SUMMARY AND CONCLUSIONS

This study makes a number of contributions to the current understanding of local economic effects of natural disasters: original data assembly, development of new theory, new tests of the way disasters affect a local economy, and evaluation of public policy implications. For many readers, the arguments made here will appear to be a significant break with understanding based on previous literature. Therefore, in this section we consider carefully how the current research differs from previous literature which has often focused on direct damage measures rather than on indirect effects on the local economy generally. Finally, we draw from these results some of the many implications for public policy and decision making.

In this study, local economic effects are evaluated net of the current structure of government disaster aid. Public disaster assistance programs, which address the direct effects or physical damage done by a disaster, act to attenuate the market reaction to changed disaster expectations. Such compensation for direct effects, if sufficiently generous, could produce net economic reactions which are small or totally insignificant even when the gross economic effects are large. Thus the effect of compensation programs is to attenuate both direct and indirect local economic effects of disasters and make detection of local effects more difficult.

The results of this study are different from other studies in that the tests performed here indicate that the main body of economic theory can be applied by treating disasters as negative natural resources whose effects can be analyzed using an expectations hypothesis. This is a major difference, because the economic theory of natural resources has a rich variety of implications for the local economic effects of disasters. Some of these implications are developed in this section, with particular attention given to

estimation of the potential economic effects of changes in the expected rate of natural disasters, which can be extremely large in real dollars, and to the estimation of returns from hazard mitigation.

Original Data Assembly

To determine the local economic effects of natural disasters, it was first necessary to estimate the expected probability of disaster occurrence in particular locations. We used an expectations model in which past frequency of disasters was noted to estimate expectations of future disaster rates. It was necessary to construct such estimates for a significant number of areas so that significant variation in disaster expectations and subsequent outcomes could be observed. Because no adequate time series on disaster experiences for a large cross-section of areas were available, we developed the needed data series for this project.

We constructed time series data on the disaster experience of individual counties for 1965-1985 from information supplied by the Federal Emergency Management Agency on presidential disaster declarations. Then, the counties were combined to form Standard Metropolitan Statistical Areas (SMSAs) for which data on local economic effects were available. The expected rate of natural disasters was based on the frequency with which presidential disaster declarations had occurred in an area during the 15 years between 1965 and 1980.*

Clearly, the use of presidential disaster declarations may result in an understatement of the rate at which disasters occur in some areas. There is some evidence that the declarations are not based on a consistent set of

*For a detailed discussion of the data, see the report, Summary of Major Disaster Incidents in the U.S. (1965-85), by Rubin, Yezer, Hussain, and Webb (1986).

standards for degree of damage or threat posed. Nevertheless, the information about large disasters available because of federal record keeping regarding declared disasters is better than any alternative. Concentrating the analysis on cities means that significant hazard events occurring in an area are likely to cause sufficient damage, due to the density of economic activity in cities, to warrant a disaster declaration. If rural areas had been analyzed, the chance that a significant disaster event could occur without causing sufficient damage to warrant a disaster declaration would be significant. Again, however, in cities disaster events cause large enough losses to make declaration a virtual certainty.

Development of New Theory

This research effort centered on the development and testing of a theoretical model that treats natural disasters as a negative natural resource whose effects on the local economy are uncertain because firms and households do not know when a disaster will occur. The indirect effects of disaster experiences arise because of the connection between past events and future expectations. Firms and households do recognize that disaster events follow a probability distribution and have expectations about this distribution, based on past rates of disaster events. This gives rise to an expectations model of indirect economic effects in which local economic activity is altered when a change in the rate of occurrence of disasters modifies expectations for the future. A number of other researchers, including Brown (1972), Brookshire et al. (1985), and Ellson et al. (1984) also have analyzed economic effects of disaster events through an examination of the effects of disasters (or of disaster predictions) on expectations. Thus the expectations hypothesis has been applied to the analysis of disasters in a number of alternative

contexts.*

The most important result of the application of an expectations model to indirect economic effects of disasters is the conclusion that the unanticipated component of disaster experience leads to economic change, while the anticipated component of disaster experience does not result in indirect economic effects. Thus, if an area is expected to have a flood every three years and there is one flood during the next three years, then the actual disaster rate is equal to the expected rate, and there should be no change in disaster expectations or in the local economy. If, however, there were no disaster events during the three-year period, then actual disasters would be below expectations. In other words, there would be -1 unanticipated disasters during the period. To the extent that disaster expectations were lowered during this period, economic activity would be stimulated in the area. Conversely, two disaster events in three years produces +1 unanticipated disasters which will raise expectations and tend to depress economic activity.

The expectations hypothesis also implies that the indirect local economic effects of a given disaster rate depend on the previous disaster rate and the expectations associated with that experience. One flood during three years may increase disaster expectations in an area where floods seldom occur and lower expectations in areas that ordinarily flood every year. In the former area, the single flood in three years would depress economic activity because it was unanticipated, while in the latter, a single flood event in three years would provide an economic stimulus, there being -2 unanticipated floods in the area. In order to know whether recent disaster rates have had a positive or

*Expectations models have been used by economists to analyze problems other than disasters. The most common applications have been to examine effects of expectations on asset prices of financial instruments. Indeed, the Securities and Exchange Commission uses changes in securities prices to detect changes in expectations which may indicate the presence of insider trading.

negative effect on a local economy, one must determine the expectations for that area based on past experience.

In order to construct estimates of prior disaster expectations and to observe subsequent disaster experience so that anticipated and unanticipated components of actual disaster experience can be distinguished, we developed time series data on natural disaster experience of metropolitan areas for events that received a presidential disaster declaration. The 20-year histories of presidential declarations, disaggregated by disaster agent and county for this research, are a substantial addition to data on disaster experience. Longer time series and information on disasters not receiving a declaration would be useful both to test the expectations hypothesis further and to aid policy formulation or administration. Future research on and policy applications of the expectations approach to disaster effects would be greatly aided by an expanded data set giving the disaster history of individual cities over longer periods of time.

A theoretical model of a local economy capable of demonstrating the manner in which expectations of disasters change observable economic phenomena was needed to formulate a test of the expectations hypothesis. This is a significant departure from other studies in which no normal model of the way in which the disaster rate experienced in one city might influence the development of that city vis-a-vis other cities in a region. The theoretical model is a simple general equilibrium model of a city with housing and firms occupying the land. This type of model has been used by economists to analyze various urban development issues, and it was specially modified to relate disaster expectations to the local economy. Natural disasters affect the local economy by damaging output of firms and lowering welfare of workers who experience both damage to their homes and losses through personal injury.

The local economy model relates changes in disaster expectations to a variety of local economic variables including output, population, wages, profits, land area, land values, numbers and value of housing units, etc. This information on indirect economic effects of changes in disaster expectations on various variables was used to select variables to be used in the empirical test of disaster effects. The ideal test variable should move in an unambiguous fashion when disaster expectations change, or when the actual disaster rate differs from the expected rate producing an unanticipated component of the disaster rate. Finding such an ideal test variable was not easy because the local economy model demonstrated that many local economic indicator variables did not change in an unambiguous fashion when disasters changed. For example, a rise in disaster expectations can certainly change local wages, but the change can be either positive or negative. Similarly, the effects on the total amount of housing or population are not clear. Even where effects of changes in disaster expectations are unambiguously positive or negative, it is desirable that the changes have further economic significance. The local economy model suggested that land values and house prices were the most promising test variables.

As an indicator of disaster effects, land values have the special advantage of measuring the change in economic welfare associated with the change in natural disaster rate expectations. Thus, the change in land values can be used as a measure of the welfare effects of disaster mitigation efforts, insofar as such efforts succeed in lowering expected disaster rates.

The theoretical model was used principally to identify a particular test for local effects of natural disasters. Nevertheless, the model is quite rich and capable of elaboration by adding capital stock and investment considerations. Given the success of empirical tests in verifying conclusions of the

model, some elaboration should be seriously considered by researchers in the future.

Statistical Tests of the Expectations Model

The theoretical land market effects are formulated in a specific statistical test by using hedonic housing price techniques which rely on the translation of land values into asset values of housing. Thus movements in land values result in corresponding movements in asset prices of housing. A final theoretical issue concerned the exact manner in which current disaster experience changes disaster expectation. A model of the relation between recent experience and expectations based on past disaster rates was developed and used as the basis for estimating the unanticipated component of disaster experience. The occurrence, or non-occurrence, of a disaster in a given year will raise or lower previous disaster expectations as the public updates its expectation of disaster probabilities. Current disasters have a local economic effect through the changes they cause in the expected future disaster rate. Thus, it is not the direct measure of damage done but an indirect measure of the effects of that damage on expectations for future economic productivity of the city which should be used to measure local economic effects. For example, over a given time interval a city may experience direct damage from flooding measured in terms of replacement or repair cost of property damaged, but if the flood damage is below prior expectations, the indirect effect will be positive. Conversely, another city with less direct flood damage could have a large negative indirect effect if prior expectations for the possibility of flooding had been very low. In sum, direct property damage during a given time interval is a poor indicator of the indirect local economic effects of disasters.

Statistical tests of the relation between rates of appreciation in the

asset price of housing and disaster rates found the expected negative effect of the difference between the recent disaster rate and past rates on appreciation rates. This is consistent with the expectations hypothesis that recent disasters affect local economic activity to the extent that they diverge from expected rates based on past disaster experience. The empirical results also indicate that the rate of disasters is already incorporated into economic decision making so that, if recent disaster rates are the same as past rates, there is little or no local economic effect. Indeed, simple tests of the relation between asset prices of housing and the past rate of disasters actually indicate positive effects. Again, this result indirectly confirms the need to formulate economic effects in terms of an expectations process in order to obtain sensible and valid estimates of the change in a local economy due to its disaster experience during a given period.

The test for local economic effects of natural disasters includes the influence of aid from the local, state, and national governments. Such aid was forthcoming for the disasters included in our data set because these were all situations receiving a presidential disaster declaration and hence national assistance. If disaster relief efforts provided full compensation for damage, or led to the expectation that future disasters would be fully compensated, then disasters would have no local economic effect whether they were anticipated or unanticipated. The calculations of total economic effects of changed disaster reactions performed in the next section will indicate why negative net effects of unanticipated disasters were observed. Basically, the local economic effects occurring in areas that have a significant component of unanticipated disaster experience are of sufficient magnitude to dwarf available governmental and insurance compensation which is directed mainly at dealing with direct effects.

Policy Implications of the Research Results

The empirical results are consistent with the implications of the expectations hypothesis and the urban economic model which were used to develop the tests. These tests also demonstrated that failure to separate anticipated and unanticipated disaster effects results in biased statistical estimates of economic effects. Thus, there is strong evidence that local economic effects of disasters can be understood within the framework of expectations models and neoclassical urban development theory. This theory can be used to produce a variety of implications for the role of natural hazards in regional economic development, some of which are noted here. Greatest attention is given to the calculation of overall economic effects of disasters net of compensation payments.

The theoretical model of local economic responses to natural disasters presented earlier has implications far beyond those that were tested empirically. They include positive economic results regarding the way in which development in an urban area may be altered by a particular natural hazard or by changes in the expectation that disasters will occur. In addition, the model can be used to develop normative economic results about the way in which disasters affect social welfare. Specifically, the change in social welfare, as measured by value of output lost and changed real compensation required by workers, is fully reflected in the change in land rents and house prices. This change in social welfare is appropriate for use as a measure of benefits in economic benefit/cost analysis and has been used as such in the other literature on economic effects of natural disasters reviewed earlier. The intuitive reason for measuring social welfare changes through land and housing market effects is that capital and labor are mobile and may move away from areas where disaster expectations increase. Indeed the rate of return to

capital and the real wage of labor must be equated across regions. Only land prices vary in a fashion which reflects differences in disaster expectations.

Given the potential importance of measuring the decline in total land values within an urban area associated with an increase in disaster expectations caused by disaster experience during a given period, such calculations are reported here based on the empirical results previously presented. Great care in interpretation and use of these results is necessary. First, the results are net of current government disaster aid programs. Second, there is substantial uncertainty about the point estimates used to perform the calculations given the large standard errors accompanying the coefficient estimates in Tables 4 and 5. These limitations should be considered when referring to the estimates of net economic effect made below.

The effect of unanticipated disasters on asset prices of housing in a city can be estimated as follows. If disaster expectations had been 0 in 1979 and actual disaster experience during the subsequent period had included a single disaster episode, the disaster rate during the four-year observation period would have been 0.25 and hence CHANGD would be 0.25-0.00 = 0.25. Given that the estimated coefficient of CHANGD in Table 4 is approximately -0.08 or -8%, this implies that the percentage increase in the asset price of housing would be 0.25(-8%) = -2%, i.e., 2% lower due to the effect of the disaster on expectations. The average appreciation in asset prices of housing during the period was 36%. The effect of the disaster would be to reduce the expected appreciation to 34% at the mean of the sample.

While this point estimate of percentage effect may appear small, the total dollar effect is computed by attributing it to the entire land market. Consider only the residential component of that market. The mean asset price of housing in the 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 million in the aggregate asset prices of housing units due to the effects of a single unanticipated disaster in a city where disaster expectations had been nil. 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 million estimated above. However, it is difficult to acquire data on urban land values, and such extended estimates could perhaps be estimated best by applying the losses on residential land to all developed land in the city.

For a city in which disaster experience had been more frequent, so that prior disaster expectations were 0.50, observation of a single disaster event during the four-year period would actually produce negative values of CHANGD. Specifically CHANGD would equal 0.25-0.50 = -0.25, and the negative unanticipated disaster rate would result in a 2% increase in asset values. Finally, occurrence of exactly two disasters during the observation period in this city with expectations of 0.50 would result in CHANGD = 0.50 and not change the rate of housing asset price appreciation.

From a public policy viewpoint, the expectations approach to measuring local economic effects of disasters creates a number of problems and opportunities. For example, the calculations above illustrate that a single disaster event, occurring where prior disaster experience had been infrequent, will be largely unanticipated and hence can have substantial negative local economic effects. However, the same experience, in an area with a history of frequent disasters and many natural hazards, will be viewed by the market as a negative net unanticipated disaster, producing a fall in disaster expectations and a positive local economic effect. This is not to say that the area benefits from the disaster, but merely that, over the period in question, experiencing

fewer actual disasters than expected will produce a positive local economic response.

The economic model provides a context for understanding economic effects, and implications for public action will depend on policy goals. If the major goal of policy is to provide compensation for unanticipated losses, the implication is that aid to areas with high disaster expectations should not be large unless recent disaster experience is unusually high. Thus, "safe" areas which experience a single unanticipated disaster should receive more compensation than high-risk areas which have more than one disaster, if public policy relates compensation to local economic effect.

Undoubtedly, basing compensation on the local economic effects associated with an expectations approach is counterintuitive to many observers. The reason for this non-intuitive result is clear if one examines the theory put forward at the outset of this paper. Residents of areas where disaster expectations are high are compensated for differences in disaster probability by the higher real wages which they receive compared to individuals living and working in areas perceived as being free of natural hazards. Paying equal compensation for disasters without regard to the prior expectations in the area essentially provides double compensation for living in high disaster areas. Put another way, real wages are higher in Alaska than in the lower 48 states. This is compensation for the harsh Alaskan winter and the higher cost of living. To pay extra compensation to Alaskan residents every time there is a heavy snowfall or long period of sub-zero weather would be redundant, given the real wage differential already in force.

The expectations hypothesis presents an alternative approach to measuring the benefits of hazard mitigation. Theory suggests that these benefits are reflected in land values and that estimates of benefit can be constructed by

determining what land prices would be after a mitigation effort is completed. Presumably estimates of the value of this change could be gained by observing changes in land values in other locations where mitigation efforts had successfully lowered disaster rates. Comparisons should be made between cases in which sufficient experience with the effects of mitigation had been accumulated so that expectations had actually changed.

The potential applications of the expectations hypothesis and urban development model to public policy issues regarding natural disasters go far beyond the thoughts developed here. Indeed, this approach suggests different ways of viewing natural hazard policy problems. There is an important interaction between the models which we use to understand the local economic effects of natural disasters and the public policy questions which we choose to ask. The project team involved in this research has tried to make a contribution to both the measurement of local economic effects of disasters and to the conceptual framework within which policy issues related to those effects are viewed.

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