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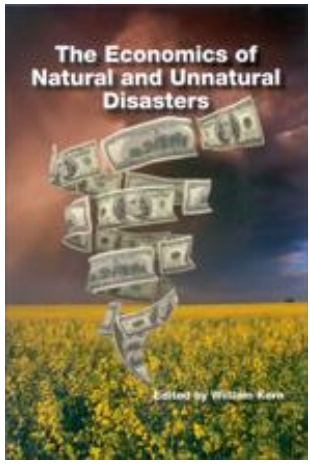
# Expectations and Unexpected Consequences of Public Policy toward Natural and Man-Made Disasters

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# The Economics of Natural and Unnatural Disasters

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# 3
# Expectations and Unexpected Consequences of Public Policy toward Natural and Man-Made Disasters

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For the purposes of this chapter, I define disasters very generally as large, sudden, infrequent occurrences that are difficult to forecast and that result in significant economic loss in the form of output, income, property, and life. Particular attention is given to disasters that are geographically concentrated as opposed to events like global depressions. This definition is broad enough to cover such disparate events as a regional recession, earthquake, hurricane, drought, oil spill, or terrorist attack.

A general approach to disasters has three advantages. First, the principle of parsimony holds that it is desirable to explain as many phenomena as possible with a single theory. Second, generality allows results developed for one type of disaster event to inform our thinking about the economic effects of other disaster types.[1] Third, models that claim to explain the effects of many different types of disasters are much easier to refute than those with few testable implications or with narrow predictive power. Theories that are easily refuted should inspire the strongest beliefs in other theories where there is an absence of successful refutation. Put another way, if someone advances a theory of the effects of Hurricane Katrina and claims that it is uniquely appropriate for the U.S. Gulf Coast, the theory is not likely to be generally useful and, because it is based on a single data point, its ability to account for the effects does not indicate that the findings on which it is based are statistically significant.

Literature on the economic effects of disasters concentrates on measures of direct and indirect effects. Direct effects are losses associated with observable damage to property, production, and persons. Indirect effects are costs of recovery and mitigation efforts. Indirect costs are more difficult to observe but can be and have been well measured. This chapter concerns itself with effects that arise through changes in expectations. Direct observation of expectations is generally either not possible, too expensive, or not precise. Accordingly, expectations models must generate a number of implications that can provide indirect validation of the underlying theory.

Three disaster expectations models are examined in this paper. First, and most direct, is the effect of disaster expectations on local property values and economic development. Particular attention is given to the possibility that recent disaster experience changes local disaster expectations. This model implies that economic effects of disaster events are based on the unanticipated component of disaster events, or on the difference between actual and expected disaster losses. Second, the effect of disaster expectations on incentives to develop land is considered. Using models taken from urban economics, it is possible to demonstrate circumstances under which private returns from development of land in hazard-prone areas are less than social returns. Third, disaster expectations of property owners should include not only direct damage to their own assets but also the possibility of asset revaluation due to the external effects of disasters on surrounding property. The findings demonstrate that expectations regarding these external effects make disaster insurance different from other forms of hazard insurance and explain some puzzles about behavior of property owners in disaster-prone areas.

The next four sections of the chapter discuss these three models of disaster expectations (the direct effect of disaster expectations is analyzed in two sections). The final section summarizes the major findings and develops implications of these models for understanding the likely effects of changes in public policy toward natural and man-made disasters.

## INDIVIDUAL AND MARKET RESPONSES TO DISASTER EXPECTATIONS

There is ample evidence that disaster expectations are priced into markets. The most obvious example is insurance against disaster events, where pricing is based on sophisticated models of the likelihood that events will occur and the estimate of damage, conditional on the event happening. Those insurance companies that do not price insurance and accumulate reserves using statistical models of disaster expectations do not remain solvent for long and can generally be dismissed as curiosities that have no long-term importance.[2]

There is a strong argument that competitive pressures force most firms to form and act upon efficient disaster expectations, because they must purchase hazard insurance in order to secure capital investment. However, the case for household responses to disaster expectations is not so obvious. Indeed, there is evidence that households are reluctant to purchase insurance against disaster events even when the insurance is subsidized. Before discussing models that trace the effect of disasters on the economy through their effect on disaster expectations, it is worth reviewing the evidence on household responses to disaster expectations.

Because disasters are infrequent and difficult to forecast, households will have difficulty forming expectations regarding their likelihood and severity. However, the literature on individual responses to other large, low-frequency hazards appears to conclude that the implied value of life based on household mitigation behavior is consistent and not unreasonable.[3] This suggests that households may have reasonable disaster expectations. Shilling, Benjamin, and Sirmans (1985) find that households, confronted with different hazard insurance rates associated with location within or near a floodplain, require a compensating differential in housing prices to live in areas where the expected cost of flood damage is larger. MacDonald, Murdoch, and White (1987) carry the analysis further by modeling the relation between house price discounts and the discounted present value of future insurance payments and conclude that, at reasonable discount rates, housing price differentials reflect differences in expected future insurance premiums.

Thus far the evidence discussed deals with cases in which static differences in disaster expectations influence household behavior. Research has also been done on the effects of changes in disaster expectations due to the provision of expert information. Brookshire et al. (1985) examined the effects on housing prices of the requirement that home sellers in California reveal proximity of the housing unit to earthquake fault lines. The regulation was passed based on the belief that this information was not available to buyers. The natural experiment, with observations before and after the information and for houses in and out of the fault areas, indicated that the proximity to the fault line affected price after the announcement was made.[4]

Perhaps the most dramatic demonstration of the economic effects of disaster information was the response to federal government notices of earthquake hazards in the resort community of Mammoth Lakes, California, from 1980 until 1984. The unique feature of this incident was that the United States Geological Survey (USGS) recognized that making public announcements of changes in the probability of seismic events could have serious consequences and implemented an experimental design around the pronouncements. The USGS adopted a three-level index of potential hazard and, from 1980 to 1984, announced seismic risks for Mammoth Lakes that began with the lowest and ended at the highest risk level. The results of this experiment, as reported in a detailed study by Bernknopf, Brookshire, and Thayer (1990), were dramatic. Surveys of the resident population showed that there was a substantial increase in perceptions that a seismic event was likely after each announcement of increasing risk. Recreational use of the area did not fall. However, new construction and house values fell significantly. The market response was so dramatic that the USGS decided to abandon its three-level seismic hazard announcement policy.[5]

Overall, there is substantial empirical evidence that firms and households have significant market responses to information on the likelihood of hazard events, whether that information is presented in the form of insurance rates or government announcements. This should not come as a surprise, and the economic effects of these reactions are easily understood and consistent with economic efficiency. When increased hazard expectations are capitalized into the asset price of real property, construction in hazard-prone areas is discouraged and

property owners have an incentive to adopt designs that mitigate the likely damage should a disaster occur. All this is unsurprising and well established in the literature. Indeed, there is nothing in the foregoing discussion that distinguishes market reactions to disasters from the economics of hazards generally.

## THE ECONOMIC EFFECTS OF CHANGES IN DISASTER EXPECTATIONS

Because disasters are infrequent, large, spatially concentrated, and difficult to forecast, there is a possibility that disaster events change disaster expectations, and, of course, that failure to experience disasters changes expectations in the opposite direction. This is a distinguishing characteristic of disasters.

Hazards that are not infrequent, large, spatially concentrated, or difficult to forecast have expectations that are not significantly influenced by individual hazard events. The fact that a house in a neighborhood burns down has zero effect on insurance models or public expectations of fire damage hazards. This is true because home fires are frequent, impose modest losses, are not spatially concentrated, and can be forecast with great precision. Individual occurrences of an event that is fairly likely to happen have little effect on the expected probability of that event.

Because disasters are infrequent and difficult to forecast, firms and individuals should use recent history to update their expectations of the stochastic process generating the disasters. This was very evident in the reaction to hurricane losses in Florida during the 1990s when property insurance companies raised rates or withdrew from the market, necessitating the formation of a government-sponsored Florida Hurricane Catastrophe Fund. This is one of many examples in which it appears evident that an increase in the frequency or extent of disaster events causes insurance companies to modify stochastic models of disaster loss and substantially raise insurance premiums. The natural presumption is that firms and households behave similarly and that in addition to the direct and indirect effects of disasters, disaster events have an

expectations effect due to the consequences of the modified estimates of disaster losses. Such effects might well have negative implications for recovery and growth of income, output, population, and so on.

There is contradictory evidence regarding the effect of disasters on expectations based on the relation between disaster experience and economic development. In a very influential statistical analysis of disaster events, Wright et al. (1979) concludes that the rates of growth are higher after disasters than before and that long-run growth is higher in areas that experience disaster events. An extensive literature has compared economic outcomes in areas with and without disaster events. Most recently, Belasen and Polacheck (2008) apply a generalized difference in difference estimator to counties in Florida over the 1988 to 2005 period, when the state experienced 19 major storms. They find that employment fell by about 4.8 percent and total earnings rose 4.4 percent in counties experiencing direct hits, while total earnings fell 4.5 percent in neighboring counties. These differences dissipate over time. Studying international disasters, Cuaresma, Hlouskova, and Obersteiner (2008) find evidence that countries with higher disaster rates experience higher rates of subsequent economic growth.[6] Further evidence presented by Worthington (2008) indicates that natural disaster events have no significant effects on overall stock market returns. These and a large number of other statistical studies of cross-section and panel data on areas with and without disaster events tend to produce evidence that disasters are not associated with significant negative effects on output, earnings, and employment. One or more of these variables may decline, but the type of general negative implication for economic growth that would be expected from an upward revision in disaster expectations has not been observed.

There is a parallel literature consisting of case studies conducted in the aftermath of disasters. Dacy and Kunreuther (1969) contend that the rush of aid in response to the great Alaskan earthquake of 1964 gave an area in long-term decline a chance to reverse its falling employment. Other case studies have reached similar conclusions. Recently Smith et al. (2006) found that the recovery pattern from Hurricane Andrew varied by income group, with the numbers of high- and low-income households growing in the aftermath of the storm while the number of middle-income households fell. While case studies of the aftermath of

Katrina are not available yet, it appears certain that income, output, and employment will not recover. Still, the general sense of the literature reviewed above is that the answer to the question, "Are disasters bad for economic growth?" could be "no" or at least "not necessarily." This leads to the subsequent question, "Is postdisaster relief too generous?"

There is a problem with both of these questions as well as the proposed answer. Understanding the problem and formulating an answer will require development of a formal model of the likely effects of changed disaster expectations on economic growth. The model begins with an understanding of real estate values in an urban land market. Because real estate is immobile, differences in future expectations for regional economic activity tend to be capitalized in land and housing values. There is a well-developed literature on quality of life stemming from the work of Rosen (1974) and Roback (1982, 1988) that suggests a relation among amenity, house prices, and wages in a labor market area. Decreases in amenity are associated with increases in wages and decreased house prices in order to keep households from leaving an area. A rise in disaster expectations makes an area less attractive to both firms and households. Under these circumstances the change in wages is ambiguous because there is a spatial no-arbitrage condition for firms based on profits and for households based on indirect utility.[7] However, the theory unambiguously predicts that land and real estate prices will fall in response to an increase in disaster expectations.

Rubin and Yezer (1987) provide a general empirical test of the relation between disaster events and local economic activity by examining the change in house prices in areas experiencing different numbers of disasters. For a panel of U.S. cities in 1983, they analyzed the partial effect on the asset prices of housing, as reported in the American Housing Survey for a cross-section of cities, in relation to differences in the number of disaster events during the previous 20 years.[8] The estimated coefficient of disasters was positive, and its magnitude implied that going from an annual disaster rate of zero to one increased the value of owner-occupied housing in the city by 26 percent.[9] The authors point out that such an interpretation of the estimated coefficient of disasters is absurd, and they argue from these results that something is very wrong with models that relate the incidence of disaster events to local economic development.

The literature has documented the effects of information from insurance pricing, scientific evidence, and government pronouncements on disaster expectations. It is much more difficult to determine the effect of disasters themselves on disaster expectations. This is perhaps the most underresearched aspect of the economics of disasters. A disaster event might lower, raise, or leave unchanged disaster expectations of a rational agent, depending on the nature of the disaster. Some seismic events occur periodically and, given the slow pace of geologic time, an eruption today may mean that the next eruption is hundreds of years in the future. Alternatively, recent storm damage may lead individuals to expect that the underlying frequency of storms has increased due to global climate change.

This paper is particularly concerned with the case in which, given the complexity or lack of information on the process generating the disaster, agents update their expectations of the frequency distribution of disasters based on a comparison of recent disaster experience with the historical record. Such updating may occur for two reasons. First, individuals may believe that the disaster-generating process varies over time and may be trying to estimate the parameters of a stochastic process with drift.[10] Alternatively, they may believe that disasters are generated by a stationary stochastic process and simply use recent experience to improve their estimates of the parameters of that distribution. Because this second case is easier to describe and has been analyzed in the literature, it will be considered in some detail here.

In considering the case of a stable stochastic process, the Poisson process is quite attractive because it requires individuals to estimate a single parameter, and the probability of a disaster event is independent of the time since the last disaster. Cox and Lewis (1966) first suggested fitting the Poisson process to disaster events, and Brown (1972) adapted it to the case of flooding. Analysis of Bayesian updating of expectations regarding the Poisson process is mercifully simple. The process is based on a single parameter: the expected disaster frequency, $f$. The expected time between disasters, $T$, is the reciprocal of $f$; that is, $T = 1/f$. Assume that the historical record available at time $t$ indicates that $\alpha$ disasters were observed over the previous $\tau$ years. Then the estimate of $f$ at time $t$ is simply the ratio $f_t = \alpha / \tau$. Now assume that, in the next $X$ years, $\beta$ additional disasters occur. Then the Bayesian estimate of $f$ at

time $t + X$ is $f_{t+X} = (\alpha + \beta) / (\tau + X)$. The change in estimated disaster frequency between $t$ and $t + X$ is given by

$$\Delta f = f_{t+X} - f_t = [(\alpha + \beta)/(\tau + X)] - [\alpha/\tau]$$

$$= [\beta/(\tau + X)] - [\alpha/(\tau + X)](X/\tau)$$

$$= [\beta - \alpha(X/\tau)]/(\tau + X).$$

This final expression has a very intuitive interpretation. The change in expected disaster frequency is equal to the difference between actual disaster experience during the recent period of $X$ years, $\beta$, and expected number of disasters based on the previous $\tau$ years, $\alpha(X / \tau)$, divided by the total number of years under consideration, $X + \tau$. Thus this change represents the difference between actual and expected disasters per year of disaster history available to the individual making the estimate.

Rubin and Yezer (1987) discuss whether the difference between actual and expected disasters could help explain the more rapid increase in house prices in cities that had more disasters. Dividing the 20-year period over which presidential disaster declarations were observed in their cross-section of cities into a 16-year "history" that served as the basis for estimates of disaster expectations and a subsequent 4 years of recent experience, they computed the difference between the number of actual and expected disasters in the recent period and reestimated the model of house price change discussed above. The disaster rate for the entire period still had a positive sign, but the difference between actual and expected disasters (i.e., the number of unexpected disasters) had a substantial negative effect on house values.

How should these results be interpreted? It appears that during this period, cities where disaster expectations were higher were growing faster than those where disaster expectations were lower. Given that cities with higher disaster expectations have more disasters, this produced a positive association between house price growth and the disaster rate. This association is of no particular significance unless there is further evidence that the growth of cities in areas with higher disaster rates is being subsidized. Put another way, the literature on the relation between area economic growth and disaster frequency does not reveal the effects of disasters on growth because most disasters are anticipated. Develop-

ment takes place in high-disaster areas only in anticipation of future damage, and that expected damage is part of the cost of doing business in those areas. "What is the effect of disasters on economic growth?" is a vexed question. The appropriate question is, "What is the effect of unanticipated disasters on economic growth?"

The effect of unanticipated disasters on house values found by Rubin and Yezer (1987) is substantial. Consider an area that had no previous disaster experience and then had one disaster during the four-year event window; that is, it had one unanticipated disaster. This would lower house values by 2 percent. This change may not seem large; however, in a city with 500,000 housing units with an average value of $200,000, the change in expectations due to the single unanticipated disaster event lowers total house values by $2 billion! This is only one example of how the effects of unanticipated disasters can be large compared to the direct damage and indirect recovery costs.

The implications for public policy of these substantial effects on local economies of changes in disaster expectations based on disaster events will be discussed in some detail in a subsequent section. It should be clear that disasters that have the same direct and indirect effects in terms of damages to property, income, output, and individuals have very different long-term local effects depending on the extent to which they were anticipated. Furthermore, while it is possible, at least in theory if not in practice, to insure against direct and even some indirect losses due to disaster events, insuring against losses due to changed expectations is impossible. Indeed, it is likely that firms and households in areas with high disaster expectations are well insured against direct and indirect losses, whereas those in areas where expectations are low are unlikely to insure against these insurable losses. Thus the overall uninsured losses from unanticipated disasters are likely to be very large. It should also be obvious that the economic effects of man-made disasters, particularly acts of terrorism, are best understood in terms of changes in expectations.[11] Other things being equal, those terrorist acts that produce damages of a type or in a location where expectations were low have the largest economic effects. These considerations will prove very important in the discussion of policy implications.

## Disaster Expectations and Efficient Land Use and Mitigation

Most of the literature on disaster expectations and efficient economic development deals with excess development and insufficient mitigation efforts in areas where disaster frequencies are high. This problem has been the object of congressional testimony and reports as well as academic inquiry.[12] Once disaster relief became a regular and mandated part of federal policy, there was an incentive for states, localities, and individuals to self-insure development in hazardous areas. The normal disincentives to such development—namely, the prospect of loss and the cost of insurance—were mitigated by the prospect of postdisaster relief.[13] Concern over this problem has led to a number of initiatives, including the National Flood Insurance Program, which dealt with excess development and inadequate mitigation by combining disaster relief provisions with mandatory insurance and design requirements. The Coastal Zone Management Act of 1972 promoted state and local planning efforts to control and direct development, and the Coastal Barrier Resources Act of 1982 attempted to deter development by cutting off federal funding to designated areas that had high disaster probability and environmental sensitivity.

The general sense of the literature appears to be that government policy for disaster relief is subject to the Samaritan's dilemma: these efforts create major problems of moral hazard, adverse selection, and time inconsistency that encourage development and discourage mitigation in disaster-prone areas.[14] Mandatory insurance, design controls, mandatory mitigation, and even designation of areas in which government assistance will not be provided are generally seen as the proper response to the distortions produced by disaster relief programs.

This section focuses on an issue that has attracted negligible interest in the literature: spatial land market models suggesting that there is too little development in areas where disaster expectations are high. The overdevelopment literature discussed above tends to ignore issues of space and location that are governed by the functioning of the land market. Because land subject to high disaster risk is spatially concentrated, the development of significant areas is contingent on the treatment of disaster losses. Frame (1998, 2001) has considered this issue explicitly, as follows. Take the land market in a standard urban model in which

land at a particular location has special value based on unique locational advantages, such as the central business district of a city or a shoreline location. For simplicity's sake call this the high-productivity area. Land rents will peak at such points and decline with distance. What happens if some of the land at or near the peak of this land rent surface is not developed because it is subject to flooding or some other hazard that would inflict substantial damage on real property? Frame demonstrates that this undeveloped land yields a general loss of community welfare because the area as a whole is less efficient at providing developed sites with access to the high-productivity area. This result holds even if the high-hazard area does not impede through access; for example, if the area lacks housing but highways can be built through it to transport workers or consumers from distant points to the high-productivity area.

More recently Liu (2008) has examined the relation between the private and social returns from developing land in and around high-productivity areas. The private gain from developing land in hazardous areas is the difference in value between undeveloped and developed land. Part of the development process is the opportunity for mitigation, and the assumption is that insurance markets are available or that developers are risk-neutral. His results are quite intuitive. If there are no externalities associated with the functioning of a perfectly competitive land market, private benefit from development of land subject to hazards is equal to the social benefit, and private land market allocations are socially efficient. However, if there are externalities in the operation of the land market, particularly problems of traffic congestion, social benefit can be significantly larger than private benefit. Using a numerical urban simulation model with congestion calibrated to Kansas City, Liu finds that the social value of development near central city areas is approximately twice the private benefit realized by the land owner.[15] This means that land subject to hazards could have too little development. McDonald (2009), in a similar model calibrated to Chicago, confirms the general result that, in the presence of congestion, private benefits to development of land near the central business district are significantly below social benefits. While he does not relate these results to effects of hazards, the arguments made here would hold in his model also.[16]

Nothing in this discussion of the land market models and the possibility of underdevelopment of high disaster risk areas should be seen

as a contradiction of the literature on incentives for excess development due to moral hazard arising from federal disaster relief programs.[17] However, land market efficiency considerations do suggest that, in some circumstances, there are countervailing forces that tend to restrict development below optimal levels in areas that are prone to disasters. Accordingly, such areas should be given careful attention to determine which of the conflicting forces is larger.

**Disaster Expectations, External Effects, and Disaster Insurance**

One puzzle in the disaster literature involves the reluctance of households in high-risk areas to purchase insurance even if the price appears to be below expected losses. The failure to use subsidized insurance has troubled many observers. Kunreuther (1978) noted that, in the first four years of the National Flood Insurance Program (1968–1972), only 3,000 of 21,000 eligible communities with substantial flooding history participated in the program, and fewer than 300,000 homeowners voluntarily purchased a policy. Even though the NFIP was subsidized, participation was initially achieved only by threatening to withhold federally assisted or guaranteed construction from nonparticipating communities, and by denying mortgage loans to property owners in nonparticipating communities that were identified as special flood hazard areas.[18] Palm et al. (1990) documented a similar failure of homeowners and mortgage lenders to seek earthquake insurance in high-risk areas. Kunreuther and Kleffner (1992) and Kunreuther (1996) have even argued that homeowners do not behave as if they are maximizing expected utility in their decisions to purchase insurance or engage in private mitigation efforts.

The discussion of disaster insurance is generally conducted using models standard in the insurance literature. A household owns an asset whose current value is $A$ which is subject to expected damages of $D_A$ so that its expected value in the next period is $A - D_A$ with variance $V_D$. The variance in $A - D_A$ is due to the possibility that the hazard event might occur during the current time period. Given that the expected value of damage due to the hazard is generally known to be $D_A$, the household can purchase hazard insurance at a price of $D_A + F$, where $F$ is the normal fee associated with providing this insurance product

under perfect competition. Households have a choice of purchasing full insurance or no insurance. What are the consequences for wealth in the next period? Expected wealth under full insurance is $A - (D_A + F)$, with certainty compared to expected wealth of $A - D_A$ with variance $V_D$ without insurance. Insurance reduces the variance in return to zero because the insurance payment is perfectly correlated with the damage to asset value. Households that are moderately risk averse will choose insurance, and there is no reason to assume that households owning property in disaster-prone areas are not moderately risk averse.[19] This line of argument has treated disaster risk the same as other risks to property, such as fire, liability, collision, or theft.

One distinguishing characteristic of disasters, as defined in this essay, is the extent and spatial concentration of damage. In terms of the simple example above, any damage to asset value $A$ is likely associated with damage experienced by the full alphabet of asset values owned by other households in the area. In this case, the fall in wealth experienced by the household is equal to $A - (D_A + E_A)$, where $E_A$ is the external effect of disaster damage to other properties in the area on the value of the asset. Assume that $V_E$ and $r_{ED}$ are the variance of $E$ and the correlation between $E$ and $D$ respectively. A household that purchases insurance has expected wealth of $A - (D_A + F + E_A)$ with variance $V_E$, and the household that self-insures has expected wealth of $A - (D_A + E_A)$ and variance of $(V_D + V_E)/2 + r_{ED}\,(V_E V_D)^{0.5}$. The variance in second-period wealth of those who purchase insurance depends crucially on $r_{ED}$. Consider the stylized but not unreasonable case in which $V_D$ is equal to $V_E$ and $r_{ED}$ equals one, so that the external damage is perfectly correlated with the damage to the structure. Then the variance becomes $2V_D$ and the risk of self-insuring has doubled. In this case, the household has the choice between two risky alternatives but, again abstracting for other opportunities for risk diversification, the moderately risk-averse household is likely to have a risk premium greater than $F$ and will choose to purchase insurance. Now consider the other extreme, in which $V_D$ is equal to $V_E$ and $r_{ED}$ equals $-1$. The household that self-insures has expected second-period wealth of $A - (D_A + E_A)$ and variance of zero. This household thus will rationally self-insure unless insurance is heavily subsidized. Indeed, there is a separating equilibrium for $r_{ED}$ sufficiently

small that even very risk-averse households switch from buying to not buying insurance.

The incentive to purchase insurance and the effects of mandatory insurance depend on the relative sizes of $D_A$ and $E_A$ and particularly on the sign and size of $r_{ED}$. Given that the indirect effects of disasters take the form of a local public good, it may appear that this correlation is positive and close to one. However, one line of argument suggests $r_{ED}$ is negative. If a structure is damaged but the damage is less than that of surrounding structures, then the rental price of its services may well rise because the disaster reduces the supply of real property for a significant period after the event. Furthermore, the reduction in real property may be permanent.

Perhaps the most obvious case for a negative $r_{ED}$ is that of beach property located in the third or fourth row of homes from the shoreline. In most beach communities, there is a sharp decline in value as distance from the shoreline increases: that is, value varies inversely with row. In storm events, most damage is experienced by the first and second rows. In some cases, the first row cannot be rebuilt due to shoreline erosion, and each subsequent row then moves up the value gradient. Put another way, the third row is one large hurricane away from being beachfront property.

This simple model illustrates that, if there are significant external effects that are negatively correlated with private damages, the effect of insurance on economic development becomes rather complex. As noted above, many property owners will fail to insure even if insurance pricing is based on shared expectations of future damages. The provision of such insurance benefits those owners whose expected external effects are either small or positively correlated with private damages. It does not benefit owners with large external effects that are negatively correlated with damages. Therefore, mandating disaster insurance for all property owners imposes net costs on owners of properties with significant external effects that are negatively correlated with damages. This leads to the surprising result that mandatory purchase requirements for insurance that is priced based on expected damages distorts asset prices and property development by lowering asset prices for properties with large external effects that are negatively correlated with damages.

The example noted of beach property in different rows may offer a test of the theoretical arguments made above. The nature of external effects should vary significantly with distance from the shoreline. Given that the hazard is storm damage by wind and waves, it is likely that private damage in the first row will be much larger than any external effects and that external effects will be positively correlated with damages.[20] Moving back to the second and third rows of property, these relative effects are likely to be reversed. Shoreline erosion may imperil the first row, but it simply makes inland areas more proximate to the beach. Damages to interior areas are very likely to be smaller than in the first row. Overall it appears that shoreline areas provide an excellent natural experiment to assess the varying importance of private damages versus external effects for economic activity.

The difficulty with testing the effects of private damage and external effects on investment in beach property is that the test requires differentiating among rows of beach development: that is, the geographic scale is very small. Testing for insurance effects is further complicated because the current NFIP has been in place in most beach communities since the mid-1980s, so insurance coverage has not varied significantly in recent years. The most direct way to measure effects of insurance coverage is to look for capitalization in asset prices by monitoring the variation in house values by row and over time. Some research on the effects of government policy on beachfront residential development has been done using hedonic house value equations (Keeler, Kriesel, and Landry 2003), repeat sale house price indexes (Cordes, Gatzlaff, and Yezer 2001), and building permits issued (Cordes and Yezer 1998). Unfortunately, none of these techniques is suitable for tracking development effects on shoreline property based on distance in feet from the water's edge in beach communities over the period extending from before the NFIP through its current form. Such an analysis would require price or permit data going back to 1968 differentiated by row from the shoreline. No such data are available.

Cordes, Yezer, and Asadurian (2008) found another way to test for the differential effects of flood insurance by row from the beachfront. Property records include the number of square feet of interior space of dwellings and the date that the housing was built. Using aerial photographic maps, they were able to divide beach developments into

rectangles corresponding to development rows whose land area is fixed and measurable. Using building records that gave the number of square feet of interior space in each dwelling in a rectangle, it was possible to construct a time series going back to 1968 of the square feet of interior space per square foot of land area, commonly known as the "floor/area ratio." The result of this effort was a 40-year time series of the capital/land ratio in each rectangle for the period from 1968 to 1997. The maps also facilitated calculation of distance of each row from the water's edge and, together with information on erosion rates, this allowed computation of estimated time until erosion undermined the structures in a given rectangle.[21]

Each beachfront community entered into the NFIP in two stages. First it entered the emergency program, where flood insurance was heavily subsidized, and then, after completion of a flood insurance map (FIRM), it entered the regular program, in which insurance subsidies for new construction were much smaller or nonexistent.[22] Given that the various communities entered these two phases in different years, the data include observations of communities with and without each of the programs in any given year as well as before and after information for each community. The estimation results demonstrated that entering both the emergency and regular NFIP had the effect of tilting real property development toward the shoreline. The rate of growth in density, measured as floor/area ratio, increased the most in the first row, but this positive effect fell off rapidly, reaching zero at a distance of 350 feet from the water's edge. The effect was large, statistically significant, and congruent with the theoretical prediction that programs mandating insurance encourage development in areas where the external effects of hazards are negligible or positively correlated with the private damage—the first rows of shoreline development. At the same time, mandatory insurance programs discourage development in areas where the external effects of hazards are large or negatively correlated with private damage—rows located inland.

Thus it appears that the existence of expectations that disasters are associated with both private damage and external effects creates the paradoxical possibility that mandating universal purchase of insurance based on expected private damage estimates distorts the location of economic activity toward areas where expected hazard losses are

higher. While this may appear counterintuitive, it does explain the difficulty in getting some households in high-risk areas to participate in the NFIP.

## IMPLICATIONS OF DISASTER EXPECTATIONS FOR PUBLIC POLICY

Formal models of the economic effects of natural and man-made disasters should include careful modeling of expectations, because the prior level of disaster expectations, and any resulting changes in the expectations, are very important determinants of those economic effects. This essay has developed some of the pathways relating expectations and economic effects, but other important linkages in need of research may exist. Nevertheless, the analysis presented here is sufficient to demonstrate some important principles whose implications for public policy toward disasters will be discussed, including the effects of changed disaster expectations, efficient land use considerations, and potential distortions due to mandated insurance and mitigation.

### Changes in Disaster Expectations

The economic effects of disasters depend on the relation between prior expectations and actual disaster experience. This is illustrated in the literature on the effects of earthquakes on property values and disaster expectations. Beron et al. (1997) find that property values near fault lines actually rose after the Loma Prieta earthquake and argue that prior expectations were too high. In contrast, Naoi, Seko, and Sumita (2009) report that for earthquakes in Japan, surveys show that quake expectations double after an event and property values fall significantly. If actual disasters reflect disaster expectations, then those expectations will be unchanged and negative expectations' effects on economic development should be minor. The economic effects of a disaster depend not only on how much damage it does but also the extent to which the disaster event and the associated damage were anticipated. Furthermore, it is not possible for firms and households to insure against the eco-

nomic losses associated with changed expectations after unanticipated disasters. What does this imply for public policy? First, it suggests that insurance markets are inherently incomplete and that there is a role for postdisaster aid. However, the aid should be focused on areas experiencing unanticipated disaster events.

While such selective targeting of disaster relief to unanticipated disasters is likely politically impossible, some elements of disaster relief policy seem consistent with a focus on events that raise expectations. First, there is a scale effect in disaster declarations, so larger disasters get proportionally greater postdisaster compensation.[23] To the extent that unusually large disaster events are unanticipated, making federal participation a nonlinear function of the size of the aggregate losses is appropriate. Furthermore, NFIP aid diminishes for repeated flooding events. The subsidized insurance for grandfathered structures can be withdrawn after repeated losses. Finally, the amount of publicity and attention given to disaster events may decrease to the extent that the event is regular and anticipated. This may lower the amount of public and private aid following such events. Certainly, more could be done with formal policies toward postdisaster aid to concentrate public funds on unanticipated disaster events, but in this case political expediency likely will triumph over economic logic.

Another implication of the losses associated with unanticipated disasters is that terrorists who wish to inflict maximum total damage for a given amount of physical damage will concentrate their actions where damage is not anticipated. There are many other considerations in selecting targets, but areas where disaster expectations are low have two advantages. First, victims will likely not be taking precautions. This makes success in inflicting damage more likely, and perhaps also lowers the probability of apprehension and sanction if that is a consideration. Second, the unexpected component of the disaster event is largest in areas where prior expectations are lowest. In this case the implications for public policy are clear and, fortunately, the politically expedient course does not tend toward moral hazard. Provision of generous relief from damages lowers the expectation of loss from man-made disasters. This lowers the economic effects because the economic reaction will depend both on the change in expectations of the probability of loss and on the expectation of the size of loss conditional on the act taking place.

Relief can do nothing about the change in probability, but it can lower the conditional expectation of loss and hence the economic effects produced by the change in expectations.[24]

## Incentives for Efficient Land Use and Mitigation

The moral hazard and time inconsistency problems associated with federal provision of disaster relief are well understood.[25] Indeed, the cornerstone of disaster policy since the passage of NFIP has been to resolve the Samaritan's dilemma by forcing those developing property in hazardous areas to face an insurance price that reflects expected future losses and required mitigation to control those losses. Insurance and mitigation costs, in turn, discourage development.

Because hazards are spatially concentrated, public policy toward disasters has an important effect on when and how densely significant tracts of land are developed. When this issue is considered in terms of a continuous land market model, it is important that the private incentives to develop land in hazardous areas be consistent with the social benefits from such development. If land is homogenous, private benefit equals social benefit and private landlords should develop land only when the private returns to development are sufficient to compensate for the cost of development, including any expected disaster losses. However, all land is not homogenous, and there may well be externalities associated with land development, particularly in an urban setting where accessibility is important and transportation systems are congested. Under such circumstances the social benefit from developing sites may exceed the private benefit, and landlords may fail to develop land or may do so at a density that is below the social optimum. In these circumstances, public action to subsidize mitigation or insurance can be justified.

There are many examples of public policy efforts to subsidize development of hazard-prone land in an urban context. Many communities have used general public funding for flood control and land reclamation efforts.[26] The arguments made in this essay suggest that there is an economic rationale for these actions and that public subsidy calls for a demonstration of social benefits in excess of private benefits. In cases where subsidized mitigation is not feasible or not economical, provision of subsidized insurance can also align private and social ben-

efits from development. Such policies must be implemented with some care, because political abuse by subsidizing development where there is no externality is also possible.

## External Effects and Disaster Insurance

Because disaster effects are spatially concentrated, the usual insurance model should be applied cautiously in developing the economic effects of disaster insurance. When disaster strikes, owners of property suffer private damage and insurance compensates for those losses. Insurance is also available for some of the disruption following the disaster—that is, for the indirect effects of the disaster. It is easy to construct an argument for mandatory participation in an actuarially sound disaster insurance program, particularly when the government is committed to providing relief services.

This argument ignores external effects of disasters on asset prices in an area. One can easily identify situations in which these external effects are positive and offset the private losses. This explains why some property owners in hazardous areas rationally fail to purchase hazard insurance, even when the insurance is subsidized. Public policies that mandate purchase of actuarially fair insurance in such cases will distort the pattern of economic development toward areas where expected private losses are high compared to any external effects. These may well be the areas where disaster damage expectations are highest. The end result could be to encourage the movement of economic development into harm's way.

This does not mean that it is necessary to abandon public policies of mandating the purchase of disaster insurance. It does suggest that the case for mandating purchase should be very strong. In such cases, it should be possible to provide insurance at rates that are higher than actuarially fair in areas where external effects are positively correlated with private losses and at a discount to fair rates where external effects are negatively correlated with private losses. Identification of these areas need not involve substantial economic analysis: they should be apparent based on patterns of participation in voluntary insurance programs or even in our current "mandated" programs by observing areas where actual participation rates are either very high or very low.

Overall, models that integrate expectations of natural and man-made disasters into the body of economic theory suggest that public policy toward these events needs to be carefully considered. The great difficulty facing the federal government is the general presumption that programs and policies need to be nationally uniform. Considerations of economic efficiency appear to run counter to this presumption.

## Notes

1. There is currently a national need to understand the effects of terrorist events. In the absence of the ability to extend results from other types of disasters to terrorism, this understanding would have to wait for a significant number of terrorist incidents to accumulate to provide a database suitable for testing. This is not a happy prospect.
2. This is not to say that the consequences of failure to price risk correctly are uninteresting or unimportant. Surely the credit default insurance industry of the past decade has had large negative economic effects, and so the "solution" to risk can itself result in a disaster event if that solution is unsound. These issues are beyond the scope of this paper, which assumes that insurance pricing is based on the latest and best estimates of risk.
3. See, for example, the recent discussion by Hakes and Viscusi (2007).
4. In this case proximity to a fault line was not indicated by insurance rates in ways that would make it apparent to home buyers. Indeed, the provision of earthquake insurance in California has been problematic for some time now for reasons that would easily justify an essay of considerable length.
5. The subsequent absence of a seismic event of any size proved embarrassing to the USGS, and there were threats of litigation by property owners.
6. The conclusion is somewhat more nuanced, as the authors find that the higher growth rate postdisaster depends on the initial economic circumstances of the country.
7. A rise in disaster expectations lowers expected profits or raises insurance costs for firms, which then require compensation in the form of lower wages and/or lower rents. The same rise lowers indirect utility of households, and they require compensation in the form of higher wages and/or lower rents. The change in wages is ambiguous but rents, and hence property values, must fall.
8. Specifically, they estimated a standard hedonic model for the logarithm of house value explained by a variety of housing characteristics standard in the literature but with area disasters added.
9. A disaster event is defined as one that resulted in a presidential disaster declaration. The disaster variable is the number of disaster declarations in the previous 15 years divided by 15 to produce an annual rate.
10. Recent attention to climate change may lead individuals to believe that the frequency of disasters is changing. Whether this belief is scientifically valid or not,

those who hold it will be updating based on an underlying stochastic model that allows for drift. Further research on this possibility is warranted.

11. These statements are based on an implicit model in which the supply of terrorist acts is elastic. Models with a fixed supply of terrorist events, such as those described in Barker (2003), may result in different implications than those discussed in this paper.
12. For an extensive discussion see Congressional Research Service (1992).
13. See, for example, the analysis in Shilling, Benjamin, and Sirmans (1985).
14. Moral hazard arises in the form of the Samaritan's dilemma. Individuals fail to insure or mitigate because they expect government postdisaster relief. Adverse selection problems occur if individuals with unrealistic expectations for disaster probabilities selectively migrate to hazardous areas. The time inconsistency problem arises when individuals believe that, by moving to a hazardous area, they can prompt public expenditures to mitigate the hazard by governments anxious to conserve on disaster relief cost. In other words, move onto the floodplain and the government will be forced to build a dam or levee at public expense.
15. Congestion in commuting is endogenous in this model. Given highway capacity, the model generates congestion based on the number of individuals choosing to commute through a particular segment of the city.
16. Chicago presents an interesting historical case because the portion of the city north of Lake Street is built on fill land that was created to realize the high social return of filling in the shore of Lake Michigan.
17. In addition to the standard arguments about excess development in high-risk areas already discussed, there is a more general literature on excess investment in real property, particularly second homes, based on the tax preference for owner-occupied housing; see Poterba and Sinai (2008).
18. While the subsidy component of NFIP insurance for new construction is not large, the subsidy for existing units built before the insurance was implemented is very large. Furthermore, lenders are required to check for flood insurance in connection with mortgage servicing. Kriesel and Landry (2004) report survey evidence indicating that the participation rate is only 49 percent in spite of the mandate that mortgage servicers require evidence of insurance in force.
19. Evidence for the degree of risk aversion could be gleaned from portfolio behavior of households based on property ownership. It has been argued that perception of risk from hazards is selectively faulty or that households owning property in areas with high disaster probability are selected to be those who systematically underestimate the hazard.
20. Damages in interior areas may impede recovery and repair in shoreline areas as well as raise the cost of these activities.
21. Obviously, beach erosion can sometimes be zero or even negative, i.e., the beach is accreting. In such cases estimated erosion time is infinite. The areas considered in this study are all beaches and subject to erosion. They are not protected by natural or man-made barriers. The potential for storm damage is substantial in these areas.
22. New construction was also subject to special construction requirements designed to raise vulnerable structures above flood surge levels.

23. Note that there is an element of size needed even to qualify for a presidential disaster declaration.
24. To the extent that the object of terrorism is to produce the greatest economic dislocation possible through the expectations effect, lowering the expectations effect reduces the returns to terrorism.
25. For an early discussion of these issues along with an estimate of the wealth redistribution effects of the NFIP, see Shilling, Sirmans, and Benjamin (1989).
26. The reclaimed land is then sold back to the private sector at a loss. Policy toward urban brownfields follows a similar pattern.

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