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The Economics Of Natural Disasters

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I. Introduction

The economic problems produced by natural disasters have long occupied the attention of mankind. Along with preparation for war and self defense, the response to problems of flood, drought, earthquake, and windstorms has been used as a test of the ability of governments and economic institutions to serve a population. In our own time, there is increasing concern with the unwillingness of private insurers to operate in high risk areas and with the escalating cost of government disaster assistance. In spite of all this rationale for studying of the economics of natural disasters, a search of on-line sources for books, articles, and other academic publications on the subject provides only a modest number of references.¹ Apparently governments have found little need to examine the economic effects of their policies towards actual or potential natural disasters.

Although the literature is thin, it includes a surprising diversity of theoretical models and empirical results responding to a number of different issues and problems. Unfortunately, these individual approaches to the economics of natural disasters often bear little relation to one another because they proceed from very different assumptions and analyze different aspects of the relation between disasters and the economy. The first task of this review is to organize these approaches under a modest list of

¹ For example, the on-line index to the *Journal of Economic Literature* lists only thirty-eight citations under the topic "natural disaster," seven under "earthquake," and eighteen under "floods."

headings and to show the relations among them. Ideally, they would all be placed within the context of an overarching general statement of the economics of natural disasters but this review will settle for the more modest goal of identifying distinctive approaches and pointing out differences in their assumptions and purposes.

Probably the most familiar branch of literature dealing with the economics of disasters involves various aspects of economic impact analysis in which the effects of a disaster event on a local or regional economy are modeled. Because it is important to understand the theoretical basis for expecting an economic response to disasters before reviewing empirical models, these economic impact models will be discussed in the last section of this review. The next section will discuss attempts to model the theoretical effects of natural disasters within the context of a general equilibrium theory of regional development. An intermediate section considers disaster insurance and mitigation models, leaving economic impact analysis for the final section.

II. Expectations and Information Effects In Models Local Economic Development

Once they have occurred, natural disaster events have direct and indirect effects on a local economy because they damage local capital stock and kill or injure local population. The result of these *ex post* (after the fact) effects is a temporary reduction in the supply of inputs, some of which are highly specialized to local production. Local output will fall for two reasons. First, a direct effect arises because reduced availability of local capital and labor causes lower output as predicted by any normal production relation. Second, indirect effects arise because the damage to local capital and labor tends to be concentrated in the infrastructure system, particularly transportation and public utilities. Because of the

disruption caused by failure of these infrastructure inputs, output falls below what would normally be predicted based on the surviving local capital and labor inputs. Put another way, output will be below what would ordinarily be expected under technically efficient operation of the surviving capital and labor because essential inputs to the production process are missing.

Another indirect *ex post* effect of natural disasters is a change in the composition of local output. The post-disaster period includes a shift toward production designed to replace the damaged local capital stock, and an increase in imported inputs. These changes are often financed by receipt of insurance payments or public transfers and they may last for two or three years. Finally the area should return to a long run equilibrium level of growth in production and input accumulation based on fundamentals characteristic of the economy prior to the disaster. All these direct and indirect effects arise even when the occurrence of the disaster event has no effects on perceptions of the likelihood of future losses. Most of the literature on the economics of natural disasters focuses on analysis and measurement of direct effects along with some subset of likely indirect effects depending on the purpose of the study.

The Theoretical Role of Expectations and Informational Effects

There is substantial evidence that natural disaster events have informational effects whether they occur or not and that the economic consequences of these *ex ante* (before the fact) effects may be larger than either the direct or indirect effects. Informational effects arise *ex ante* because disaster events are inherently local in character and expectations for future events, both their frequency and severity, are very uncertain. As noted by Kunreuther and Kleffner (1992) the range of probability estimates for serious earthquakes offered by experts is often sufficiently broad to argue for major mitigation expenditures (at the high probability end) and no mitigation (at the low end). The occurrence or non-occurrence of

disaster events over a period of time allows for substantial updating of these expectations. Surveys of households before and after disaster events show a substantial change in attitudes toward purchase of insurance and expenditures for mitigation. Brown (1972) provides an early discussion of the likely informational effects of disaster events and models a process in which prior expectations of disaster probabilities are subject to Bayesian updating based on recent disaster experience. Note that, in such models, non-occurrence is just as important as occurrence in its effect on expectations. Recent experience is added to the individual's information set and expectations are updated periodically.

The potential importance of disaster expectations was demonstrated by Ellison, Milliman, and Roberts (1984) through use of a small region econometric model of the Charleston, South Carolina area that included investment equations in which expectations played a role. They were then able to simulate the effects of an earthquake under alternative *ex ante* informational scenarios: a fully anticipated event, an unanticipated earthquake, and an earthquake announcement with no subsequent earthquake. There are a number of features of this modeling effort that are noteworthy and will be discussed later but the essential informational feature is the comparison of an unanticipated event with a true prediction and a false prediction. Because the model was structured so that migration of labor and capital (investment) depended on expectations, credible earthquake predictions that are not believed have a substantial negative effect on output in the affected area. These negative effects would probably have been larger if the model had incorporated an option to invest in mitigation efforts. Ellison, Milliman, and Roberts (1984) reach conclusions that should be sobering for those who predict disasters. While they find that the present discounted value of local production when a local earthquake is correctly predicted is greater than the present discounted value of production when there is an unanticipated earthquake scenario, this gain

from correct production of an earthquake occurrence is far less than the fall in present discounted value of production when an earthquake event is incorrectly forecast.² The losses from an incorrect prediction exceed the gains from a correct prediction.

If false announcements can have substantial ex ante information effects, then it follows that disaster events themselves may have information effects because they influence future expectations. This view is advanced in Brown (1972) and tested empirically in Yezer and Rubin (1987). Papers by MacDonald, Murdoch and White (1987), Shilling, Benjamin, and Sirmans (1985), and Brookshire, Thayer, Tschirhart, and Schulze (1985) relate the asset prices of housing in a given area to proximity to natural disaster hazards, flood planes or earthquake faults. The standard finding is that houses further from the hazard sell for higher prices that appear to reflect differences in insurance costs.³ Bernknopf, Brookshire, and Thayer (1990) demonstrate that the announcement of a probable future disaster in Mammoth, California had significant negative effects on both real property investment and residential property values but not on recreational visitation. These results suggest that there is a market response, at least on the part of investors, to new information on disaster probabilities in a specific area. One limitation of these studies is that they involve comparisons of a single change in disaster probabilities. While this is sufficient to show the importance of information effects of natural disasters, it gives little insight into the dynamic

² The loss from an incorrect prediction is computed as the difference between present value of production under a no earthquake baseline scenario and present value of production when an incorrect earthquake forecast is announced to the public.

³ A number of studies have found that events with low probability but high losses are reflected in housing prices. For example, Dunn (1986) has shown that hazardous waste leakages reduce property values near the leakage site.

component of expectations formation. It would be useful to know more about the process that individuals use to formulate their disaster expectations.

Empirical Evidence That Disasters Have Significant Informational Effects

In addition to the Bernknopf, Brookshire, and Thayer (1990) demonstration of specific announcement effects in Mammoth, California, Rubin and Yezer (1987) tested a model in which the divergence between actual disasters and disaster expectations was related to changes in a local economy. First, they developed measures of the expected frequency of natural disasters for cities based on their previous disaster history. Comparison of this expected frequency, based on historical disaster rates, with subsequent disaster experience over a subsequent four-year period allowed them to compute the unanticipated component of recent disaster rates, based on the divergence between actual and expected (historical) disaster rates.⁴ Second, they identified the rate of change in the price of housing services as one appropriate indicator of the local economic effects of disaster expectations. Third, they estimated a model relating the number of disaster events, the number of unanticipated disaster events, and other

⁴ The expectations hypothesis regarding market responses to disasters implies that, if the frequency of disasters in each city during the 1980's were identical to prior expectations, then the observed disaster rate in each city would have no effect on economic activity. Unanticipated disasters are equal to zero in this case. If actual disaster experience were significantly higher (lower) than expectations, the expectations hypothesis suggests that disaster expectations would rise and the consequent negative (positive) effects on employment, housing, and land rents discussed above would be observed. For example, the occurrence of 3 floods during the 1960's in an area expected to have 1 (3) [5] floods per decade should have a negative (neutral) [positive] effect on expectations of flood danger and a corresponding positive (neutral) [negative] effect on the local economy. In an area expected to flood 3 times per decade, the danger of flooding has already been discounted at that frequency and is reflected in both land values and levels of employment and population. As unanticipated disasters rises from -2 to 0 to +2, the local economy experiences increasing negative effects.

factors to the change in local housing prices. The test results were consistent with expectations that the number of disaster events had no significant relation to house price changes but the unanticipated component of recent disaster experience was negatively related to the rate of house price appreciation. Specifically, occurrence of one unanticipated disaster event was estimated to lower house prices by 2%, or a negative effect of several hundreds of millions of dollars in a city with 250,000 households.⁵

Theoretical Effects of Disaster Expectations on Development

It is useful to compare models that include the information effects of unanticipated disasters with the results of models that ignore information effects and implicitly ignore local differences in disaster expectations. The evidence from case studies of disaster events is mixed. Many have shown significant long term effects, both positive and negative. The record also contains observations of little or no effect. (See Friesma et al. (1977)). Rossi, Wright, and Weber-Burdin (1982) report results indicating that natural disaster concerns are not particularly important among public officials, many of whom might be charged with dealing with their consequences. A major econometric study of a large national crosssection of disaster events occurring during the 1960-1970 period, which was conducted by Wright, et al. (1979), found no long term effects on population or housing trends. While this study might be criticized for using only population and housing units as indicators, the Rubin and Yezer (1987) results suggest that no

⁵ The mean asset price of housing in their sample was \$64,000 in 1979. For a city with 250,000 housing units, the 2% fall in asset price implies a decline of over \$300,000,000 in the aggregate asset prices of housing units due to the effects of a single unanticipated disaster event in a city where disaster expectations had been zero. A loss of 2% in housing asset price implies a fall of approximately 8% in the underlying land values. If this fall were extended to all values of developed land throughout the city, the economic effects would be far larger than the \$300,000,000. Unfortunately extending estimated information effects from residential to commercial and industrial real estate is difficult due to data limitations and potential modeling issues.

significant effects would be observed even if housing or land price changes were being analyzed. Failure to find significant economic effects of the rate of occurrence of disaster events merely indicates that, on average, disaster events occur where they are expected. It does not imply that unanticipated increases in the frequency or severity of disaster events could not have significant economic consequences or attract the attention of public officials.

Models of natural disasters with information effects have significant implications for patterns of residential land use. These implications have been developed by Frame (1998) applying the standard (monocentric) urban model to a city with differentiated levels of natural disaster expectations. This application of the urban land market models has much in common with earlier modeling efforts by Scawthorn, Iemura, and Yamada (1982). Frame (1998) models a closed urban area in which a fixed number of households, earning a given market wage at a central location, choose housing quantity and location to maximize utility from consumption of housing and a composite good whose price does not vary.⁶ Within the urban area there are different location-specific expectations of the probability of damage from natural disasters.

Because households are free to move throughout the city, the price of housing services must fall in less attractive areas - i.e. areas with larger commuting cost to center city jobs or higher expectations of disasters. This is not a particularly strong assumption, given that it has been demonstrated in empirical

⁶ Hazard events lower utility of households through the damage that is done to housing, and the consequent reduction in consumption. The loss function is sufficiently general to allow for a direct financial cost reflecting personal danger to the household. By assuming a closed city, the model allows wages and population to vary independently. An open city model would hold utility constant by allowing intercity migration to equalize welfare.

studies by MacDonald, Murdoch and White (1987), Shilling, Benjamin, and Sirmans (1985), and Brookshire, Thayer, Tschirhart, and Schulze (1985). All of these studies have demonstrated the presence of price discounts for increases in expected risk, but empirical evidence on other market reactions, such as lower rates of investment or lower population densities have not been the object of substantial testing.

Based on this assumption of household mobility, Frame (1998) is able to establish the following theoretical propositions regarding the effects of increasing the expected frequency of hazard events. Producers of housing respond to the lower price per unit of housing services in areas with greater hazard risk by bidding less for undeveloped land in such areas and producing housing services with a lower ratio of capital to land - i.e. the ratio of housing services per unit land is lower in areas with greater hazard risk. In areas characterized by a mixture of high commuting cost and/or high hazard risk, land prices may be depressed to the point where no housing is built. The effect of the lower supply price of housing on quantity of housing demanded in areas with greater hazard risk is ambiguous because lower price encourages consumption and decreases the significance of any damage that is done but greater hazard risk also makes housing consumption less certain. Because the effect of greater hazard risk on quantity of housing demanded by households is ambiguous, it is also not possible to prove increasing risk lowers the density of population. However, this effect seems likely and certainly is true when increasing risk lowers developed land rents below the level needed to promote any residential development - i.e. when land is withheld from residential use, population density falls to zero.

The model developed by Frame (1998), like the earlier efforts of Scawthorn, Iemura, and Yamada (1982), generates downward shifts of housing prices and development densities in parts of the urban area where disaster probability is high. This result fits intuition well, with natural hazards operating in a

manner similar to any natural barrier that raises costs of producing housing. It is likely that analogous results could be obtained for noxious plants producing outputs on such sites although an additional consideration would involve any supplemental wage compensation required to attract workers to a hazardous site.

Frame (1998) also provides a number of results on the effects of disaster insurance. Provision of unsubsidized insurance, at a price reflecting the actuarial value of future losses, allows households to diversify away geographic risk. Because the premium payment increases with expected loss, provision of unsubsidized insurance does not change the negative relation between hazard probability and the price of housing, and the density of housing production per unit land. If insurance is subsidized, the effect of hazard risk on housing prices and on the density of housing supplied is attenuated compared to the unsubsidized or no insurance cases. The positive effect of insurance subsidies on housing prices was noted empirically by Shilling, Sirmans, and Benjamin (1989). While these predicted effects of providing actuarially fair or subsidized insurance may generally agree with intuition, a final result provided by Frame (1998) is likely surprising. The effect of insurance, even subsidized insurance, on the density or welfare of population in high risk areas is ambiguous.⁷ It would be interesting to extend these results to open city models in which one city is subject to greater natural hazard risk and must compete for capital and labor against another city.

⁷ Insurance subsidies increase the welfare of current landowners by raising housing prices but they do not increase population density or welfare of those living in the high risk area after housing prices rise. The reason for this counterintuitive result is that when insurance subsidies raise housing prices and the quantity of housing produced per unit land, they also raise the demand for housing per household, which makes effects on density of households per unit land ambiguous.

The Frame results are compatible with models of information updating in which recent rates of disaster activity or announcements of new disaster forecasts are used to update disaster expectations. This implies that either the recent rate of disaster events or announcements concerning such events can have information effects to the extent that expectations of future disaster events in that area are changed. The result will be a change in the prices of housing and land, and in desired density of development. These predictions appear to be testable.

III. Models of the Insurance Market, Mitigation, and Post-Disaster Aid

The rising cost of insurance claims, both private and government sponsored, in the last decade has stimulated substantial interest in various aspects of the provision of insurance against losses from natural disasters. Among the most important issues appear to be: (1) reluctance of individuals to purchase insurance and invest in mitigation efforts, (2) the interaction among insurance, mitigation expenditures, and post-disaster aid and their effect on economic development, and (3) the design of financial instruments appropriate for capitalizing private insurance against major disaster events. Examples of the literature on these topics will be considered in turn. All three have been the object of significant recent research efforts motivated in no small part by the rising costs to both private insurance companies and government of natural disaster events in the United States during the 1990's.

Behavior and Perceptions of Property Owners in High Risk Areas

Significant efforts have been made assess if individuals in high risk areas perceive those risks and act upon them in their insurance and mitigation decisions. The National Flood Insurance Program (NFIP) has served as a poster child for non-participation. Kunreuther (1978) noted that, in the first four years on the

program (1968-72), 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. In spite of the fact that NFIP was subsidized, participation was only accelerated by threatening communities with denial of federally assisted or guaranteed post-disaster aid, specifically construction or mortgage loans, to property owners in non-participating communities that had been identified as special flood hazard areas.⁸ Palm, et al (1990) have documented the failure of homeowners and even mortgage lenders to seek earthquake insurance in high risk areas.

Taken at face value, this stylized fact regarding failure to insure has, in the view of some, called into question the use of standard models of the economics of insurance in the special case of natural disasters. Kunreuther and Kleffner (1992) and Kunreuther (1996) have argued that homeowners do not behave as if they were maximizing expected utility in their decisions to purchase insurance or engage in private mitigation efforts.⁹ They hold that behavior most closely resembles the contingent weighting model in which individuals place different weights on the probability of a hazard event and on the contingent loss should it occur. If individuals place low weights on the probability of infrequent natural hazard events, they will act as if the expected utility of insurance and mitigation is lower than that perceived by experts. The failure of the public to use seat belt restraints has been rationalized this way. Kunreuther and Kleffner

⁸ While the subsidy component of the NFIP for structures constructed since Flood Insurance Mapping or January, 1975, is likely small, older structures receive a significant subsidy and yet have significant non-participation rates. This in spite of requirements that lenders require flood insurance as a condition for giving a mortgage because owners have allowed policies to lapse after a modest period without hazard losses. Overall only about one-fourth of homeowners in flood-hazard areas have purchased NFIP insurance.

⁹ Kunreuther (1978) first argued that property owners fail to purchase insurance and spend for mitigation some time ago.

(1992) consider simple benefit cost estimates of a loss mitigation measure, bracing pre-1940 homes in California so that they would not slide off their foundations. They find that low rates of mitigation appear to suggest low probabilities of hazard events - or low weighting of those probabilities. Overall, it appears that property owners in areas subject to natural hazard risk underspend on insurance and mitigation efforts compared to standards that are justified by sound benefit-cost analysis.¹⁰ Even where building codes require cost-effective mitigation efforts, Kunreuther (1996) reports serious cases of underinvestment and failure to comply, resulting in significant additional damage, for example, in the case of hurricane Andrew.

In contrast to the evidence that property owners in high risk areas ignore those risks, research also indicates that their behavior changes with additional information. While property owners are observed to be "insensitive" to levels of risk, they do respond to "changes" in risk. Most dramatic is the finding by Palm, et al (1990) that, prior to the Loma Prieta earthquake, there was no relation between proximity to the San Andreas fault and the rate of purchase of earthquake insurance but that after the earthquake the purchase of insurance increased and that insurance rates fell with distance from the fault. Survey evidence indicates further that attitudes toward the importance of earthquake insurance shifted substantially after the Loma Prieta earthquake. There is also evidence that market prices reflect learning behavior. Brookshire, Thayer, Tschirhart, and Schulze (1985) find that publication of information on the distance from properties and established fault lines causes house prices to fall within the earthquake prone zone. Shilling, Benjamin, and Sirmans (1985) found that NFIP subsidies to pre-FIRM structures were capitalized into house values. As noted in some detail above, Yezer and Rubin (1987) find that housing

¹⁰ See Palm, et al (1990) for survey evidence on the failure of property owners to adopt any mitigation actions in earthquake-prone areas of California.

prices respond to unanticipated disaster events, i.e. to differences between the frequency of floods, windstorms, etc during a given period and the previous history of such events. Thus it appears that the standard insurance model, in which expected loss and the variance in expected loss motivate behavior, works in a dynamic context. Changes in disaster events have the predicted effect on property owners perceptions and behavior as well as on market prices.

Research on the economic behaviors and responses of property owners in high hazard risk areas are, at least, partly consistent with standard expected utility models employed to explain expenditures for insurance and mitigation. Surely, more research is needed to resolve these issues and they are important to public policy toward insurance, mitigation, and post-disaster aid. One possible explanation for the failure of property owners in high risk areas to make insurance and mitigation decisions that appear economically justified is that they are selected into high hazard areas based on their perceptions of risks. If markets provide price discounts for properties in areas with greater hazard risk, those properties will be differentially attractive to individuals who fail to perceive the risks. Alternatively, if there is a risk distribution, those whose expectation of actual risk is at the low end of expert opinion will likely occupy properties in areas rated as highest risk by the experts. With low probability events where expert opinion on frequency has high variance, particularly events such as earthquakes, it would not be surprising if property owners in the highest risk areas believed that risks were at the low end of the distribution of expert opinion. Subsequent occurrence of an event, could have a dramatic effect on these expectations as survey evidence and behavior have shown.

Interaction Among Insurance, Development, Mitigation, and Post-Disaster Aid

From the point of view of the property owner, insurance, mitigation, and post-disaster aid are all substitutes, providing either funds to cover losses or lowering losses contingent on a natural disaster event occurring. As noted by a number of authors, establishment of public subsidies for insurance or mitigation, or the provision of post-disaster relief have the effect of shifting the burden of loss, both loss expected *ex ante* and loss experienced *ex post*, from the property holder to others.¹¹ Unsubsidized insurance shifts the burden of loss *ex post* to those entities who have purchased the contingent liability but not *ex post* as actuarially sound premiums reflect expectations of loss. These issues are part of current public policy debates regarding the establishment or extension of government insurance programs and requirements for mitigation in the form of zoning.¹² Another response has been the Costal Barriers Resources Act of 1982 which prohibits federal government programs, including the NFIP, from activity in areas designated as part of the Costal Barriers Resources System (CBRS). New development in such areas is totally dependent on private funding for infrastructure, mitigation, and insurance. This has led to the curious situation in which, along a given beach, successive areas are full participants in NFIP and beach nourishment programs while neighboring areas rely entirely on private sector development and insurance.

The expectation that government subsidized insurance and mitigation followed by post-disaster aid will lead to overdevelopment and under mitigation in high risk areas is largely based on partial equilibrium models in which the expected cost of hazard events born by property owners is reduced by the subsidy.

¹¹ Note particularly the extensive discussion in Kunreuther (1996).

¹² See, for example Congressional Research Service (1992), for a discussion that treats insurance, mitigation, and disaster relief as substitutes and the possibility of moral hazard problems associated with public expenditures for any one of the three. Kunreuther and Kleffner (1992) make the case for mandatory mitigation.

There is some empirical evidence in Schilling, Sirmans, and Benjamin (1984), that subsidized insurance is capitalized into land values. This is consistent with Frame's (1998) general equilibrium result that insurance subsidies raise land prices, house prices, and the physical density of development, while the effect of insurance subsidies on the density of population in high risk areas is ambiguous, except that some areas previously considered too risky for development are developed.

Cordes and Yezer (1998) test directly for the empirical effects of subsidized insurance through the NFIP, and mitigation, in the form of beach enhancement by the U.S. Army Corps of Engineers (Corps). They estimate a model of beachfront residential development, specifically the rate at which new building permits are issued, for a panel of beach communities that allows for the observation of communities with and without insurance and enhancement programs and also observation of given communities before and after programs were implemented. The results suggest that provision of subsidized insurance under the NFIP encouraged higher levels of real estate development in beachfront communities. However, subsidized mitigation in the form of U.S. Army Corps of Engineers beach enhancement had no such effect on development. These results may appear surprising because only a modest fraction of property owners in beachfront communities chose to maintain insurance in force. Nevertheless, insurance availability appears to have encouraged new construction while beach enhancement failed to do so.

Overall, a number of papers have produced theoretical results suggesting that provision of subsidized insurance or mitigation efforts tends to increase the density of real property development in high hazard areas. The implications of insurance for both development and mitigation in such a general equilibrium setting have been neglected along with the implications of post-disaster aid. Finally, there is little empirical evidence on the size of these real estate development effects. The effects of insurance

availability and/or public mitigation efforts on the decision to develop high hazard areas are clearly important and should be the object of additional testing.

The interaction between development and mitigation efforts and the provision of post-disaster aid is well recognized as an important policy concern but has not been the object of substantial formal modeling. A number of authors, including Rubin (1982), have noted that systematic withholding of disaster relief from individuals who have failed to mitigate risks is not politically credible. Most disaster relief schemes clearly include a measure of equity and efficiency for reasons discussed in Dacy and Kunreuther (1969). These implicit equity-efficiency tradeoffs have been examined explicitly by Butler and Doessel (1981) and a scheme for partial loss compensation, with the replacement rate varying inversely with income, developed as a remedy. The full set of tradeoffs among *ex post* disaster relief expenditures and *ex ante* decisions regarding development and mitigation expenditures, was developed by Lewis and Nickerson (1989). In this model, risk averse households living in areas varying in hazard risk can invest either in risky structures or in risk preventing mitigation. While "expected" findings of excess spending on risky structures and underinvestment in mitigation in the presence of disaster relief are obtained from this model, the results are complex. Mitigation expenditures designed to prevent small losses are undertaken because those losses do not result in aid but there is underspending on efforts to avoid substantial losses where relief is expected. The authors conclude with a list of potential research extensions that are still waiting to be made.

Design of Financial Instruments for Capitalizing Private Insurance

In addition to the concern expressed by Kunreuther (1978, 1996) and others that property owners fail to demand actuarially fair insurance against hazard losses, there is also concern with the supply side of the

hazard insurance market. Insurance markets normally provide policies in which the price of coverage reflects differential risks of loss plus a margin for normal returns and administrative costs. Companies maintain sufficient capital to cover expected losses and, in periods where losses are high, are able to raise additional capital at moderate cost. Private insurance should price risk appropriately and provide incentives for deterring investment in high-risk areas and for mitigation efforts, in the form of reduced premiums. A number of sources, including the Congressional Research Service (1992) and Kunreuther and Roth (1998) have noted that private insurance markets have failed to perform this function for property owners in areas with high hazard risks. Nine smaller insurance companies failed in the wake of hurricane Andrew while others tried to reduce coverage or asked for increased premiums. The public sector response was to insist on continuing coverage at current rates. Clearly neither the initial structure of the market nor the regulatory response fit the normal insurance market model.¹³

In response to the problems faced by private insurance companies providing coverage in areas where expected hazard events are particularly severe, a recent literature has considered innovative financial instruments and changes in tax law that could provide substantial capital for companies supplying disaster insurance. Problems identified in the current system as noted by Cummins and Geman (1995), Lewis and Murdock (1996), and Jaffee and Russel (1997), arise from the extraordinary payouts of claims in excess of the flow of premium revenues. These payouts produce periods of negative cash flow and profits which reduce the accumulated capital reserves of insurance companies when major disaster events occur. Four possible solutions to this problem have been considered. Obviously, premium rates must be sufficient to

¹³ See Kunreuther and Roth (1998) for a discussion of hazard insurance regulation and subsidies including the California Earthquake Authority and the Florida Joint Underwriting Authority.

cover expected losses plus normal profits and administrative costs.¹⁴ Second, private reinsurance markets could be further developed to better diversify risk across the nation and even the world. Third, tax law changes could delay recognition of profit on insurance against natural disaster events by substituting a multi-year accounting period for the current annual period used to compute taxable income. Actuarially fair insurance will generate apparently large accounting profits over short periods followed by large losses when disasters occur. Unfortunately, it may be difficult for insurance firms to recapitalize after particularly large losses even if they have tax advantages associated with a large loss carryforward. While corporate profits taxes may appear to diversify some of the risk of large claims to the government, the very uneven nature of disaster losses appears to reduce the value of the diversification benefits.¹⁵

The fourth solution to the capitalization problem has captured recent attention and involves the design of contingent liabilities whose value depends on the amount of disaster claims losses in any given period. Purchasers of such liabilities earn high returns in periods where claims are negligible and low or even negative returns when major disaster events produce high claims rates. This line of inquiry has been spurred by specific attempts in the private sector to develop new instruments including "Act of God" bonds, and catastrophe futures and options.¹⁶ Jaffee and Russell (1997) note that accounting

¹⁴ Regulators in areas experiencing high loss rates may be under pressure from constituents to keep premiums low and maintain coverage rates when companies attempt to retreat from the market as in Florida after hurricane Andrew.

¹⁵ This argument that corporate taxation of insurance company profits reduces the attractiveness of high risk business, such as disaster insurance, contrasts with the normal theoretical result that profits taxes increase risk taking because the variance in after-tax profits is less than that of before tax profits. The literature argues that large disaster events create huge losses and that the consequent threat of bankruptcy may deter recapitalization of companies even if they have large tax losses.

¹⁶ The pricing of catastrophe futures and options is taken up in Cummins and Geman (1995).

requirements, tax provisions, takeover threats against firms with large cash surplus, and regulatory constraints all limit insurance company capital held for catastrophes. Nevertheless they argue that primary problems of disaster insurance reside in capital markets and that some form of government sponsored reinsurance may be required. In order not to crowd out private sector innovations, the government reinsurance program would only apply to disaster events in which aggregate losses exceeded some substantial threshold, say twenty billion dollars.

Overall, the ability of insurance markets to serve areas subject to large scale disaster losses is an active topic of research involving both insurance and capital market issues. Actual innovations are producing new opportunities for analysis even as this review is being written.

IV. Empirical Models Of Economic Impacts Of Disaster Events

These models trace the likely economic effects of a disaster event. In contrast to the theoretical models of effects on housing markets and residential real estate development, these models emphasize effects on industrial output, although effects of rebuilding of the residential capital stock are usually included. The effects of disasters are generated by simulating a base line economic scenario and then comparing this with one or more disaster event scenarios. The appropriate comparison is economic activity with and without the disaster event. It is important to model effects so that all costs can be measured without double counting. For example, it is a model should estimate both the cost of damaged property and subsequent output loss due to inoperable equipment, However it is not appropriate to add both the value of damaged equipment and costs of replacing that damaged equipment. A model should also be capable of estimating costs over time because a cost experienced today is worth more than a cost

years after the disaster event. Finally, it is important to distinguish positive models of the most likely effects of a disaster and normative models that attempt to reallocate resources in the post- disaster period in order to minimize losses.

There are two distinct modeling approaches, regional econometric models and interindustry (input-output) models. In either case, some special adaptations of the standard regional model are necessary if it is to be used for estimating effects of disasters. Specifically, disasters lower subsequent output levels by disrupting the availability of inputs locally and the ability to transport inputs from alternative locations. Most regional econometric and input-output models are designed to estimate the effects of fluctuations in national demand for regional products on regional output assuming that input supplies are very elastic. Therefore, modeling effects of supply disruptions as well as efforts to rebuild damaged local capital stock requires some special adaptation of the usual model.

The two primary examples of regional econometric models adapted to study regional disaster impacts are Ellison, Milliman, and Roberts (1984) and Guimaraes, Hefner, and Woodward (1993). Regional econometric models consist of a series of equations characterizing output, usually disaggregated by a few broad sectors, employment, consumption, labor supply, wages, and prices with additional specialized modules, often including local government and housing. In order to capture the effects of natural disasters on local economic activity, the econometric model should include equations reflecting the process of local investment and capital stock accumulation and then relate local output levels to both capital and labor inputs. Special attention to residential real estate production and accumulation is also needed if the recovery process is to be modeled. The model should allow both labor migration and local capital investment decisions to be modified by expectations in response to disaster events. It is also

important to include a role for transfers from private insurance and public disaster aid. The regional econometric model is usually estimated using annual data often available for only 30 or 40 years. With so few observations, the complexity of individual equations is limited. Ellison, Milliman and Roberts (1984) argue that it is important to disaggregate the region into subareas when disaster events are localized within an urban area. Data are available to disaggregate Metropolitan Statistical Areas by county. Overall, substantial modification of traditional regional econometric models is necessary if these models are to be used in disaster impact evaluation. A guide to these needed modifications along with practical suggestions for their achievement in the face of data limitations has been provided by West and Lenze (1994).

Regional interindustry models are traditionally demand driven with in changes exogenous national demand for regional exports drive the local economy. However, these models can be substantially modified to include supply side feedback effects and their superior industrial disaggregation allows them to trace specific interindustry effects of supply disruptions. Earlier examples of the adaptation of input-output approaches include Cochrane (1974), Wilson (1982), and Rose (1991). An regional input-output modeling effort requires that the extent of local interdependence among industries be identified. The extent to which local industries rely on inputs of locally produced intermediate product is made apparent in the modeling process. Accordingly, the output effects of an interruption of these sources of local supply can be determined. Of course, it is difficult to determine the effect of a disaster on the availability of inputs imported from outside the area to replace local supplies. But the input-output model can be used to estimate the effects of local supply interruptions under alternative assumptions on the availability of imports.

It is also possible to adapt interindustry models to an optimizing mode and to draw implications for the effect of alternative post-disaster responses on local output. The optimizing model works to achieve an allocation of infrastructure inputs to minimize the output effects of disruption. This literature has reached very sophisticated levels with models such as Rose et al (1997) in which programming models are used to allocate scarce electricity disrupted by a disaster event. This model is remarkable in the extent of geographic disaggregation which allows for the simulation of effects of electricity outages at the substation level. The model operates in normative mode to identify patterns of electricity restoration that minimize the loss of local value added in the post-disaster period.¹⁷

Although there is a tendency to think of using economic impact models to estimate the likely losses from disaster events, their greatest value may be in simulating the effects of alternative approaches to post-disaster recovery.

IV. Conclusions Regarding the Literature on the Economics of Natural Disasters

There are two obvious conclusions from this review. First, the economic effects of natural disasters is a remarkably under researched area. The total number of citations to research in economics of disasters is very small and the number of potential topics is quite large, leaving a very thin rate of coverage. Second, various approaches to the economics of disasters have remained segregated. Theoretical models including information effects have had little effect on economic impact modeling. There are few empirical tests of information effects. The relation among insurance, mitigation, and post disaster relief has been

¹⁷ The modeling effort includes numerous clever tricks that allow the authors to overcome limitations in the availability of data at the local level. These should be useful in a variety of research applications.

examined but the exploration is far from complete. One branch of literature has concentrated on the response of households and residential housing markets while the economic impact literature has dealt largely with firms. Hopefully this review will inspire additional efforts to fill in gaps between the literatures and, more important, to produce models that integrate the economic effects of disasters on both households and firms.

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