NATURAL HAZARDS AND RESIDENTIAL MOBILITY:

GENERAL EFFECTS & RACIALLY UNEQUAL OUTCOMES IN THE UNITED STATES*

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September, 2012

ABSTRACT

Researchers still know relatively little about the influence of natural hazards on residential mobility in general and how this influence intersects with social inequalities to shape migratory patterns of racial groups across the United States. The main reason for this gap is that most studies focus on extreme events that while revealing offer a highly selective view of what is actually a larger and more pervasive set of migratory interactions with the natural world. To address this gap, the present study provides the first nationwide analysis of the influence of natural hazards on residential mobility. Results affirm that natural hazards occur regularly throughout the country. They also reveal that natural hazards generally increase residential mobility; that this increase is particularly noticeable among racial and ethnic minorities; and that subsequent resettlement tends to pull members of these groups to more hazardous places than white counterparts. Implications are discussed.

* Paper submitted for presentation at 2013 annual meeting of the Population Association of America, New Orleans, April 11-13. Please direct correspondence to Prof. James Elliott via email at elliott@uorgon.edu. Please do not cite or circulate without author's permission.

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One way humans have historically responded to natural hazards such as floods, droughts, and hurricanes is to move, and U.S. society is no exception. The most famous example is the Dustbowl drought of the 1930s, which pushed an estimated 400,000 migrants west to California (Gregory 1989) and prompted the federal government for the first time to begin collecting census data on residential mobility. Since then, natural hazards have continued to occur. Federal records indicate close to 700,000 locally distinct events within the United States since 1960, with recent years continuing to set new records for frequency and total damages. These historic events coupled with forecasts of more in the future are now encouraging researchers to bring environmental factors "back" to the study of demographic processes, especially migration (Axinn & Ghamire 2011; Groen and Polivka 2010; Hunter 2005; Hugo 1996; Lueck 2011l; O'Lear 1997; Oliver-Smith and Shen 2009). This trend is evident not only in global debates over the definition and political rights of environmental refugees (Morrissey 2012) but also in burgeoning research in the United States on unequal dislocations triggered by major disasters such as Hurricane Katrina (see Brunsma, Overfelt and Picou 2010; Gutmann and Field 2010).

Yet despite these events and efforts, we continue to know relatively little about the influence of natural hazards on residential mobility generally and how this influence intersects with social inequalities to shape migratory patterns of different groups across the United States. The main reason for this gap is that most studies focus on extreme events that while revealing offer a highly selective view of what is actually a much larger and more pervasive set of migratory interactions with the natural world. The result is not only unknown bias when extrapolating findings to less severe but more common cases but also a temptation to think of natural hazards as somehow exceptional when in fact they are normal and ongoing parts of social life. Indeed, recent research indicates that 95 percent of U.S. counties have experienced damage from some type of natural hazard over recent years (Schultz and Elliott 2012).

To address this gap and to situate disaster research within a broader context of ongoing natural hazards, the present study examines the influence of such hazards on residential mobility within, from, and to affected areas across the continental United States. The aim is to engage several basic questions that remain unanswered in the literature and, in the process, develop a richer understanding of natural hazards as part of a dynamic and ongoing process that interjects itself continually into the making and remaking of U.S. society and the spaces it occupies. The first question is whether – in the context of current affluence and technology – natural hazards increase residential mobility generally, or just in extreme cases. The second question is how and to what extent existing racial and ethnic inequalities intersect with local hazards to produce different mobility responses for different groups. And the third question is to what extent such differences end up selectively redistributing members of different groups to more hazardous areas over time, thereby influencing future as well as current probabilities of exposure.

To address these questions, the present study offers the first nationwide analysis of local natural hazards and individual-level migration to date – an approach that recent research has deemed critical for advancing understanding of environmental migration "because migration decisions are made at the micro level….by actors embedded in aggregate contexts" (Myers, Slack and Singelmann 2008: 288; see also Hunter, White, Little and Sutton 2003). In this study, individual-level data come from the U.S. population census, and local data on natural hazards come from a publically available dataset assembled from federal sources, including regular reports from the National Climatic Data Center. Results affirm that natural hazards occur regularly throughout the country. They also reveal that natural hazards do generally increase residential mobility; that this increase is particularly noticeable among racial and ethnic minorities; and that subsequent resettlement tends to pull members of these groups to more hazardous places than white counterparts.

The literature review below sets the theoretical context for these findings, beginning with human ecology's classic conceptualization of environmental stress, household strain and residential mobility. It then segues to more recent work on the political ecology of disasters to incorporate the role of racial and ethnic inequalities in hazard-related mobility processes. Finally, it concludes by extending this perspective to highlight the unequal migratory pull, as well as push, of natural hazards for less advantaged residents.

THE HUMAN ECOLOGY OF NATURAL HAZARDS AND MOBILITY

In considering the general and selective influences of natural hazards on residential mobility it is useful to begin with sociology's human ecological tradition, which extends longstanding interest in the territoriality of social life to conceptualize local communities as ongoing interactions between population, organization, environment and technology, or POET (Duncan 1959). In his review of the field, Hawley (1986: 13) clarifies that within this framework, "thinking of environment solely in physical and biotic terms is…manifestly a mistake." Such a conception might prove useful when all other factors are assumed constant, but such is rarely the case. Local environments, for example, can shift, destabilizing local populations that in turn adjust organizationally through webs of "functional relationships" that seek to restore disrupted capacities. Hawley's underlying point is that environmental influences do not generate "natural," or automatic, demographic responses. Rather, they occur within and interact with organizational and technological arrangements to simultaneously permit and constrain certain types of outcomes. In this way, environmental influences such as natural hazards are best conceptualized as necessary but insufficient causes of probabilistic rather than deterministic demographic responses, including residential mobility (see Hawley 1986: 15-16).

In the 1960s, Wolpert (1966) extended this ecological perspective on mobility to advance a model of human migration that focused explicitly on the importance of local "environmental stressors." He argued that relationships between individuals and their local environment occur along a "continuum of harmony" that influences decisions about whether to migrate and, if so, where to resettle. In this model and under normal conditions, local environmental stressors are presumed to be present but latent. However, Wolpert explained, "under conditions of abnormal stress…strain may induce additional bias into the migration decision by (perhaps) triggering off a hasty decision to move [or] encouraging a disorganized search for other places to go" (1966: 95l, original parentheses). Moreover, Wolpert (1966: 97) explained, a person's socioeconomic status will influence how this process unfolds, underscoring the point that links between environment and migration are complex, ongoing and socially mediated.

Early efforts to test this ecological model of residential mobility focused largely on intra-metropolitan moves, wherein researchers defined environmental stressors in terms of increased blight, pollution, and other nuisances found in many inner-city neighborhoods (e.g., Ritchey

1976; Speare 1974). Later, however, Wright and colleagues (1979) extended this line of analysis to focus specifically on natural hazards. Lacking information on individual moves, they used aggregated data at the level of census tracts and counties to test whether areas experiencing significant natural hazards also experienced net population change. In the end, they found no such effect. Instead they conclude that, "comparison of average damages to average resources makes it implausible in the extreme to expect that these disasters would have residual and observable effects. In our studies, none were found'' (Wright, Rossi, and Wright, 1979:198).

Similar studies around the same time corroborated this claim and helped to forge a new scholarly consensus that areas experiencing natural hazards tend to rebound quickly to achieve a "functional recovery" with little demographic consequence (Cochrane 1975; Dacy and Kunreuther 1969; Friesema et al. 1979; Haas et al. 1977). This notion of "functional recovery" challenged the ecological idea that natural hazards still influence residential mobility in affluent societies such as the United States while at the same time drawing theoretical connections back to human ecology's notably Durkheimian roots. These roots emphasize how residents of local areas, despite being socially differentiated, connect through crosscutting social relationships to stabilize interactions with the local environment as well as with each other.

More recent research, however, has begun to challenge this consensus on several fronts. First, it argues that communities hit by natural hazards are best understood not as monolithic wholes adjusting to a common environmental stressor but rather as mosaics of unequal subpopulations responding differently to local environmental impacts. This perspective is evident in Stallings (2002) reinterpretation of Moore's (1958) classic, *Tornadoes over Texas*. Whereas Moore's original account highlighted the collective resilience of all involved, Stallings revisionist analysis shows how socially disadvantaged residents actually became worse off, thereby recasting disaster recovery not as a unified act of functional recovery but as a struggle by privileged residents to restore the local social order, with them on top. The corollary, now widely accepted in disaster studies, is that socially disadvantaged residents are vulnerable not just to the direct impacts of natural hazards but also to post-hazard recoveries that reflect and reproduce unequal access to personal, social and economic resources (Bolin and Stanford, 1998; Dash et al., 2007; Fothergill and Peek, 2004; Tierney 2007). Anticipating these unequal responses and their implications for residential mobility, particularly displacement, is where the political ecology of disasters becomes useful.

THE POLITICAL ECOLOGY OF DISASTER DISPLACEMENT

Although classic human ecology explicitly acknowledges the influence of social organization on demographic responses to environmental stress, over time this point slipped from view as empirical research came to focus on functional recoveries at the aggregate level. By contrast, research on the political ecology of disasters deliberately seeks to recover this organizational dynamic and in the process highlight how deeply embedded inequalities – particularly those of race and class – render some groups more vulnerable than others to displacement from natural hazards (see Hewitt 1998; Hunter 2005; Peacock, Morrow and Gladwin 1997; Tierney 2007). Globally, this perspective is evident in the "critical position" on environmental refugees, which emphasizes how historical and political processes turn local environments into sources of stress for marginalized groups around the world (Morrissey 2012). In the United States, this perspective is evident in ongoing research on extreme cases, which emphasizes "the various ways in which social systems operate to generate disasters by making people vulnerable" (Wisner et al. 2004: 11). The unifying point is that environmental stressors – including natural hazards – are filtered through pre-existing social inequalities that result in not one functional recovery but many unequal ones, as members of different groups negotiate different opportunities and constraints before them.

Recent empirical research supports this reconceptualization, especially for racial and ethnic minorities. For example, Morrow-Jones and Morrow-Jones (1991) analyzed nationally representative data from the American Housing Survey in the 1970s and found that respondents who reported moving because of natural disasters were more likely than other movers to be low-income, racial minorities. Thus they conclude that, "All groups may be equally likely to be involved in a disaster, but the more powerful subpopulation is less likely to move because of access to resources to recoup its losses in place" (1991:129). Case studies of major disasters offer similar findings and clarify proximate causes.

Research shows, for example, that less advantaged residents often live in structurally weaker dwellings that are often left uninhabitable when hazards strike (Cochrane 1975) and that these same residents often lack financial resources necessary to recover in place (Bolin and Stanford 1998; Hewitt 1997). Research also shows that poor and minority residents tend to have more difficulty accessing (Dash et al. 2007; Peacock and Girard 1997) and navigating (Rovai 1994; Forthergill and Peek 2004) bureaucratic systems of disaster assistance, leaving more advantaged residents better positioned to absorb available housing, thereby exacerbating shortages for less-advantaged residents of affected areas (Quarantelli, 1994; see also Pais and Elliott 2008). Consequently, researchers commonly discover that after natural hazards, less-advantaged families "find themselves moving frequently from one place to another (or even leaving the area forever), or in housing they can't afford" (Haas et al., 1977: xxviii, original parentheses). Such findings are also consistent with recent surveys of displaced residents from

New Orleans after Hurricanes Katrina and Rita (Elliott, Haney and Sam-Abiodun 2010; Fussell, Sastry and Vanlandingham 2010) and with aggregate-level research on net outmigration from the region as a whole (Myers, Slack and Singelmann 2008).

In highlighting these unequal responses to local hazards, the present study draws particular attention to racial and ethnic inequalities because these type of inequalities continue to persist among otherwise similar individuals; because they influence exposure to other types of environmental hazards, such as industrial pollution (Grant et al. 2010; Crowder and Downey 2010); and, because they take spatial as well as social forms that reduce access to vital resources, leaving all residents worse off regardless of individual status (Sampson, Morenoff, and Gannon-Rowley, 2002). This collective, or group-level, vulnerability stems not just from individual and family deficits in financial resources but also from the spatial accumulation of social and political disadvantages associated with minority status that limit access to opportunities and resources to recover in place. Exacerbating these inequalities is the fact that local municipal budgets often become strained after major hazards, limiting public funds (and political will) for fair housing assistance and regulation (Weil 2009).

This idea of segmented response to disaster is now widely accepted within the field of political ecology (see Tierney 2007), but it has not been tested adequately beyond extreme cases or for the nation as a whole. Nor has it been clearly determined if natural hazards increase the mobility of minorities because they raise the mobility of all groups or because they raise the mobility of minorities disproportionately. Filling these gaps is one of the primary objectives of the present study. Another objective is to extend the ecological perspective on hazard-related mobility beyond the presumed push, or displacement, associated with local hazards to also consider their potential pull, thereby offering a fuller view of hazard-related mobility.

THE POLITICAL ECOLOGY OF RESETTLEMENT

Ignoring where migrants resettle after natural hazards, as most studies do, yields an incomplete view of hazard-related mobility for several reasons. First, it ignores Wolpert's (1966) classic observation that mobility requires not only a decision about whether to leave but also a decision about where to resettle, and human ecology posits that environmental stressors influence both of these decisions. Second, it ignores the fact that recoveries from local hazards stimulate capital inflows that create new economic opportunities, including jobs, which often draw outsiders to damaged areas. Decades ago, Belcher and Bates (1983) called this dynamic the "convergence problem." More recently it has been echoed by research on "hurricane chasers" who move to devastated areas to help rebuild (Fussell 2009) and by research on post-disaster "recovery machines" that put economic growth ahead of neighborhood restoration (Pais and Elliott 2008). Third, ignoring the pull as well as push of natural hazards, especially among racial minorities, oversimplifies how social and environmental stressors intersect by implying that a migratory push is a migratory push in all contexts. A more sophisticated understanding of social inequality recognizes that the same types of social disadvantage that limit opportunities to recover in place may also render new opportunities created elsewhere by hazard recovery all the more attractive. In this way, social inequalities of race and ethnicity refract hazards into a local push and into a distant pull.

Correcting these shortcomings requires extending the study of hazards and mobility beyond the political ecology of displacement to include the political ecology of resettlement. Such an extension begins with the recognition that members of disadvantaged groups are not just hapless victims but also active agents making decisions about whether and where to resettle, however constrained these decisions may be. This analytical extension then proceeds to emphasize how social disadvantage can increase the pull as well as push of natural hazards by limiting resources and opportunities in place and making their emergence elsewhere a positive consideration for resettlement, despite the apparent riskiness of such destinations. Such patterns, if they exist, would be similar in outcome but different in process from well-documented social inequalities in exposure to industrial hazards (Crowder and Downey 2010). Whereas, evidence shows that areas rendered environmentally risky by industrial pollution tend to trap and attract less-advantaged minority residents, areas experiencing heightened damage from natural hazards are likely to work in the opposite direction. Instead of pushing advantaged residents away, recent natural hazards are likely to retain advantaged residents who can afford to recover in place while displacing less advantaged residents who may then be drawn to areas of even greater damage elsewhere because of the opportunities that local recoveries there generate. From this perspective, the imagery of social inequality and natural hazards is less of the "disadvantaged and trapped" and more of the "disadvantaged and mobile," with this type of individual mobility leading in aggregate to increasing concentrations of racial and ethnic minorities in more hazardous areas over time.

Extending the political ecology of natural hazards from displacement to resettlement in this way not only provides a more complete view of related residential mobility, it also provides a more complete view of natural hazards, which not only inflict damage across a wide range of potential destinations but also open new economic and political opportunities for local growth. The broader implication is that what may appear at the aggregate level to be stable, functional recoveries following local hazards may in fact hide considerable and highly selective migratory churning beneath the surface, reflective of socially unequal forces of hazard-related displacement and recovery-related resettlement.

RESEARCH HYPOTHESES

To summarize, existing research suggests several basic hypotheses that have eluded direct empirical test beyond extreme cases. Figure 1 summarizes these hypotheses and provides a clarifying schematic. The first hypothesis is that net of individual and household-level factors that also influence residential mobility, greater frequency and impact of local natural hazards will increase individual displacement from home and area. The second hypothesis has a weak and strong version. The weak version posits that strain produced by the stress of natural hazards and racial disadvantage "add up" to make minority residents more likely than otherwise similar whites to become displaced by natural hazards (i.e., there is an *additive* effect between social inequality and natural hazards). By contrast, the strong version asserts that the greater the damage from local natural hazards, the greater racial inequalities in displacement will become (i.e., there is an *interactive* effect between social inequality and natural hazards). The final hypothesis is that, conditional on out-migration, less advantaged migrants, especially racial and ethnic minorities, will tend to resettle in destinations with greater impacts from recent natural hazards because of the disproportionate pull that opportunities generated by local recovery tend to hold for less-advantaged migrants.

[Figure 1 about here]

DATA AND METHODS

Empirical analyses used to test the above hypotheses link individual-level data on place of residence at two points in time with local hazards data over the same period. Individual-level data come from the 2000 5-percent Public Use Micro Sample, which is well-suited to the present study for several reasons. First, it provides micro-level data on place of residence in 1995 and 2000. This five-year span means that analyses are less likely to pick up temporary movers, thereby focusing attention more squarely on long-term displacement and resettlement. Second, use of the 2000 Census avoids extreme outliers in local hazardous events, including Hurricane Katrina in 2005 and the Northridge Earthquake in 1994 – the first and second costliest natural hazards in U.S. history respectively. Exclusion of these extreme cases provides a more conservative test of central hypotheses by eliminating the disproportionate influence of outliers highlighted by recent case studies. Third, these data offer a spatially as well as socially representative sample of the U.S. population, including sufficient counts of Latinos, Asians and African-Americans necessary for comparative analyses of racial and ethnic inequalities. Finally, these data contain rich information on a number of individual- and household-level traits that are crucial for proper analysis of residential mobility.

Data on local natural hazards during 1995-00 come from the Spatial Hazard Events and Losses Database for the United States (SHELDUS), which is a government-funded, publically available database containing nearly 700,000 records on 18 types of natural hazards that caused at least one death or $25,000 in property or crop damage since 1960. Assembled from existing federal data sources, including the National Climatic Data Center's monthly Storm Data publications and Tsunami Event Database, SHELDUS currently provides the most comprehensive and detailed national record of natural hazards available to researchers. For

1995-00, it contains information on 29,118 hazard events that occurred within the continental United States, causing an estimated $65 billion in property damage and $21 billion in crop damage (in constant 2011 dollars). [1]

Matching these local hazard data to individual respondents from the 2000 Census required assigning county-level hazard data from SHELDUS to the level of 1995 Public Use Micro Areas (PUMAs), which are the smallest unit of local geography available in the PUMS for both 1995 and 2000. For this assignment, county-level hazard data were weighted using Geographic Information Software (GIS) and Master Area Block Level Equivalency Files to determine how much of a county's population fell within a respective PUMA (Missouri Census Data Center). Local hazard data were then weighted accordingly. So for example, if County A's population fell entirely within PUMA 1 and half of County B's population did as well, then all of the hazard impact recorded in SHELUS for County A and half of that for County B would be assigned to PUMA 1. Any error introduced by this weighting strategy is assumed to be minimal and spatially random, with the resulting dataset containing information on a representative sample of individuals living in one of 1,028 PUMAs throughout the continental United States.

Sample

The 2000 PUMS contains data on more than 12 million respondents, which is unnecessarily large for purposes of the present study. So a 10 percent random sample was drawn from each PUMA of residence in 1995. From this sample, only household heads in 2000 were retained because residential decisions of the household head typically determine those of other members of households and imposing such a criterion avoids counting as unique and distinct those

[1] Recorded hazards include avalanches, droughts, earthquakes, flooding, fog, hail, heat, hurricanes/tropical storms; landslides; severe lightning/storm/thunderstorms; tornado; tsunami; volcano; wildfire; wind and winter weather (including blizzards). For simplicity, I refer to all of these hazards as geophysical hazards.

changes in residence made by members of the same family who stayed within the same household. (Family members who became new household heads by 2000 are included in the sample.) The resulting database consists of 509,948 household heads who lived within the continental United States in 1995 and 2000.

Dependent Variables

Empirical analyses focus on three dependent variables. The first two measure residential mobility. One of these measures is a simple dummy indicator that equals 1 if the respondent changed addresses between 1995 and 2000 and 0 otherwise. The second measure of mobility is a five-category ordinal indicator of relative spatial displacement, which is computed as follows: 0= same residence in 1995 and 2000; 1= different residence within the same PUMA; 2= different PUMA within the same state; 3= adjacent state; 4= non-adjacent state. Using both measures of mobility offers a test of robustness for key findings as well as information about the degree of displacement associated with different groups under different conditions. The third dependent variable is total property damage from local natural hazards during 1995-2000 at destination, or place of residence in 2000, which is computed only for household heads who migrated to another PUMA during 1995-00.

Explanatory Variables

The local impact of natural hazards during 1995-00 is measured three ways: by the *number* of unique events that occurred during this time period; by cumulative *property damage*; and by cumulative *crop damage*. Cumulative property and crop damages are normalized to constant 2011 dollars prior to summation and then logged to reduce the statistical influence of outliers.

The question of which of these dimensions of hazard impact exerts the most influence on residential mobility remains an empirical question, but property damage is often presumed to be most tightly linked to housing disruption and subsequent recovery resources.

The *racial status* of household heads is indicated by a set of dummy variables that differentiate between those reporting Latino ethnicity (hereafter "Latinos"), non-Latino whites (hereafter "whites"), non-Latino African Americans (hereafter "blacks"), and non-Latino Asians (hereafter "Asians"). Additional control variables follow closely from prior research on selective residential mobility related to local industrial hazards (Crowder and Downey 2010). One of these controls is income, which is measured as the natural log of reported annual family income in 1999. Other demographic and life-cycle correlates of residential mobility include: *educational attainment*, measured as estimated years of school completed by 2000; *age*, and *age squared* to account for the nonmonotonic dependence of mobility on age; *gender*, which is measured using a dummy variable equal to 1 for females, and 0 for males; m*arital status*, which is measured as a dummy variable equal to 1 for those who were married, and 0 otherwise; and *parenthood*, which is measured as the number of related children under 18 years old living in the same household. All variables along with descriptive statistics appear in Table 1.

[Table 1 about here]

Analytic Strategy

Consistent with Wolpert's (1966) assumptions of a sequential mobility decision-making process that begins with the decision to move and ends with the decision of where to resettle, the present study pursues a two-step modeling strategy. For the first step, all household heads are included in logistic regression analyses of residential mobility, which use robust standard errors to correct for intra-PUMA correlation, lending a conservative bias to tests of statistical significance. For the second step, the sample is restricted to household heads who migrated to another PUMA to assess if they tended to end up in more or less hazardous destinations. Because these migrants do not represent a random sample of household heads, selection bias is addressed using a maximum likelihood Heckman procedure (Heckman 1979), which involves a two-stage process: a selection stage that predicts the probability of migration across PUMA boundaries; and a substantive stage that estimates the average amount of property damage at destination, controlling for the latent probability of migration and amount of property damage at origin. The selection equation of the Heckman procedure includes all socio-demographic predictors employed in the initial analysis of mobility, while the substantive equation omits socio-demographic controls for age, education, gender, marital status, and number of children because the influence of these factors is restricted largely to the likelihood of migration (not destination outcomes). This model specification is consistent with recent research on residential mobility and environmental stress in the form of industrial hazards (Crowder and Downey 2010), which also uses robust standard errors to correct for intra-PUMA correlation.

In addition, a number of supplemental analyses were performed to assess the robustness of results under different model specifications. Most prominently, these supplemental analyses included the computation and inclusion of spatially lagged variables to assess the sensitivity of local effects to conditions in surrounding areas. Each spatially lagged variable (e.g., average hazard impact or mobility likelihood) is computed using Geographic Information Systems (GIS) software and a first-order queen contiguity matrix. Using 1995 PUMA boundaries, this type of matrix identifies adjacent PUMAs in a movement similar to that of a queen in chess, with neighboring units selected based on shared borders radiating out from the local unit, or PUMA, on all sides and diagonal corners. From these neighboring PUMAs an average value of the respective variable is computed as a spatial lag, under the assumption that spatial dependence operates as a relatively short-distance process whereby proximity increases similarity among neighboring areas. In this way, similarities among household heads in the same PUMA are statistically controlled using robust standard error procedures; and supplemental tests of surrounding regional influence are conducted using spatially lagged independent and dependent variables.

RESULTS

Table 1 shows that during 1995-00, the average U.S. household lived in an area that experienced 33 hazard events and approximately $64 million in property damage and $18 million in crop damage, with the most common types of hazard being severe storms, followed by floods, tornados and high winds. Yet, significant local variation exists around these averages. Some areas, for example, along the Gulf of Mexico experienced more than 120 events during the late 1990s, while other areas – including some in North Dakota and Oklahoma – experienced more than $3 billion in cumulative damage from far fewer events. So, natural hazards occur frequently throughout the country, but they also vary greatly in local frequency and impact.

Human Ecological Hypothesis

Table 2 begins to test the human ecological hypothesis that cumulative local impact from natural hazards increases household mobility, all else equal. The positive and statistically significant coefficients for hazard frequency and property damage in both Model 1a and 1b support this hypothesis; crop damage, by contrast shows no significant effect. To illustrate the joint influence of frequency and property damage, we can solve Model 1a to predict the odds of changing residence under different local conditions, holding individual and household-level variables constant at their sample means. For household heads living in an area that experienced no hazard or property damage, predicted odds of mobility are .44; for household heads living in an area of high impact – 100 events and $3 billion in property damage – these odds double to .88. So, the greater the frequency and property damage of recent natural hazards, the higher residential mobility becomes.

[Table 2 about here]

Results of Model 1b for the ordinal measure of displacement show similar influences of local frequency and property damage, with different cut points providing additional information about the relative likelihood of different types of mobility. This information confirms that local moves are by far the most common form of residential mobility, followed by migration to elsewhere within the same state, followed by migration to other states. To illustrate, we can solve Model 1b for the same conditions as above. For "no impact" areas (0 hazards and 0 property damage) predicted odds of moving within the local area are .28; for migrating elsewhere in-state they are .08; for migrating to an adjacent state they are .02; and for migrating to a nonadjacent state they are .04. By contrast, for "high impact" areas (100 hazards and $3 billion property damage), these predicted odds increase to .35, .10, .03, and .06, respectively, or between 20 and 50 percent. So, local impacts from natural hazards increase odds of longer distance moves in addition to residential mobility generally.

To test these results further, Models 1a and 1b were re-estimated with the addition of a squared term for each hazard indicator, which allows for a possible curvilinear relationship with residential mobility. These tests (not shown) indicate that only property damage has such a relationship and that it is positive, implying that results reported in Models 1a and 1b *understate* the effect of property damage on mobility at higher levels of impact. To illustrate, we can again solve the supplemental model for the same “high impact” scenario described above (100 events and $3 billion in property damage), holding all else constant. Here, instead of the predicted odds of .88 for any change in residence (reported above), predicted odds increase to .98. This upward shift implies that extreme cases that are so often the focus of scholarly inquiry into hazard-related mobility serve as both examples and exceptions: They are examples in that they reveal the general push of natural hazards on local residents; but, they are also exceptions in that this push is greater than we might otherwise expect in less extreme cases. The implication is that findings reported in Table 2 are statistically conservative at higher levels of property damage.

Political Ecological Hypotheses on Displacement

Models 2a and 2b of Table 2 add dummy indicators for the household head’s race and ethnicity to test a weak version of the political ecological hypothesis that the stress of local hazards and racial disadvantage “add up” to increased mobility for minorities, net of variation in other important individual and household-level factors. Positive and significant coefficients for Asians and Latinos, in addition to those for hazard frequency and property damage, support this hypothesis. To illustrate the magnitude of these additive effects, we can solve Model 2a for different groups experiencing the same average number of events (33) and property damage ($64 million), all else equal. For whites, expected odds of moving under such conditions are .66; for otherwise similar Latinos, they increase to .79; and for otherwise similar Asians, they increase to .85. For comparison, we can re-estimate the same odds for household heads reporting zero rather than average family income ($53,000). For these respondents, expected odds of mobility increase only slightly to .67 for whites; to .80 for Latinos; and to .87 for Asians. So, race and hazard impact appear to influence residential mobility more substantially than family income when all three factors are considered together.

Findings for African Americans are more equivocal. On the one hand, results in Table 2 show no significant difference from whites with respect to either measure of residential mobility. On the other hand, supplement analyses (not shown) indicate that this statistical parity results largely because black household heads tend to be younger than white household heads, and younger household heads tend to be more mobile generally. So when age differences are statistically controlled, as they are in Table 2, black-white differences become statistically attributed to age rather than racial difference. Thus behind the apparent non-effects for African Americans in Table 2, there still exists modest if qualified support for the weak version of Hypothesis 2.

Next, Models 3a and 3b test the strong version of the political ecological hypothesis that racial differences in mobility increase with local impacts of natural hazards, reflecting multiplicative rather than simply additive disadvantages for minorities in the face of natural hazards. For this test, all possible two-way interactions were computed between respective indicators of hazard impact and race/ethnicity, as well as for hazard impact and family income for comparison. Of these twelve interaction terms, none proved statistically significant alone or in combination with one another in predicting residential mobility in general. However, two of the interaction terms proved significant in Model 3b, predicting the ordinal measure of displacement, and these results run counter to expectation. Reported coefficients in Table 3b indicate that the displacing effects of local property damage actually *decrease* at higher levels among African Americans and Asians, relative to white counterparts. So for the nation as a whole, there is no empirical support for the strong, multiplicative version of the political ecological hypothesis of displacement, only the weak, additive version.

As a test of robustness, all models in Table 2 were re-estimated with the inclusion of several sets of spatial lags. The first set included a spatial lag for the average mobility rate of household heads in surrounding PUMAs, which had a computed Moran's *I* of only .05 for the dummy indicator of any change in residence and a computed Moran's *I* of only .13 for the ordinal measure of displacement. Results reveal no significant effect for these spatial lags, implying that the average push from local hazards is unaffected by average mobility rates in surrounding areas. The second set of supplemental analyses included spatial lags for average hazard frequency, property damage, and crop damage in neighboring PUMAs, which exhibited much higher Moran's *I* statistics of of .68, .44, and .66, respectively. Results (not shown) generally confirm those in Table 2 but also offer a few refinements.

First, they indicate that the average "push" of local hazard frequency declines a bit when the hazard frequency of surrounding areas is also considered. Second, results indicate similar albeit less pronounced patterns for cumulative property damage. The implication is that the push of local hazards is reinforced by the push of hazards in surrounding areas. This pattern adds additional support to key findngs reported above. Third, spatial lags for crop damage reveal the opposite pattern. When local crop damage is high, it tends to reduce household mobility, all else equal; but when it is surrounded high levels of crop damage in surrounding areas, this retention effect becomes statistically insignificant. This countervailing effect of local and surrounding crop damage may help to explain its statistical insignificance in Table 2.

Political Ecological Hypothesis on Resettlement

Next, Table 3 reports results from Heckman-corrected regression models that predict property damage from natural hazards at destination for household heads that changed PUMAs during 1995-00, adjusting for the nonrandom selection of such migrants. Results from Model 1 indicate that, conditional on migrating, the average U.S. household head resettled in an area that experienced twenty percent *more* property damage from natural hazards than the area he or she left behind (.199, $p < .001$). This pattern supports Hypothesis 3 and indicates that in terms of migratory response, natural hazards pull as well as push. Results also indicate that this effect is significantly higher for Latinos and Asians, who on avearge resettle in areas with 29 and 25 percent more property damage than white counterparts, respectively.

[Table 3 about here]

Next, Model 2 adds interaction terms for race/ethnicity and family income to assess the extent to which observed racial and ethnic differences in the pull of affected areas depend on the income of those involved. Here, statistically insignificant coefficients for Latino and Asian interaction terms indicate that all members of these groups, regardless of family income, tend to settle in areas of greater impact than whites, all else equal. Results differ, however, for African Americans. Specifically, results now show a statistically significant coefficient of .171 ($p < .05$) and interaction coefficient of -.001 ($p < .05$), which indicate that it is high-income African

Americans who behave most similarily to white counterparts with respect to hazardous destinations and that by contrast, low and middle-income African Americans behave more similarly to Latino and Asian counterparts, all else equal. Supplemental analyses indicate that this similarity with Latinos and Asians persists to family incomes of approximately $114,000, above which African Americans begin to resettle in areas similar to white counterparts. This affluent subpopulation, however, accounts for less than five percent of all African American households.

So, overall, results from Table 3 indicate that all U.S. residents tend to migrate from hazardous to more hazardous areas and that this tendency is consistently elevated among minority groups, including all but the most affluent African Americans. The broader implication is that the general push and pull of natural hazards is omnipresent but unequal for members of less advantaged racial and ethnic groups, even when they have the same income and likelihood of migrating as white counterparts. To assess the robustness of these findings, two additional analyses were conducted. One analysis computed simple difference scores in property damage in areas of residence in 2000 and 1995 for all household heads. For whites, the average difference score was -$480,080, which means their area of residence in 2000 experienced roughly a half-million dollars *less* damage from natural hazards than their area of residence in 1995. By contrast, the average difference score for respective minority groups is positive, ranging from +$163,000 among African Americans, to +$1.6 million among Latinos, and +$2.0 million among Asians.

Next, models in Table 3 were re-estimated to assess if any control variables in the selection equation (not shown) were also statistically significant in the substantive equation reported. Two variables were: being female and number of children in the household, both of which negatively predict not only migration but also the amount of property damage at destination, conditional on migrating. In other words, female-headed households and households with more children are less likely to resettle in more hazardous destinations when they migrate, which is less often than most other households. Accounting for this pattern statistically, however, does not alter findings reported for racial and ethnic minorities above, including the observed interaction effect for African Americans in Model 2. So, overall results it Table 3 appear quite robust, adding further support to Hypothesis 3.

As a final test, all analyses in Table 3 were repeated for total crop damage at origin and destination, conditional on migrating. Similar to property damage, results reveal a positive correlation between damage at origin and destination. However, in these supplemental analyses none of the ethnic and racial differences reach statistical significance. The implication is that migration from crop damage to higher levels of crop damage is common but not racially and ethnically selective in the way that migration from property damage to higher levels of property damage is. This pattern further highlights the unique selection effects associated with hazard-related property damage.

CONCLUSION

Learning more about how environmental and social dynamics intersect to shape demographic processes, including residential mobility, is an increasingly important endeavor. The present study contributes to this effort by moving beyond extreme cases to conduct the first nationwide study of recent natural hazards and residential mobility in the United States, paying particular attention to racial and ethnic inequalities in addition to the potential pull as well as push of local impacts. Findings from these analyses make several specific contributions. First, they affirm the human ecological hypothesis that hazard frequency and cumulative property damage increase the displacement of local residents from home and area. Second, they affirm a weak version of the political ecological hypothesis that the stresses of natural hazards and minority status “add up” to displace minority residents – particularly Latinos and Asians – more than white counterparts of the same age, education, income and family status. Finally, findings reveal how all migrants but especially minority migrants gravitate towards destinations with more (not less) damage from recent hazards, thereby unintentionally redistributing the nation’s population toward areas of greater recent hazard. Several notable implications follow from these findings.

First, despite recent emphasis on functional recoveries at the aggregate level, human ecological theory appears to be correct about the general displacing effects of natural hazards. Consequently, there’s no need to wait for future climate change to see evidence of hazard-related migration; it is already happening, even in affluent societies such as the United States. Moreover, it is not limited to extreme cases but rather ubiquitous, ongoing and in these senses normal. This last point is important for a couple of reasons. One, it underscores the fact that even affluent societies have not eliminated environmental influences on migration; and two, it suggests that the best planning for future hazards may start not with long-range forecasting but with paying closer attention to current, ongoing hazards, which are many. Paying such attention, however, is not our current approach. Our current approach is to downplay present challenges through several interlocking processes. The first is to emphasize the statistical improbability of natural hazards in any given place. The second is to limit hazard preparedness to a small if well-meaning circle of professionals, who develop plans without much public input or awareness. The third is to restrict direct government assistance to relatively short periods of time before handing recovery over to market forces. These approaches maintain the status quo, including social inequalities, and preclude comprehensive planning for more inclusive recoveries in place.

Another notable implication of the present study is that natural hazards do not just displace residents but rather accelerate residential mobility in all directions, as increased numbers of households move from, to and within affected areas. This realization suggests that analyses that focus exclusively on displacement or net population change miss a good deal of what is going on demographically in response to natural hazards, which is a disproportionate redistribution of minority households from less to more hazardous areas.

As future research scrutinizes these findings and implications, several limitations of the present study are worth clarifying. First and most obviously, positive correlations between local hazards and residential mobility do not prove causation, but their consistency with recent case-study research helps. What remains to be done, among other things, is to turn our attention back to the broader interplay of these dynamics within the context of current technological and organizational conditions. Such research would not only help to clarify these broader conditions but also further underscore the social embeddedness of demographic responses to natural hazards and the fact that they remain probabilistic rather than automatic or deterministic outcomes of exogenous environmental forces.

Another limitation of the present study is that while it uncovers racial and ethnic inequalities in migratory responses to hazards, it does not fully explain them. Relatedly, it is unable to determine the degree to which observed migration is a function of the vulnerability or resilience of those involved. Future research will need to do more work on this front, paying particular attention to group-level dynamics that may influence destination decisionmaking and perhaps developing a concept of bounded or segmented resilience to underscore how the same structural inequalities present in everyday society produce unequal responses to environmental stress. I look forward to future research in these areas.

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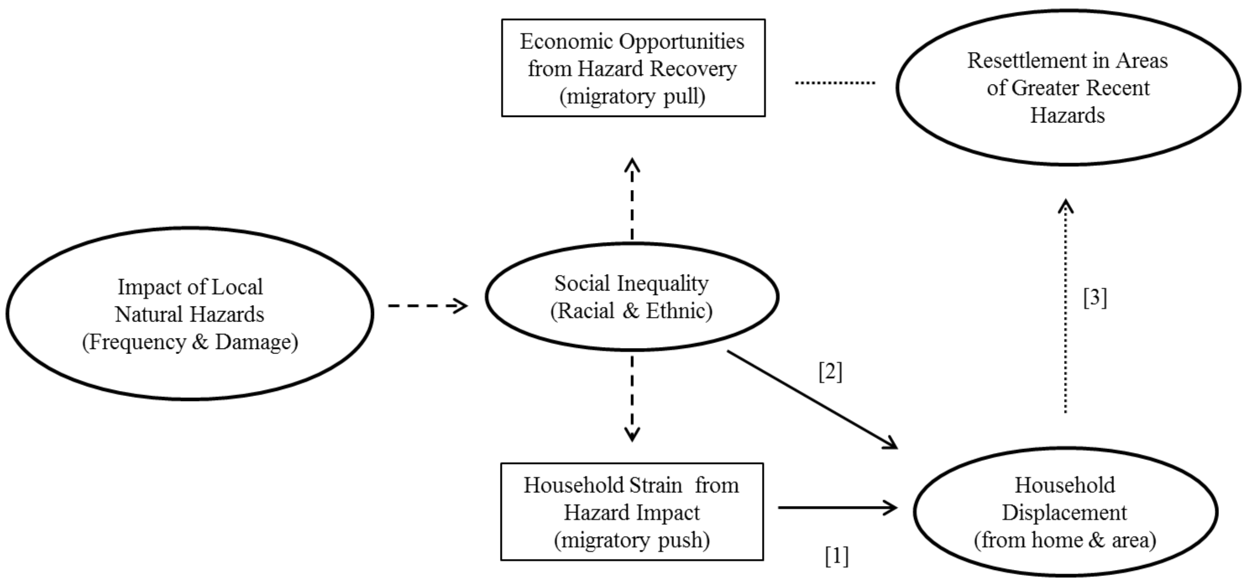
Figure 1. The Unequal Push and Pull of Natural Hazards



H1: Human Ecology Hypothesis
Greater local impacts from recent natural hazards increase residential mobility.

H2a: Weak Political Ecology of Displacement Hypothesis
The strains of recent natural hazards and racial inequalities add up to higher rates of residential mobility for racial and ethnic minorities than whites. (Additive disadvantage = [1] + [2])

H2b: Strong Political Ecology of Displacement Hypothesis
The greater the impact from recent natural hazards, the greater racial and ethnic inequalities in residential mobility be. (Multiplicative disadvantage= [1] x [2])

H3: Political Ecology of Resettlement Hypothesis
Conditional on migration, racial and ethnic minorities are more likely to resettle in areas with greater impacts from recent natural hazards, due to the unequal pull of local recovery opportunities.

Table 1. Descriptive Statistics for Household Heads, 1995-00

	Mean	s.d.	Min.	Max.
Local Natural Hazards				
# of unique hazardous events [a]	33.19	23.81	1	129
Total property damage ($000) [b]	63,700	160,000	0	3,140,000
Total crop damage ($000) [b]	17,800	59,000		389,000
Household Heads				
Different residence (0= no; 1= yes)	.41	.49	0	1
Degree of displacement (0 – 4)	.79	1.09	0	4
% No move (0)	.59			
% To different house in local area (1)	.24			
% To different local area, in state (2)	.09			
% To adjacent state (3)	.02			
% To nonadjacent state (4)	.05			
Race				
White (non-Latino) [ref.]	.78	.41	0	1
Latino	.08	.27	0	1
Black (non-Latino)	.11	.31	0	1
Asian (non-Latino)	.03	.15	0	1
Family income ($000)	53.82	58.88	-20	1,316
Years of School	12.82	3.21	0	21
Age	50.09	17.23	15	93
Female	.34	.47	0	1
Married	.55	.50	0	1
Number of own kids	.79	1.11	0	9
N of household heads		509,948		
N of PUMAs		1,028		

[a] Measured as the number of locally unique start dates, regardless of the number of different types of hazards recorded for that date. (E.g., If a storm and flood are recorded as starting on the same day, this hazard is counted as one unique event, not two.)

[b] Calculated for PUMA of residence in 1995 using constant 2011 dollars. (A PUMA can experience $0 in damage but still be considered to have experienced a hazard if there was injury or death attributed to the hazard.)

Table 2: Logit and Ordered Logit Results Predicting Residential Mobility, 1995-00. (Robust standard errors in parentheses) [a]

	Changed Residence [0/1]			Degree of Displacement [1-4]		
	1a	2a	3a	1b	2b	3b
Natural Hazards at Origin						
# of unique events [a]	.002** (.0006)	.002** (.0006)	.002** (.0005)	.001* (.0004)	.001* (.0004)	.001* (.0004)
Ln(Total property damage) [b]	.024** (.009)	.022** (.008)	.024** (.008)	.015* (.007)	.014* (.006)	.017* (.007)
Ln(Total crop damage) [b]	-.005 (.004)	-.005 (.003)	-.005 (.003)	-.006 (.003)	-.006 (.003)	-.006 (.003)
Race/Ethnicity [c]						
Latino		.171*** (.035)	.170*** (.034)		.115** (.034)	.114** (.034)
Black (non-Latino)		-.055 (.035)	.241 (.163)		-.084 (.034)	.295* (.154)
Asian (non-Latino)		.257*** (.033)	.583* (.244)		.319*** (.056)	1.295*** (.315)
Significant Interactions [d]						
Ln(Total property damage) x Black			-.018 (.010)			-.023* (.009)
Ln(Total property damage) x Asian			-.019 (.014)			-.058** (.019)
Controls						
Family income ($000)	-.0003** (.0001)	-.0003** (.0001)	-.0003** (.0001)	-.0002** (.00009)	-.0003** (.00009)	-.0003** (.00009)
Years of School	.028*** (.003)	.031*** (.002)	.031*** (.002)	.050*** (.003)	.051*** (.003)	.051*** (.003)
Age	-.186*** (.003)	-.186*** (.003)	-.185*** (.003)	-.131*** (.002)	-.131*** (.002)	-.131*** (.002)
Age squared	.001*** (.0002)	.001*** (.0002)	.001*** (.0002)	.0007*** (.00002)	.0007*** (.00002)	.0007*** (.00002)
Female	.029** (.010)	.033*** (.009)	.033** (.009)	-.003 (.009)	.004 (.009)	.004 (.008)
Married	-.316*** (.013)	-.322*** (.012)	-.322*** (.012)	-.251*** (.011)	-.259*** (.011)	-.259*** (.011)
Number of own kids	-.122*** (.006)	-.127*** (.005)	-.127*** (.005)	-.104*** (.005)	-.106*** (.005)	-.106*** (.005)
Constant/Cut 1	5.069*** (.142)	5.033*** (.137)	4.999*** (.142)	-3.357 (.107)	-3.345 (.104)	-3.329 (.109)
Cut 2				-1.863 (.112)	-1.850 (.108)	-1.792 (.114)
Cut 3				-.940 (.111)	-.926 (.107)	-.868 (.113)
Cut 4				-.527 (.108)	-.513 (.105)	-.455 (.110)
Wald χ^2 (df)	28,856(10)	29,747(13)	30,174(15)	27,534 (10)	27,197(13)	27,572(15)
Model Form		Logit			Ordered Logit	

* p < .05; ** p < .01; *** p < .001

[a] Computed using STATA's cluster command for 1995 PUMA of residence.
[b] Measured in constant 2011 dollars for all years for PUMA of residence in 1995.
[c] Non-Latino white is the reference category.
[d] To assess interactions between hazard impact and socioeconomic status, a full model was estimated with all possible interactions between hazard indicators and race and income respectively. In addition, each interaction term was evaluated separately in its own model. Models reported above include the three interaction terms that proved statistically significant at the .05-level in either the full or separate interaction models.

Table 3: Results of Regression Predicting Property Damage from Natural Hazards (Logged) at Destination among Migrant Households (Robust standard errors in parentheses) [a]

	Model 1	Model 2
Ln(Total property damage) at origin [b]	.199***	.199***
	(.017)	(.017)
Race/Ethnicity [c]		
Latino	.291**	.279**
	(.100)	(.106)
Black (non-Latino)	.118	.171*
	(.075)	(.086)
Asian (non-Latino)	.255**	.247*
	(.085)	(.099)
Family Income ($000)	.0004	.0005
	(.0003)	(.0003)
Interactions		
Latino x Total Family Income		.0003
		(.0007)
Black x Total Family Income		-.0015*
		(.0006)
Asian x Total Family Income		.0001
		(.0007)
Constant	13.133***	13.130***
	(.321)	(.321)
λ	.0001	.0003
	(.074)	(.074)
Log likelihood	-385,517.3	-385,513.8

* p < .05; ** p < .01; *** p < .001

[a] Models are estimated with maximum-likelihood Heckman selection, using regressors reported in Table 2 for the selection equation (not shown). N of uncensored observations = 84,719; N of censored observations = 425,229. Robust standard errors are computed using STATA's cluster command for 2000 PUMA of residence.

[b] Measured in constant 2011 dollars for all years for PUMA of residence in 1995.

[c] Non-Latino white is the reference category.