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ARE THERE LONG TERM EFFECTS OF AMERICAN NATURAL DISASTERS?

ESTIMATIONS OF EFFECTS OF FLOODS, HURRICANES, AND TORNADOS OCCURRING 1960 TO 1970 ON U.S. COUNTIES AND CENSUS TRACTS IN 1970*

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I. INTRODUCTION

Hardly a week goes by without some attention in the mass media to the damage from and the victims of natural disasters. The damages and injuries wrought by the tremendous forces of nature lead to dramatic news stories and television footage. Disaster victims quite deservedly attract sympathy, with public agencies and voluntary organizations providing quick rescue help and emergency shelter and care. However, last week's damages and victims recede in memory to be supplanted by this week's occurrences. Clearly, floods, tornados and hurricanes excite public interest and enjoy public sympathy, at least in the very short run period after occurrence.

If last week's flood is old news, what then is last year's damage? The immediate aftermath of a natural disaster is usually the focus of considerable attention and proffered help, but what about the long term needs for reconstruction? Are there significant long term needs that result from disasters that require more attention than is currently being given under current American policy?

To be sure, current federal disaster relief and rehabilitation policy in the United States as expressed in PL 93-288 "Disaster Relief Act of 1974," shows some nominal concern for long term effects of natural disasters, containing a provision (Title V) aimed at providing relief and rehabilitation support for the long term needs of disaster stricken communities. But, this section of the legislation has never been implemented, possibly expressing federal agencies' concern whether there are demonstrable needs for such relief and rehabilitation efforts.

These are the questions to which the research to be described in this paper is addressed. We have attempted to estimate the long term effects of the major floods, tornados and hurricanes that occurred in the decade 1960 to 1970, a period chosen because of accessible data. The effects studied are those that manifest themselves in distorted population, housing and economic decline (or growth) in small areas – census tracts – within urbanized places and in counties throughout the United States. These estimated changes are calculated using data from the 1960 and 1970 U.S. Censuses, and several disaster data bases in a unique, powerful research design, to be described in greater detail later in this paper.

The nature, duration, and magnitude of long

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term effects of natural disasters has been the focus of previous research, almost exclusively in the form of case studies of relatively large disaster events typically occurring in smaller settlements (Bates et al., 1963; Cochrane, 1975; Erikson, 1976; Friesma et al., 1977; Haas et al., 1977; Barton, 1969; Dacy and Kunreuther, 1969). These case studies have provided rich detail on how some communities reacted to disaster events but they all suffer from the chronic problems of case studies. First of all, they focus on events that are quite atypical, usually on the most serious end of the continuum of disaster magnitude. Secondly, they are all handicapped in being unable to disentangle the events that took place after the disaster that were reactions to the disaster from events that would have taken place anyway. Thus, the conclusions of some case studies that the disaster events accelerated growth (or brought about a decline) cannot be evaluated since we ordinarily have no way of discerning what would have happened to the community had the disaster not occurred.

The research we report here is free and clear of some of the deficiencies of case studies. We will present analyses of the long-term effects of all the major floods, tornados and hurricanes that occurred in the period between 1960 and 1970. Furthermore, we have developed a method that will provide estimates of what would have occurred to places experiencing disaster events if the disaster had not occurred. Finally, the disaster events we will study are serious occurrences, but not exclusively those whose magnitudes swamp the capacities of the places involved: our events include those that occur in large urban places as well as those that occur to relatively sparsely settled spots in the country.

II METHOD

The method employed to estimate the long-term effects of natural disasters takes advantage of the fact that the U.S. Census provides fairly detailed demographic, housing and some economic measures on small sub-areas within metropolitan places and for all counties. Since two adjacent censures can be linked (with some error, as we were to learn) it is possibly to calculate the changes in those respects experienced by such areas over the decade intervening. Those calculated changes represent the outcome of many processes, some of which can be modelled. Based upon our understanding of change processes for small areas generally, we can calculate for each such area, what its expected 1970 state is, given its position in that respect in 1960, and the change processes typical of places that are roughly comparable. If we then identify those areas that have experienced disasters within the decade 1960 to 1970, we can estimate how change processes have been effected positively or negatively by such experiences. Since disasters occur at various times during the decade, we can also see how 1960–1970 change is affected by when the disaster occurred within the decade. Presumably those disasters that occurred closer to the 1970 Census should show stronger impacts on small area changes than those occurring earlier in the decade.

This general approach was applied separately to all counties in the United States and to all tracts in metropolitan areas that experienced major disasters, along with all tracts in a "control" sample of metropolitan areas that did not experience a disaster. The general linear model was applied to the estimation procedure using models of the general form shown below (for tracts):

$$Y_{1970i} = Y_{1960i} + \Sigma b_i T_i \ \Sigma + b_k M_k + \Sigma b_i D_i + e$$

where

Y_i is some 1960 or 1970 measure for tract i, e.g. total tract population, total housing in tract,

$\Sigma b_i T_i$ is a vector of tract characteristics that relate to tract change, e.g. land area, location in SMSA, socio-economic

composition in 1960,

$\Sigma b_k M_k$ is a vector of SMSA and regional characteristics for the SMSA and region in which the tract is located, e.g. SMSA size and growth rate,

$\Sigma b_i D_i$ is a vector of variables indicating whether or not the tract experienced a disaster in the period and of descriptors of such events,

e is the usual stochastic error term.

Similar models were used for counties with appropriate modifications. Since economic activity measures were ordinarily not available in any detail for tracts, and are available only for counties, the economic activity effects of disasters could only be estimated for these larger units.

Although the models used provide a means for estimating disaster effects that are net of other changes occurring either in tracts or counties, the models were unable to separate out the effects of disasters from the effects of public policies that were applied to relief and rehabilitations activities that were reactions to the disaster. Hence, the estimates for long-term disaster effects that will be presented later on in this paper are estimates for disasters *and* accompanying endogeneous recovery efforts, aid given by political units and private organizations originating outside the disaster stricken areas, and the resulting reactions of housing markets for both rental and owner occupied units.

Clearly the worth of the procedure employed is highly dependent on our ability to undertake with some degree of accuracy two important steps: First, we have to be able to match 1960 and 1970 census tracts and counties so that data from the two censuses refer to the same spatial areas. Secondly, we need to be able to pinpoint the location of natural disasters finely enough to be able to detect which tracts and which counties had such experiences in the 1960–1970 decade. The next section of this paper addresses those two issues.

III THE CENSUS DATA BASES FOR COUNTY AND TRACT ANALYSES

The decade 1960–1970 was one that marked considerable growth in the American population and an even greater growth in its housing stock. Urbanization trends continued with more and more of the American population congregated within metropolitan areas. At the same time within metropolitan areas, growth and decentralization led to some degree of reapportionment of residential locations within such areas. All these trends meant that areal aggregates used by the U.S. census and designed to reflect the political boundaries of American localities and the population distributions within such boundaries were changed. The consequence for our study was to make it difficult to identify areal units that were identical in boundaries from the 1960 to 1970 Censuses.

Least difficulty was found for counties, important political units outside of the New England states and Alaska [1], and hence less likely to change. Of the 3,141 counties to be found in the relevant portions of the U.S., 3102 comparable county units could be defined consisting overwhelmingly of exactly comparable counties and a few units made up of combined contiguous counties whose boundaries when combined were comparable. Hence, our data base for our county impact analysis consists of the 3,102 counties and county units whose boundaries were essentially unchanged in the Censuses of 1960 and 1970.

A Census-defined Standard Metropolitan Statistical Area consists of a county containing a city of 50,000 or more and includes the contiguous counties that are urbanized. In a period of rapid urbanization and growth, new SMSA's are recognized by the census for each new census. The period 1960 to 1970 was no exception. However, since tracts are defined only for existing SMSA's, those places advanced to SMSA status with the 1970 Census were not tracted in 1960. Hence, our census tract analysis must necessarily be based on only those SMSA's

which were already defined as such in 1960. Since the number of SMSA's for the U.S., so defined, far exceeds the number that experienced a natural disaster in that period, we devised a sample of SMSA's which consists of all the 1960 SMSA's experiencing at least one disaster and a probability sample of all other SMSA's drawn so that the final sample of SMSA's represents the size distribution of SMSA's in the U.S.

Much more difficulty was experienced with census tracts, areal subdivisions of metropolitan areas that are created for census purposes. Tract boundaries are drawn when an area becomes an SMSA according to rough guidelines that direct local census tract committees to observe physical demarcations as boundaries (e.g., rivers, major highways, and the like) and to encompass roughly homogeneous areas with about 1,500 dwelling units and 4,000 residents. Clearly, a tract first defined in 1940 or even 1960 may have changed a great deal by 1970 while areas that were essentially unpopulated in 1950 or 1960 may now house many thousands of residents. Each decennial census recognizes these changes by redrawing some of the tracts. Of the 10,720 tracts that we finally used in our analysis, 70% were exactly comparable in boundaries (or changed in trivial ways) in 1960 and 1970. An additional 12% of the tracts represent merges of groups of tracts (usually pairs) that through mergers maintain comparable boundaries between the censuses. An additional 18% are "roughly"comparable encompassing areas that are 90% or more identical from one census to the other. Merged and roughly comparable tracts are precisely those experiencing the greatest amount of change from 1960 to 1970; that is the reason they were split or merged or boundaries changed. Hence, in the census tract analysis the degree of area comparability has to be taken into account.

Merging the two census files required a great deal of handwork, especially for census tracts. We are confident that we have units that are either exactly comparable in area or are comparable enough for our purposes when the small degree of incomparability is taken into account.

IV THE DISASTER DATA BASE

To conform to the requirements of the form of analyses specified by the model presented earlier, we needed to be able to identify all the disaster occurrences taking place between 1960 and 1970 along with information on their locations in space and time, as well as on their magnitudes. Unfortunately, there is no single source that contains all the required information with sufficient specificity. Instead, there are a variety of data sources, each of which suffers to some degree from more or less grievous faults.

To begin with, there are literally thousands of events that could have precipitated natural disasters, but which occurred in sparsely populated areas or were of minor magnitude even though occurring in a populous area. For example, the National Severe Storm Forecast Center's tornado file enumerates more than 7,000 tornado events in the decade 1960–1970. The vast majority of these events, however, are not natural *disasters* because they neither inflict injury nor damage. Of this very large number, only 24 were serious enough to be the occasion of a Presidential Disaster Declaration and only 129 were serious enough to be the object of a Small Business Administration declaration. Clearly, events which had no short term consequences for life or property can scarcely have any long term effects. Similar counts can be made of other types of potentially disastrous events: Most riverine floods cause little or no damage because they are either minor in extent or because they occur in places where there are few people and little in the way of property.

Secondly, there is a variety of sources of data on natural disasters each of which takes a different slice into the total set of events that might qualify as disaster occurrences. One of the more comprehensive files is the tornado file (machine readable) compiled by the National Severe Storm Forecast Center which purports to contain every tornado occurring in the United States since 1945. Although this data

base is more inclusive than we need, it also contains important locational information (latitude and longitude to nearest minute of points where each tornado touched land and where it raised again) and damage and injury estimates.

Another set of comprehensive sources is the American National Red Cross Chapter Reports filed with national headquarters. While the Chapter Reports contain fewer accounts of disaster events, more serious events are almost certain to be included. Other sources used include the files of the Small Business Administration, the Federal Disaster Assistance Administration, the National Hurricane Center, publications of the U.S. Geologic Survey – especially the *Hydrological Atlas* and *Water Supply Papers* – flood hazard boundary maps filed with the Federal Insurance Administration, and files of the New York Times.

These data sources each take a different slice into the universe of natural disaster events, provide different items of information about each event recorded and are difficult to reconcile one with each other. Fortunately, when they cover the same classes of events, they each tend to record more faithfully the more serious occurrences.

Finally, with the exceptions of the tornado tape, most of the data sources are at best vague and at worst silent on an important characteristic of the disaster events. They do not record precisely where the disasters took place, a characteristic that is quite critical for our purposes of locating which small areas experienced disaster events in the period 1960 to 1970.

Two main questions lay behind our use of the disaster data bases. First, we needed to enumerate all the disaster events that were serious enough that their long term effects might conceivably be measurable. That is, the amount of damage to property or to persons had to be more than simply minimal. We were surprised to learn how trivial were most of the events that were recorded. Employing a definition of "serious" that would mark off about the top 20th of disaster events [2], we arrived at the enumerations shown in Table I separately for counties and for SMSA's. It should be noted that the criteria used were not high: we were concerned that too high a threshold would leave us with very few natural disaster events to study.

A second use of the disaster data base was to locate in quite precise terms where the natural disaster events occurred within metropolitan areas, in order to identify which census tracts were likely to have been impacted by a disaster event. To answer this question, the tornado tape provided by the Severe Storm Forecast Center was the most adequate since it provided the latitude and longitude to the nearest minute of the beginning, end, and major bends in each tornado's path. Even this information was not as accurate as desired since accuracy to the nearest minute meant that the path's location

TABLE I

Serious Natural Disaster Events Occurring in the Decade 1960–1970

A. Counties:
   1. Number of counties experiencing at least one natural disaster event = 1,140 (or 37% of all counties in Census data base)
   2. Number of counties experiencing disaster events:*
      Tornados: 677
      Floods: 516
      Hurricanes: 137

B. Standard Metropolitan Statistical Areas (SMSA's):
   1. Number of SMSA's experiencing at least one natural disaster event = 56
   2. Number of SMSA's experiencing disaster events:*
      Tornados: 33
      Floods: 35
      Hurricanes: 8
   3. Number of tracts experiencing disaster events:*
      Tornados: 505
      Floods: 419
      Hurricanes: 260

* Since the same natural disaster event could have affected more than one county, SMSA, or tract, these numbers represent a considerably smaller number of separate and distinct disaster events.

was obtained with an accuracy ± one mile, a relatively large measurement error calibrated to the average size of census tracts (averaging 8 square miles). The hurricane tape provided by the National Hurricane Center also contained detailed locational data on the eye of each hurricane and its position at frequent time intervals. However, since hurricanes are rather diffuse phenomena, this information had to be supplemented with data from the Small Business Administration's home loan program.

Locational data on floods posed the most serious problems. Detailed maps showing the extent of flooding in the major urban flood of the 1960's do not generally exist; the few exceptions to this pattern (for example, certain *Hydrological Atlases*) were found to be unusable for other reasons (for example, only a small portion of the total flood area was mapped). It was therefore necessary to rely upon Flood Hazard Boundary Maps outlining the 100 year flood plains for the areas in question, picking those flood plains containing addresses upon which SBA home loans had been given as a consequence of the floods in question.

The locational data upon which the census tract analyses are based are obviously only approximately correct. We are most sure that we have tracts that experienced tornado damage among the tracts we have so designated, but most likely we have included as such tracts that actually were not impacted. The errors of over-inclusiveness are greater most likely for hurricanes and floods [3]. It should be noted that the consequences of these errors are to water down the estimates of effects to be presented later in this paper, since areas have been included that did not actually experience disaster events. This under-estimation applies primarily to the analysis of disaster effects on census tracts: We are quite certain that we have correctly classified counties as to whether each was impacted by a disaster.

V COUNTY LEVEL DISASTER EFFECTS

For most sections of the United States counties are important (and sometimes the only) units of local government, providing in many cases police protection, medical services, educational services and emergency rescue and relief. Even in metropolitan areas such as Los Angeles and Chicago, county governments provide a significant number of local urban services, and in rural areas counties are often the only local government body able to provide essential services. In short, counties are important political units and often important economic units as well.

For our purposes, we have identified 3102 counties (or combinations of counties) for which we have census data for both 1960 and 1970. Because counties are relatively large geographic units, we are quite certain that we have been able to correctly identify those hit by natural disaster events in the decade 1960–1970. However, by the same token, it seems unlikely that we will be able to find long lasting disaster effects because counties are large enough to obscure, possibly, those enduring effects that are characteristic of the smaller areas within them that may have been impacted by the disasters in question. The damages and injuries inflicted by the typical flood, hurricane or tornado have occurred to so small a proportion of the structures, enterprises and households located within typical counties that it is not likely that these events have been a serious threat to the total resources of the counties in question.

To discern the effects of disaster events on counties we employed the model described earlier in this article. The results of the application of this model to the percentage changes (1960–1970) in housing stock and population are shown in Tables II and III. The county characteristics that we have included in the model are measures of the composition of the population in the counties, certain economic variables such as median household income and propor-

TABLE II

Regression of Percentage Change in Total County Housing
Between 1960 and 1970 on Disaster Hits and Selected 1960 County Variables

Independent variables	Dependent variable is percentage change in total county housing, 1960 to 1970[1]		
	b	SE	signif.
Area of county (square miles)	0.000	**[2]	0.850
% non-white (1960)	−0.020	0.021	0.352
Median age of all persons (1960)	0.122	0.071	0.089
Median family income (1960)	−0.002	**[2]	0.000
% unemployed (1960)	−1.038	0.117	0.000
% in manufacturing (1960)	0.253	0.026	0.000
% in trade (1960)	0.101	0.085	0.235
% built after 1949	0.916	0.032	0.000
County in SMSA[3]	8.495	0.803	0.000
Flood hit	0.417	0.785	0.531
Hurricane hit	2.001	1.435	0.163
Tornado hit	0.810	0.693	0.243
Intercept	−10.837	2.890	0.000
R^2 =	0.384		0.000
N =	(3078)		

[1] $\text{Percentage change} = \dfrac{\text{Total county 1970 housing} - \text{Total 1960 housing}}{\text{Total 1960 housing}} \times 100$

[2] Standard error too small to record.

[3] Any time during decade or by 1975.

tion unemployed in 1960, as well as measures of the housing stock in the counties.

The regression coefficients (b_i) shown in Tables II and III should be interpreted as follows: a unit change in an independent variable is accompanied by a change in the percentage growth in population or housing that is shown by the value of the corresponding b. Thus in Table II, a shift upwards of one year in the median age of all persons in a county is accompanied by 0.122% increase in the housing stock. The value R^2 shown at the bottom of the tables represents the extent to which the characteristics used in the model "account" for the percentage changes in housing or population in the decade in question [4]. In addition, the last (right hand) columns of Tables II and III contain significance levels for the b's, a measure of the extent to which the b in each row differs significantly from zero. Thus an entry of 0.000 in this column indicates that there are fewer than 1 in a thousand chances that a coefficient of that size could have been drawn by random sampling of circumstances in which the "real b" was zero.

While there may be some interest in all the coefficients of Tables II and III our primary concern is with those associated with the three types of natural disasters, as shown in the last three lines in each of the tables. Note that these coefficients are not large enough to be significantly different from zero: that is, *there are no discernable effects of either floods, tornados, or hurricanes on the changes in population or housing stocks experienced by counties in the period between 1960 and 1970.*

Additional analyses were also made of the effects of natural disaster events on other characteristics of counties, including housing values, rents, age composition, educational level of population, and family income. In the interests

TABLE III

Regression of Percentage Change in Total County Population
Between 1960 and 1970 on Disaster Hits and Selected 1960 County Variables

Independent variables	Dependent variable is percentage change in total county population, 1960 to 1970[1]		
	b	SE	signif.
Area of county (sq. miles)	0.000	[2]	0.199
% non-white (1960)	−0.046	0.021	0.030
Median age of all persons (1960)	0.455	0.072	0.000
Median family income (1960)	0.001	0.000	0.028
% unemployed (1960)	−0.252	0.119	0.034
% in manufacturing (1960)	0.191	0.026	0.000
% in trade (1960)	0.148	0.086	0.084
% built after 1949	0.867	0.032	0.000
County in SMSA	9.904	0.814	0.000
Flood hit	−1.245	0.796	0.118
Hurricane hit	2.562	1.454	0.078
Tornado hit	0.306	0.703	0.663
Intercept	−37.002	2.930	0.000
R^2 =	0.395		0.000
N =	(3078)		

[1] $\text{Percentage change} = \frac{\text{Total 1970 population} - \text{Total 1960 population}}{\text{Total 1960 population}} \times 100$

[2] Standard error to small to record.

of simplicity of presentation, these tables are not presented here [5]. While there were a few instances in which the disaster coefficients were large enough to be statistically significant, no coherent interpretable pattern emerged. In short, there appear to be no firm findings that indicate that natural disasters have any effects on counties that last for an appreciable period of time.

The expectations we stated at the beginning of this section – that no direct and lasting effects of natural disaster events would be found on the level of counties – have been borne out. For the entire set of counties, it is clear that there are no significant effects of disasters on growth trends in either population or housing. There are several reasons for this finding: first of all, the damages and injuries directly attributable to the disasters are very small in relation to the population bases and housing stocks of the counties involved. Even in rural counties, where the ratios of damage to stock may be regarded as largest [6], this ratio is apparently too small to expect that the task of reconstruction would absorb significant proportions of county resources. Secondly, disaster policies on the federal, state and local levels in effect during the decade of the 1960's may have been sufficient to provide enough additional support for reconstruction to dampen considerably the lasting effects of natural disaster events on counties.

In short, the general thrust of the findings presented above lead to the following conclusion as the most plausible interpretation: *disaster events occurring within counties in the period between 1960 and 1970 have no discernible consistent effects that survive more than a very short period of time.*

VI THE LONG TERM EFFECTS OF NATURAL DISASTERS ON CENSUS TRACTS

Compared to counties, census tracts are very small in population and area. If size were the only conditioner of discernible long term disaster effects, we should be able to discern such effects when we shift to census tracts as the unit of analysis. This section presents the results of the application of our general model to intercensal tract changes for the period 1960 to 1970.

The specific model used was constructed with the following consideration in mind. First, changes in a tract during the period 1960 to 1970 are partially a function of the characteristics of the tract at the start of the period. In particular, it is necessary to take into account the 1960 level of the characteristic being studied, i.e. heavily populated tracts as of 1960 are likely still to be heavily populated in 1970. In addition, one must take into account 1960 housing characteristics, the 1960 socio-economic composition of the tract, the location of the tract in the SMSA. And so on.

Secondly, trends in a particular tract are likely to reflect changes that are occurring in the SMSA in which the tract is embedded. Thus a tract in Dallas is likely to share in the overall growth patterns of Dallas just as tracts in a declining SMSA, as Worcester Mass., are likely to share in the general SMSA decline in that place.

Thirdly, binary dummy variables were used to represent whether a tract was "hit" by a natural disaster of a given type during the period 1960 to 1970 [7]. More elaborate specifications of disaster events were also tried (results not reported here) but with no resulting enhancement of our understanding of the effects of natural disaster events.

Finally, variables were entered into the model that captured the degree of merging and uneven matching that was necessary to make the 1960 and 1970 tract files compatible. Since such adjustments were made most often for tracts in areas experiencing high growth or decline, these variables were especially important in removing artifacts of method from our estimations of disaster effects.

The direct impact of a natural disaster event is felt upon the physical structures, land and inhabitants of the areas impacted. The destruction of residential dwellings, stores and factories, public utilities and public facilities and injuries and deaths inflicted upon inhabitants constitute the direct impact of a natural disaster. Consequently, we can expect that at least a major indicator of long term disaster effects would be alterations in the growth patterns of an area's housing and population. Certainly the destruction of dwellings lowers the population carrying capacity of an area, at least temporarily. Deaths and injuries directly lower population levels and can possibly make an area less attractive as a place to live in. Clearly, were nothing else to happen, the expected impact of a natural disaster event would be to alter the growth patterns in housing and population in a downward direction, i.e. fewer houses and persons than would otherwise be expected. Of course, the occurrence of a disaster does cause "other things to happen," including relief and rehabilitation measures along with reconstruction of the damaged physical structure of the area.

On the average, five years have elapsed between the occurrence of the average disaster we studied and the taking of the 1970 census [8] with some occurring as much as ten years earlier but none less than a year. In that period much could have happened to restore the *status quo ante* and possibly to catch up with general local growth trends. Hence all we can discern in our data is whether the tracts that were subject to tornado, flood, and/or hurricane events showed growth trends in the period between 1960 and 1970 that were more, less, or the same as tracts that did not suffer such incidents. Tables IV and V present our findings with respect to population and housing growth trends [9].

Population growth trends are analyzed in Table IV. Obviously the most important pre-

TABLE IV

Regression of Total Population 1970 on Disaster Hits and Selected Tract and SMSA Characteristics

Independent variables	Dependent variable is total population in tracts, 1970		
	b	SE	Signif.
Total tract population 1960	1.09	0.009	0.000
Median age 16 and over (1960)	–44.0	5.6	0.000
Median household income (1959)	0.095	0.017	0.000
% housing built before 1940	–16.3	1.29	0.000
Number of trailers (1960)	5.36	0.580	0.000
% Non-white (1960)	–12.05	1.37	0.000
Tract area (sq miles)	9.88	0.896	0.000
SMSA population 1960 (000's)	0.084	0.013	0.000
SMSA population change 1960-1970	21.9	3.41	0.000
SMSA % unemployed (1960)	–67.4	25.2	0.008
Exactly comparable tract 1960–70*	–769.1	80.2	0.000
Ring City tract	–444.1	21.5	0.000
Central City tract	–767.6	75.4	0.000
Tornado hit	224.7	142.8	0.116
Flood hit	239.1	156.6	0.127
Hurricane hit	250.6	198.0	0.206
Intercept	2850.5	254.2	0.000
R^2 =	0.706		0.000
N =	(10654)		

* "Exactly comparable tract" is a binary variable taking on the value of 1 if the tract in question was identical in 1960 and 1970 or formed over a group of tracts that had as a group identical boundaries in 1960 and 1970.

dictor of a tract's total population in 1970 is the same tract's population in 1960. The regression coefficient, 1.09, associated with this variable indicates, *ceteris paribus*, that tract populations grew by 9% from 1960 to 1970. The remaining coefficients can be interpreted directly in terms of the numbers of people over and above that expectation that may be found associated with each of the tract characteristics shown. Thus for each additional year in the 1960 median age of persons 16 and over there are 44 fewer persons than predicted in tracts in 1970.

The reader's attention is directed toward the coefficient for "exactly comparable tract," a measure that marks whether a tract (or group of tracts) changes boundaries in between the two censuses. Tracts that did not change boundaries (and hence are exactly comparable) were most likely to decline in population, by an estimated 769 persons, expressing again the fact that tracts whose boundaries it was not necessary to change were tracts that remained relatively constant in population.

As one might expect the determinants of tract housing stock, as shown in Table V, are quite similar to those for population as shown in Table IV. It should be noted that the housing stock in that period was growing at a faster rate than tract population, 13% as compared with 9%.

At the bottom of Tables IV and V are shown the coefficients for each of the three types of natural disasters. Although all the coefficients are positive, none of them are statistically significant. As in the case of counties, *there are no*

discernible net effects of natural disaster events on growth trends in housing or population stocks for census tracts in the period 1960 to 1970 [10].

Additional analyses were performed on subsets of tracts. No particular pattern was shown for tracts from SMSA's of different sizes indicating that disasters had negligible effects in small sized metropolitan areas and in larger ones as well. Stratifying tracts by median family income in 1960 (an indicator of socio-economic level), we found that high income tracts (approximately the upper third in median income level) appear to be favorably impacted by flood disaster events. They have significantly higher growth rates than would be expected on the basis of their other characteristics. No explanation comes to mind for these counter-intuitive findings: perhaps all they indicate is that residential locations on the flood plains of urban places are attractive sites and hence are both likely to have higher income households and higher growth rates.

Regression with tract characteristics other than housing and population were also run with no particularly strong patterns emerging. Drastic alterations in income, age structure and housing values were not associated with any of the three disaster events [11].

The results of our analyses of the long lasting effects of the three types of disaster events on both counties and Census tracts can be succinctly summarized: *for the period 1960 to 1970, there are no discernible effects of the natural disaster events occurring in that period which materially altered population and housing growth trends for counties and for census tracts.*

VII IMPLICATIONS FOR DISASTER RESEARCH AND DISASTER POLICIES

The attempt to assess long-term effects of

TABLE V

Regression of Total Tract Housing 1970 On Disaster Hits and Selected Tract and SMSA Variables

Independent variables	Dependent variable is 1970 total tract housing		
	b	SE	Sign.
Total housing 1960	1.13	0.008	0.000
Median age (16 & over) (1960)	–12.31	1.74	0.000
Median household income (1959)	0.036	0.005	0.000
% housing built before 1940	–6.24	0.398	0.000
Number of trailers (1960)	2.0	0.178	0.000
% non-white (1960)	–2.58	0.422	0.000
Tract area (sq miles)	3.85	0.276	0.000
SMSA population 1960 (000's)	0.016	0.004	0.000
SMSA population change (1960–1970)	6.39	1.05	0.000
SMSA % unemployed (1960)	–20.12	7.78	0.010
Exactly comparable tract	–245.45	24.72	0.000
Ring City tract	–115.19	29.53	0.000
Central City tract	–206.8	23.25	0.000
Tornado hit	64.65	44.0	0.142
Flood hit	72.21	48.26	0.135
Hurricane hit	103.20	61.03	0.091
Intercept	906.9	76.4	0.000
R^2 =	0.711		0.000
N =	(10654)		

natural disasters that was described in the previous sections of this article have led us to a number of conclusions concerning both the existing data bases that are available to the research community for the study of natural disasters in the U.S., about the nature of the distributions of such disasters for what may be called a typical decade in recent U.S. history, and finally about natural disaster relief and rehabilitation in the United States. Each of these sets of implications are taken up in turn in this section.

A. Concerning the Existing Natural Hazard Data Bases

The data bases upon which this report was constructed were not collected, obviously, for the purposes to which we put them and hence our experiences with trying to use them for our goals were frustrating. The ideal natural hazards data bases would most likely have been far from the agencies' capabilities and certainly far beyond their interests to produce. Yet there are some steps that can be taken by the agencies in question which would, at minimum cost, make their data bases more usable by these researchers and by others.

These recommendations involve two steps that can be taken by the agencies in question and a third step that involves construction of a new institution, a disaster data archive. The first recommendation involves computerization of existing data bases in a form that would facilitate the transfer of information among agencies and from agencies to researchers. Although most agencies have either done so or are in the process of so doing, it is important to stress that computerization can be done in ways that restrict outside-the-agency applications and that such forms should be avoided, if at all possible. For example, the excellent American National Red Cross Chapter Reports are currently on tape, but in a form that makes it easy for ANRC to get hard copies of its reports but make it difficult for anyone else to use the computer tapes for research purposes [12].

A second step that could aid future disaster research considerably would be for agencies to standardize data bases. Standardized procedures, formats, codes, etc., should be used whenever possible, including the adoption of such general procedures as using the Federal Information Processing Standards codes for states, counties and other places.

The most pressing need for standardization is in defining and retaining in records the actual locations of disasters. The data bases, with the exception of the NSSFC's tornado tapes, do not allow one to accurately locate disasters with any precision even within such gross categories as counties and municipalities. Of course, part of the problem lies in the ambiguous locations of disasters, especially hurricanes, but damage and injuries located by counties would be a serious improvement over current imprecision.

A third step that could be taken involves the centralization of records, a step that would require the development of a new institution that would serve as an archive with the mission of collecting, cataloguing and disseminating data on the incidence, location and sequelae of natural hazards phenomena. Although it is clear that such an archive would be of immense utility to researchers, there are also policy purposes that might be directly served by the construction of such an archive that may also justify the considerable startup and maintenance costs involved. For example, hazard risk assessment would be considerably strengthened by better historical records on the risk experiences of communities and larger areas. If disaster locations could be recorded in fine detail, the disaster experiences of local communities could be used to bolster arguments for disaster mitigating land use management and structure construction standards.

B. The Distribution of Disasters by Severity and Size

It should now be abundantly clear that many events routinely labelled "natural disasters" are not really disasters in any literal sense of

the word, especially when regarded from the perspective of communities, states, and the federal establishment. *This is not to state* that the occurrence of a natural disaster event is a trivial event to the individuals, households, firms, and possibly neighborhoods that have directly experienced the impact, a topic to which we will return shortly.

This point is made dramatically if we consider damages and injuries from floods. For the 1,612 counties for which at least one ANRC Chapter Report exists for the decade 1960–1970, we may note that *over the entire decade,* the average impacted county experienced losses that amounted to less than one person killed, about 12 injuries, with four dwellings destroyed, and 22 dwellings suffering major damage. Similar average losses were experienced by counties that had experienced a tornado event. Even the most serious hazard, hurricanes, produced decade accumulated injuries and damages amounting to 1.4 deaths, 179 injuries, 42 dwellings destroyed, and 137 with major damage. What long term disaster effects could be expected from such events for counties whose average population was 78,000 people and 25,000 dwellings in 1960? For the typical disaster stricken county loss of life from automobile accidents exceeds loss of life from natural hazards by a ratio of 50 to 1; the loss of property through natural decay exceeds the loss of property through natural hazards by approximately twice that magnitude. No one would seriously maintain that automobile accidents and natural decay have long term effects on counties.

Of course, these events are not trivial from the point of view of the victims involved and there may be quite serious long term effects on the health and economic well being of the households and firms that have been directly the victims of even the smallest natural disaster events. The contrast is with the community as a whole for whom the disaster events experienced are relatively light. Three important conclusions stem from this contrast between the individual and social viewpoints:

First, in assessing the likely effects of natural disasters on various units, it is essential to take into account the magnitude of the losses involved against the resources at the command of the unit in question. Thus, the resources of an individual or household are small in comparison to the losses experienced by an impacted unit [13], while for a city, county, or state, the ratio of losses to resources available is small. The larger such an *impact ratio* (ratio of damages to available resources) the larger the need for outside help.

Secondly, although we are skeptical that there are any long term recovery assistance needs for communities, no implications should be drawn for such statements about individual, household, and business victims. We do not know from this analysis whether or not there are some long term disaster assistance needs on the levels of individuals, families and businesses.

Thirdly, the preceding points address themselves primarily to *average* disasters, and are not addressed to those outliers in the severity distribution, the Betsy or Agnes hurricanes, a Topeka-sized tornado or a Denver-sized flood. These outlying disaster events are ones in which the impact ratios are high, i.e. where the damages and injuries represent an important proportion of the persons and structures available. For example, we estimate that in the Topeka tornado, the ratio of damaged dwelling units to total dwellings is about 1 in 10 [14]. Of course, we are not sure what values of the impact ratio indicate the need for long term rehabilitation measures, but we are sure that only when this impact ratio is high does it make sense to look for such long term needs.

It should also be noted that the impact ratio is affected both by its numerator and denominator. This means that the same physical event when experienced by a small community may have much *more serious implications than when experienced by an SMSA.* Indeed, that is why so much attention has been given in the disaster literature to events which have occurred

in small towns, e.g. Xenia, Rapid City, Conway, Buffalo Creek, and so on [15]. Catastrophic events for larger places – events on the order of the 1906 San Francisco earthquake – can hardly be understood with any degree of sureness by extrapolating from the experiences of a Xenia or Buffalo Creek disaster event.

C. Implications for National Disaster Policy

Wholesale revisions of our national disaster policy appear to come about in reaction to statistical outliers, not to what might be called the "average, once-a-month" American disaster. We believe that our research which presents a rather good description of the average disaster at least establishes one clear finding: The "average, once-a-month American" natural disaster does not look like Topeka 1966; it does not look like the Thompson Canyon flood, and it does not look like Agnes or Buffalo Creek. Our findings also raise the question whether it is wise to base national disaster policy on the statistically rare and unusual event.

In the ideal, but never realized, case of unlimited resources, policies based on the worst imaginable situation assumptions are reasonable and defensible. In such a world, every airport could be prepared for a Canary Islands type of aircraft accident, every hospital prepared for the aftermath of a nuclear holocaust, and every city prepared for a Topeka tornado or a 1000 year flood. But, there are other demands on resources and given such limitations, the question can be raised: How big a disaster is it rational and efficient to prepare for? Perhaps the most reasonable policy may be simply to admit in advance that such catastrophic events cannot be prepared for and to expect that special measures would have to be taken *ad hoc* if such events were to occur. There are several reasons for this suggestion:

First, there is probably no set of relief rehabilitation measures that would be fully adequate to handle what might be called "extreme value" events, most of all because no policy could ever possibly anticipate and plan for all the relief and rehabilitation problems that events of this magnitude will pose. Secondly, because such events are rare, it makes sense to tailor relief and rehabilitation measures to the specific place and specific type of disaster that would take place. Thus, a superforce hurricane hitting Miami might require different types of relief and rehabilitation measures than a superforce earthquake occurring in Los Angeles, because Miami and Los Angeles are different places and also because hurricanes and earthquakes leave behind different sequelae. Finally, federal disaster policy should not be overhauled every time a new catstrophe comes along and then applied in the interim to the average, once-a-month disasters that occur all the time. We should have a federal disaster policy that is tuned to the needs that are generated by the average disaster and applied to those events alone.

A final complication of the distributional characteristics of natural disasters is that the perspectives on the natural disaster problem varies with the level of aggregation involved. A local community's perspective may be conditioned largely by its own historical experiences with natural disasters, most likely *not* including a major serious event (at least, not within the memories of persons currently living), because such catastrophes are extremely rare for any given place. In contrast, catastrophes are not as rare when viewed from the national perspective since the experiences of local communities when aggregated to the national level represent a formidable problem indeed. What it implies is that policies designed to deal with the national disaster problem and which appear to be rational and effective from that viewpoint, may be seen as burdensome, irrational, inefficient and perhaps even counter-productive from the viewpoint of the communities to which they are

applied. No better example of this difference in perspective can be cited than the Flood Insurance Program. From a Federal viewpoint, the program has much to recommend it. From the viewpoint of a specific community whose memories do not contain a hundred year flood, the policy may appear to be capricious and inequitable. From the Federal perspective, hundred year floods occur every three months, with four or five such floods occurring each year over the nation as a whole.

This last point suggests that Federal disaster relief and rehabilitation policies have to consider not only the costs of policy to the nation as a whole but the costs imposed upon local communities. Costs imposed upon local communities without corresponding tangible perceivable benefits may lead to the deterioration of national policy in the United States as its impact upon local communities becomes felt.

NOTES

1 Alaska does not have counties or census tracts (in 1960) and hence has been dropped from the relevant analyses.

2 See Wright et al. (1978) for complete enumeration of criteria of seriousness employed. One criterion employed (in the use of ANRC Chapter Reports) was that damage from the disaster reported had to exceed 50 or more in the following index:

$$\text{Damage index} = \text{Twice the number of houses destroyed} + \text{The number of houses with major damage}$$

3 For one event for which we were able to get accurate maps showing the exact extent of flooding, our estimated flooded tracts correlate 0.7 with those shown to be flooded on the presumably more accurate maps. It should also be noted that the analysis presented in the next section is not substantially changed if we use the actual flooded tracts instead of our estimated flooded tracts.

4 Thus R^2 of 0.38 in Table II indicates that 38% of the variation among counties in percentage change in housing may be accounted for by the variables shown in that table. Clearly there are other processes that account for such changes that are not presented in Table II, including such artifactual differences as errors of measurement in either independent or dependent variables.

5 A full analysis of these potential disaster effects is shown in Wright et al., (1978) Chapter 6.

6 In Wright et al. (1978) separate analyses are shown for counties of varying population sizes. In each size class, natural disaster effects are essentially zero.

7 Alternative specifications of the disaster variable were also tried (see Wright et al., 1978) including measures of the amount of damage or injuries resulting from the event as well as interactive terms that weighted damage by the time the disaster occurred in the period 1960 to 1970. Since these alternative specifications did not materially change the results shown later in this section, we opted for the simpler binary dummy representation of disaster "hit."

8 This is not entirely accurate since the disasters were not uniformly distributed among the years intervening so this estimate may be as much as six months to a year off.

9 Note that the form of analysis for tracts differs from that employed for counties. In Tables II and III the regression equations predicted the percentage change in population and housing stocks while in Tables IV and V, the equations are predicting the absolute size of housing and population stocks, a difference in approach made necessary by the fact that there is much more continuity in population size for counties than for tracts.

10 To make certain that these results are not artifacts of the difficulties experienced in matching tracts, these analyses were run separately for exactly comparable tracts (results not shown here: see Wright et al., 1978) with results essentially the same as shown in Tables IV and V.

11 Some statistically significant disaster effects were found, but their substantive significance was usually slight.

12 Specific details about this and other data bases are given in Wright et al. (1978) Chapter V.

13 The authors are currently seeking support for research that would produce estimates of long-term effects on individuals and households through a survey of "victims" of past disasters.

14 Note that the Topeka tornado is so far out on the distribution of tornado events during the decade 1960–1970 that it must be regarded as a one-in-a-thousand year tornado for metropolitan areas subject to risk. Given the number of SMSA's in tornado prone portions of the country, a tornado the size of Topeka can be expected once every two or three decades.

15 Because such outliers are very rare for large places and relatively rare for even smaller places, statistical studies of long range disaster effects are unable to say much about what happens when the impact ratio is very large. We are forced to conclude that the study of long range impact of natural disaster events that are outliers will have to be restricted for some time to come to case studies with all the implications for generalizability that this method implies.

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