning power, a rich man essentially gets a cheaper ride in a taxi than a poor person, since he will recover more from the company should there be a fatal accident.

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