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Recovery Migration after Hurricanes Katrina and Rita: Spatial Concentration and Intensification in the Migration System

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Abstract

Changes in the human migration systems of Hurricane Katrina- and Rita-affected Gulf of Mexico coastline counties provide an example of how climate change may affect coastal populations. Crude climate change models predict a mass migration of "climate refugees," but an emerging literature on environmental migration suggests most migration will be short-distance and short-duration within existing migration systems, with implications for the population recovery of disaster-struck places. In this research, we derive a series of hypotheses on recovery migration predicting how the migration system of hurricane-affected coastline counties in the Gulf of Mexico was likely to have changed between the pre-disaster and the recovery periods. We test these hypotheses using data from the Internal Revenue Service on annual county-level migration flows, comparing the recovery period migration system (2007–2009) to the pre-disaster period (1999–2004). By observing county-to-county ties and flows we find that recovery migration was strong, as the migration system of the disaster-affected coastline counties became more spatially concentrated while flows within it intensified and became more urbanized. Our analysis demonstrates how migration systems are likely to be affected by the more intense and frequent storms anticipated by climate change scenarios with implications for the population recovery of disaster-affected places.

Keywords

recovery migration; migration system; environment; disasters; Hurricane Katrina; Hurricane Rita

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Hurricanes, typhoons, and other extreme environmental events place the growing proportion of the world's population living in coastal cities at risk of displacement (Goodess 2011; McGranahan et al. 2007). The focus on the displacing potential of these events in existing

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research on disaster-related migration neglects the longer-run population change shaped by recovery migration (Black et al. 2013). Furthermore, the focus on potential displacement leads to exaggerated estimates of the number of "climate refugees" which should be tempered by more theoretically-informed and empirically-based research (Gemenne 2011). Disaster-affected places rarely experience permanent population loss (Laczko and Aghazaram 2009; McLeman 2011; Wisner et al. 2004). Instead, they recover their populations through return migration and new in-migration (Fussell and Elliott 2009; McLeman and Smit 2006) and, we propose, adaptations of the migration system.

For scholars concerned with global climate change, the effects of Hurricanes Katrina and Rita on New Orleans and the Gulf Coast region provide an example of what could happen to coastal and nearby cities affected by hurricanes and coastal flooding (e.g., Adamo 2010). These hurricanes struck the Gulf of Mexico between Texas and Florida within weeks of each other in 2005. While hurricanes and other damaging environmental events are not rare for this region, Katrina was the sixth most powerful and costly hurricane thus far recorded and Rita ranked fourth most powerful, although it struck a less populated region so damage estimates were lower (Knabb et al. 2006). These devastating events left residents, politicians, planners, and scholars wondering whether and how the region would recover its built environment and population (Kates et al. 2006), and what it meant for areas that might confront similar disasters in the future.

Our study focuses on population recovery through migration to a disaster-affected region. We work from a migration systems framework to ask a foundational question about resiliency: does an environmental shock alter the pre-existing migration system of the affected region? Considering whether environmental events affect existing patterns of migration over time is vital to understanding large-scale and long-run impacts of environmental events on human populations (e.g., Hsiang et al. 2013). Most research on the demographic effects of Hurricane Katrina on New Orleans focuses on the unequal vulnerability of residents to displacement by socio-demographic and place-based characteristics (Cutter and Emrich 2006; Fussell et al. 2010; Groen and Polivka 2010; Myers et al. 2008). But none, to our knowledge, considers how the disaster impacted the broader system of migration flows to and from disaster-affected coastline counties over the more prolonged recovery period. Moreover, whereas migration systems research chiefly concerns identifying the system and factors that perpetuate it (e.g., Fawcett 1989; Kritz et al. 1992; Mabogunje 1970; Massey et al. 1998), our study concerns the dynamic response of the system to an exogenous shock. Indeed, our study is distinct from previous research in two ways. First, we consider places directly affected by an environmental event and places to which they are connected through migration. Second, we assess longer-run impacts by analyzing migration in the recovery period, as opposed to the immediate post-event period. In doing so, we speak to the broader spatial and temporal impact of environmental events on human settlement patterns. Our results show population recovery occurred through a spatial concentration and intensification of the migration system in the years following the disaster.

A SYSTEMS MODEL OF RECOVERY MIGRATION

We take a systems approach to investigate recovery migration (Fussell et al. 2014). In this approach, dating to Ravenstein's (1885) study of migrant streams and counter-streams in 19th century United Kingdom, the entire migration system is the object of study, as opposed to individual migrants or their places of origin or destination (Lee 1966; Fawcett 1989). The central proposition is that when one place within the system experiences a change, i.e., an environmental shock, its effects are felt throughout the entire system (Andrienko and Guriev 2004; Bakewell 2013b; Mabogunje 1970). A migration system is defined by both structure and process. The structural element of a migration system is the ties connecting places, which are the basis for measuring the size and attributes of flows of migrants between them (Mabogunje 1970). The process element of a migration system is the dynamics governing the ties, i.e., the "rules of the game that govern…elements in the system" (Bakewell 2013a: 15). The ties, flows, and their attributes and relationships, interact to perpetuate and reinforce the system by encouraging migration and other types of exchanges (e.g., capital, commodities, information) along certain pathways and discouraging it along others (Mabougunje 1970:12; see also McHugh 1987; Kritz et al. 1992). Although stability in the system over time and across space is often emphasized in work adopting a systems perspective (DeWaard et al. 2012; Massey et al. 1998), some scholars underscore the dynamic element of the system, at least conceptually, and focus on factors altering system elements and, it follows, the migration system itself (Bakewell 2013a; Bennett and Haining 1985; Bennett et al. 1985; de Haas 2010; Fawcett 1989; Plane 1987; Plane and Rogerson 1986). There are several different approaches to viewing change in a migration system, including a focus on the speed of change (Bennett and Haining 1985) and the role of historical factors in shaping the type of change (DeWaard et al. 2012; Mueser 1989) (see also Bell et al. 2002 on measuring connectivity).

Underlying the structure and processes defining a migration system are the decisions and behaviors of individuals and households. At the aggregate-level, internal migration is often framed as labor migration, with populations redistributing from places with diminishing or less economic opportunities to areas with expanding or more opportunities (e.g., Greenwood 1997). Correspondingly, at the individual- and household-level, internal migration is viewed as an economic decision in which the costs and benefits of a potential move are weighed, and migration occurs when perceived gains exceed anticipated costs (e.g., Sjaastad 1962; Todaro 1976). Factors beyond labor ties and economic pulls also shape migration decisions. Personal networks lower barriers to migrating and inform destination selection by providing information about and access to housing, employment, and other resources at the destination, and by reducing the psychic costs of migration (Greenwood 1969; Lansing and Mueller 1967; Nelson 1959). Such information, access, and costs are correlated with distances between origin and destination (Schwartz 1973; Sjaastad 1962). An exogenous shock to the migration system, such as a devastating hurricane, modifies the economic and social processes shaping decisions to move and destination choices and, we expect, the migration system itself.

As is widely noted, environmental migration is rarely distinguishable from other types of migration, i.e., labor migration or network migration, because environmental forces operate indirectly through economic, political, and social structures (Black et al. 2011; see also Perch-Nielsen et al. 2008; Hunter 2005; McLeman and Smit 2006). However, the spatial nature of environmental migration may alter the patterns of migration with a system. Drawing from a growing empirical literature on environmental drivers of migration, Findlay (2011: S51-S52) extracts several principles regarding environmental migrants' destination choices that are consistent with general migration theory. First, most potential migrants prefer not to move. However, once a decision to move has been made, the second principle states migrants will move relatively short distances. Finally, to summarize the third through sixth principles, migrants prefer to go to places where they already have ties allowing them to more easily and profitably exchange their human, social and cultural capital. For most migrants, these places are nearby, although a few more advantaged migrants follow historical, cultural or economic ties to more distant destinations. McLeman and Hunter (2010) arrive at similar generalizations by culling evidence from four cases of "climate migration." They add that such migration is rarely permanent. Barring an environmental change destroying housing and livelihoods, few places are ever completely abandoned (McLeman 2011). From these propositions we argue that return migration and new in-migration to an area after an environmental shock are to be expected, and the principles governing destination choice summarized by Findlay (2011) help identify the types of places that become the likely origins of recovery migration.

To understand how an environmental shock changes a migration system through recovery migration, the unit of analysis must shift from the household to the flows of households into affected places, and the time frame must include a longer time horizon than is typical of disaster research. In the pre-disaster period, the structure of the migration system results from migrant households' destination choices under a general migration regime. In the period immediately before and after a rapid-onset disaster, households are likely to follow established ties to nearby places within the pre-disaster migration system. To a large extent, this response to an environmental shock defines the system structure in the recovery period for displaced households. In the recovery period, the processes driving migration to the disaster-affected region are economic and social, and only indirectly environmental.[1] Displaced households attempt to minimize losses and households may even search for opportunities in the recovering economy. Thus, a migration system affected by an environmental shock exhibits three distinct periods: a pre-disaster period; the rapid-onset disaster period; and the recovery period.

An additional consideration for models of recovery migration is that not all environmental events or changes are the same and, therefore, any expectations of their impact on a migration system — short-term and, in our case, longer-term — must consider the character of the environmental shock in relation to migration decision processes (Black et al. 2011; Black et al. 2013; Hunter 2005; McLeman and Smit 2006). Environmental events are often distinguished by the speed of onset. Recovery migration is more likely after a rapid-onset and short-duration event than a slow-onset and long-duration one because of the contrasting influence on migrants' decisions. Potential migrants facing a rapid-onset event have

[1]The state and private relief agencies shape environmental migration destination choice in the emergency period. However, one cannot assume that evacuees were still located in evacuation shelters or other temporary housing in the recovery period.

comparably less time to make migration decisions and tend to make temporary moves (i.e., evacuations or short-term displacements), returning to their communities and livelihoods once the built environment is restored. These return migrations might persist for multiple years following the event, depending on the pace of rebuilding efforts (Kates et al. 2006). In contrast, potential migrants confronting slow-onset events face on-going decisions about whether to engage in cyclical or permanent out-migration as a means of coping with losses affecting their livelihoods (Laczko and Aghazarm 2009). With storm warnings reported only days in advance, Hurricanes Katrina and Rita were rapid-onset events and extremely destructive for coastline counties affected by the storm surge. In these places, recovery of homes and livelihoods was prolonged or impossible. Thus, we expect recovery migration to concentrate in the harder hit areas in the years following the hurricanes.

Our conceptual model of recovery migration is rooted in research on historical environmental events and accumulating empirical evidence on migratory flows from and to Gulf of Mexico counties affected by the 2005 hurricane season. In their historical analysis, McLeman and Smit (2006) focus on Oklahoma and the 1930s Dustbowl Migration to describe several types of migration flows affecting the population size and composition of Oklahoma counties in subsequent years. Best known is the out-migration of Dustbowl refugees, mostly displaced tenant farmers, to rural California. Less noted are the return migration of some Dustbowl refugees and the migration of rural residents to nearby cities and towns. The key points are out-migration is not the only dynamic characterizing a migration system after an environmental event, and return migration and new in-migration are important components of population recovery (Fussell and Elliott 2009).

Research specific to the 2005 hurricane season shows that the majority of residents in the most threatened Gulf of Mexico coastal counties evacuated in anticipation of Hurricane Katrina’s landfall (Elliot and Pais 2006; Groen and Polivka 2010; Haney et al. 2010). From 2006 through 2010, in-migration made several of the most devastated counties the fastest growing counties in the United States (U.S. Census 2008; Census 2011). Migratory in-flows included returning residents as well as newcomers, such as “hurricane chasers” seeking construction employment, young professionals pursuing urban development and entrepreneurial opportunities, energy sector workers repairing the damaged industrial infrastructure, and displaced residents from more severely affected counties within the recovering disaster-affected region (Ehrenfrucht and Nelson 2013; Fussell 2009).

In our study, we take as the unit of analyses the flows of migrant households among disaster-affected places and the places tied to them to understand how the migration system of Hurricane Katrina- and Rita-affected coastline counties in the Gulf of Mexico changed between the pre-disaster and recovery periods. We examine recovery migration that brought population back to the disaster-affected areas several years after the disaster, not shorter-term moves better characterized as temporary evacuations. We test several hypotheses elaborated in the following section which, if supported, contribute to a general understanding of how environmental shocks change the drivers of migration systems. In this case, the migration system adapted to generate recovery migration.

HYPOTHESES ABOUT A RECOVERY MIGRATION SYSTEM

We investigate three qualities of the migration system of coastline counties most severely affected by Hurricanes Katrina and Rita to assess three corresponding hypotheses. First, we examine whether the migration system remains stable or changes after facing an environmental shock. Stability in the system would result if disaster-affected coastline counties' populations migrated only to places in the pre-disaster migration system and if these were the only places sending in-migrants to disaster-affected counties in the recovery period. In this case, we would observe the same ties between counties in both periods. Alternatively, we might expect some change in the system given the large-scale and involuntary nature of population displacement from disaster-affected coastline counties in the immediate aftermath of the hurricanes. Some residents of these counties might have voluntarily or involuntarily relocated to counties that were not part of the pre-disaster migration system, thereby introducing new ties to the recovery migration system. New ties may also be introduced if people from counties outside of the pre-disaster migration system relocated to disaster-affected coastline counties in search of work or other recovery-led opportunities. We examine the extent of stability and change in the migration system through an analysis of ties between specific county pairs occurring only in the pre-disaster or the recovery periods, but not both: the smaller the number of these unique ties in a given period, the more stable the migration system between the two periods.

Second, we further examine stability and change in the migration system by analyzing the size of in-flows among all ties within the pre-disaster and recovery periods. Environmental and disaster-driven migrations are shaped by the nature of the environmental change in the origin community. Since hurricanes are rapid-onset, short-duration events and, in this case, resources were available for recovery, we expect displaced residents will return as the recovery progresses and new in-migrants will arrive to pursue emerging opportunities. If recovery is underway, then we would expect to see larger inflows to disaster-affected coastline counties in the recovery period than in the pre-disaster period, and comparatively smaller out-flows in the recovery period. However, if recovery is faltering, there would be smaller in-flows of displaced residents and opportunity seekers into these counties, and relatively larger out-flows.

Third, extending the previous analysis, we examine change in the average size of in-flows to disaster-affected coastline counties from proximate and urban counties between the pre-disaster and recovery periods. If the principles of migrant destination choice are correct, disaster-affected migrants are most likely to have relocated to proximate counties and urban counties where they were best able to benefit from their human, social, and cultural capital. Therefore, as displaced residents return from these places in the recovery period, we expect the average size of these flows to be larger than they were in the pre-disaster period. New migrants originating in counties connected in the pre-disaster migration system are also likely to contribute to in-flows as they pursue new opportunities in recovering areas.

DATA

We define three geographic regions: (1) disaster-affected coastline counties; (2) nearby Gulf of Mexico coastal counties; and (3) distant counties in the continental U.S. We also identify urban counties within each of these regions since our third hypothesis includes consideration of urban counties. There are a number of ways one could define regions. We focus on counties' relationship to water since the storm surge accompanying a hurricane is extremely destructive. Storm surges bring powerful waves into coastline areas and push water through rivers and other water ways, destroying and damaging buildings and infrastructure. We identify these regions by combining the definitions used in a U.S. Census report on coastline population trends (Wilson and Fischetti 2010) with FEMA disaster declarations. In the U.S. Census report, a county adjacent to coastal waters or territorial seas is designated a coastline county and is part of a subset of coastal counties. A coastal county has at least 15% of its land within the nation's coastal watershed or a coastal cataloging unit (NOAA n.d.). After Hurricanes Katrina and Rita, 36 coastline counties were declared federal disaster areas by the Federal Emergency Management Agency (FEMA). We label these disaster-affected coastline counties, and they are the focal region in our analysis. Our second region includes 124 counties that are either coastline counties not declared federal disasters or coastal counties which may or may not have been declared federal disasters. The third region includes the 2,951 remaining distant counties in the continental U.S. Slightly less than half (1,297) of all counties in the continental U.S. are urban. We refer to these three regions as *disaster-affected coastline counties*, *nearby counties*, and *distant counties*, shown in Figure 1.

Our study concerns the connections between places, which we identify as ties between origin-destination pairs of counties and the size of migrant flows across these ties. A tie refers to the presence of a flow of any size, whereas a flow refers to the number of households migrating from *i* to *j*. We focus on in-flows and out-flows between pairs, and not net flows to or from sending or receiving counties, because the meaning of the flow depends on its directionality (Rogers 1990). In our case, out-flows from disaster-affected coastline counties to counties within each region capture the out-migration dimension of the system. The in-migration dimension of the system is measured by in-flows to disaster-affected coastline counties from counties within each region. Based on existing research, we assume in-flows to disaster-affected coastline counties consist of returning residents (e.g., Fussell et al. 2010; Groen and Polivka 2010; Myers et al. 2008), newcomers attracted by opportunities related to the recovery (Fussell 2009), and disaster-affected residents migrating between counties within the region. Together, these migrants comprise recovery migration. We examine the size of in-flows and the number of ties from other counties to disaster-affected coastline counties in the recovery period to test our hypotheses about environment-induced change in the migration system from a longer-run perspective.

We measure migration flows and their attributes with the Internal Revenue Service (IRS) Statistics of Income Division (SOI) County-to-County Migration Data files. The data includes all U.S. federal income tax-payers; thus, underrepresenting the very poor and older populations, who are less likely to file income tax or be included as dependents on others' tax returns, as well as the small percentage of tax returns filed after late September of the filing year (Gross n.d.). The data lack information about migrants other than their household income and broad age groups. Despite these limitations, researchers agree the IRS migration data are the best available source for tracking changes in internal migration in the United States (Engels and Healy 1981; Isserman et al. 1982; Molloy et al. 2011). The Current Population Survey indicates in each year between 1992 and 2009 about 87% of household heads filed tax returns, making the IRS data reliable for identifying population-level trends (Molloy et al. 2011). Although some researchers have used adjustment procedures to improve coverage of the IRS data (i.e., Plane 1999), there is no clean way of making such adjustments; moreover, the issue of coverage is just one limitation common to migration estimates (Raymer et al. 2013). These data are ideal for our study because they capture annual inter-county migration flows pre-dating and following the 2005 hurricane season in the style of a natural experiment. Evacuation behavior is not our interest, and is better measured by the American Community Survey (e.g., Johnson et al. 2008; Koerber 2006), Current Population Survey (e.g., Groen and Polivka 2010) or specialized surveys (e.g., Sastry 2009). These data sources are inadequate for our analysis given their limited geographic representation or time frame.

For both conceptual and practical reasons we use the years 1999 through 2004 to measure the period before the 2005 hurricane season – the pre-disaster migration system – and 2007 through 2009 to measure the recovery period – the recovery migration system. We do not examine the disaster period (2004–2006) because migration during this time is conceptually difficult to distinguish and the data are of poorer quality. Johnson et al. (2008) found a general decline in match rates (i.e., coverage) between the tax filing years 2004–2005 and 2005–2006, which was greatest in areas affected by Hurricanes Katrina and Rita. By comparing the pre-disaster and recovery periods we compare periods in which migration systems were relatively stable and data are of comparable quality. Our approach of averaging across individual tax filing years within the pre-disaster and recovery periods produces annualized estimates, thereby negating possible problems associated with imbalanced samples, as well as those associated with using just one tax filing year.

METHODS

Our methodological approach moves beyond description to test hypotheses concerning recovery migration patterns in a natural experiment framework. As such, we address two current problems in research on population-environment interactions. First, we focus on population-level patterns to examine change over time using a cross-sectional data series. Second, we use smaller geographic units than many studies examining local-level responses to environmental change, which typically focus on the region as a whole (e.g., Grübler et al. 2007; Lutz et al. 2007). Moreover, by using all counties in the contiguous 48 states we more completely represent the migration system, thereby complementing Curtis and Schneider’s (2011) approach by connecting areas directly and indirectly affected by an environmental shock through recovery migration.[2]

[2]Studies of spatial units over time must consider the stability of the unit. Boundary lines for the counties in this analysis were stable.

Modeling Migration Systems

Our analysis adapts two methods for studying geographic mobility: descriptive estimates and maps modeling migration systems; and confirmatory tests of hypotheses based on regression models. For our models of migration systems, we use the IRS data to develop estimates and maps of changes in the Gulf of Mexico migration system taking place between the pre-disaster (1999–2004) and recovery (2007–2009) periods. Characterizing these changes requires modeling migration systems in a way that simultaneously considers the population of households "at risk" of migrating in each sending county (Rogers 1975, 1990, 1995) from the vantage points of both sending and receiving counties (DeWaard 2013; DeWaard and Raymer 2012).

We begin by summarizing migration patterns to disaster-affected coastline counties from each county in the contiguous U.S. using a multiregional transition model (Rogers 1975, 1995; see also DeWaard 2013). [3] For each disaster-affected coastline county *j*, we assemble a diagonal matrix, **l(0),** composed of a hypothetical population of households at risk of migrating to *j*.

$$\mathbf{l}(\mathbf{0})=\begin{bmatrix} l_1 & 0 & \dots & 0 & 0 \\ 0 & l_2 & \dots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \dots & l_k & 0 \\ 0 & 0 & \dots & 0 & l_j \end{bmatrix} \quad (1)$$

where l_i (i=1,2,…,k) represents the number of households in each sending county at risk of migrating to receiving county *j*. Per demographic convention, the starting number of households in each sending county is arbitrarily set to 1,000 (Palloni 2001). Given our interest in migration to disaster-affected coastline county *j*, we then fix l_j in (1) such that l_j = 0.

Using information on county-to-county flows of taxpayer households in the IRS data for the pre- disaster and recovery periods, we then assemble two matrices of county-to-county migration probabilities, **Q**. In each period, these take the form:

$$\mathbf{Q}=\begin{bmatrix} q_{1,1} & q_{1,2} & \cdots & q_{1,k} & q_{1,j} \\ q_{2,1} & q_{2,2} & \cdots & q_{2,k} & q_{2,j} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ q_{k,1} & q_{k,2} & \cdots & q_{k,k} & q_{k,j} \\ q_{j,1} & q_{j,2} & \cdots & q_{j,k} & q_{j,j} \end{bmatrix} \quad (2)$$

The matrix dimensions are 3,111 by 3,111, totaling 9,678,321 potential migration flows among each and every county in the contiguous U.S., including for *i*=*j* (i.e., non-migrants).

[3]Hypothetical examples in Appendix 1 illustrate the logic and use of these models. Our explanation of here and in Appendix 1 are more very detailed in order to highlight the particular flows (and their summaries) of interest.

Each row is a probability vector whose elements sum to 1.0. Accordingly, the population dynamics governing migration between each pair of counties can be written as:

$$\mathbf{l}(\mathbf{1})=\mathbf{l}(\mathbf{0})\mathbf{Q} \quad (3)$$

The sum of the last column vector in (3) is a count of the number of households from our starting hypothetical population of U.S. households in (1) which, in fact, migrated to disaster-affected coastline county *j*. Dividing this quantity through by the size of the hypothetical population of households at risk of migrating to *j*, i.e., the trace of the matrix in (1), gives the proportion, *p*, of households at-risk of migrating to *j* who actually did so, i.e., as governed by the probabilities in (2).[4] Subtracting this quantity for the pre-disaster period from that for the recovery period, we derive an estimate of how the system of migration flows from all sending counties in the contiguous U.S. to disaster-affected coastline county *j* changed over time while accounting for the risk of migration in each sending county. We repeat these steps for each disaster-affected coastline county and present the combined results in tables and maps.

In addition to modeling migration to disaster-affected coastline counties from the vantage point of receiving areas, we likewise consider migration to disaster-affected coastline counties from the vantage point of sending counties, and from disaster-affected coastline counties to all counties in the contiguous U.S. With respect to the former, for each row in (2), we sum those elements where receiving county *j* is a disaster-affected coastline county and subtract this quantity for the pre-disaster period from that for the recovery period. We map these results to show how migration to disaster-affected coastline counties, from the vantage point of sending counties, changed over time. To further model migration from disaster-affected coastline counties to each county in the contiguous U.S., we revise the approach in (1)–(3) above for each U.S. county *j*, with the matrix in (1) re-specified so that the starting population in each U.S. county is set to zero, excluding disaster-affected coastline counties in which the starting population is arbitrarily set to 1,000 households. For each U.S. county *j*, the sum of the last column vector in (3) gives an estimate of the number of households from our hypothetical population in (1) which, in fact, migrated to *j* from disaster-affected coastline counties. We then compare the resulting figure for the pre-disaster period to the corresponding figure for the recovery period. As before, we repeat the steps for each U.S. county *j*, and report the combined results.

Hypothesis Tests

In the second part of our analysis, we seek to determine if the change in the number of ties and the size of migration flows in the disaster-affected coastline counties' migration system between the pre-disaster and recovery periods is in the predicted direction and statistically significant. Our data allow us to construct an experimental framework offering counterfactuals used to distinguish a secular time trend from changes due to the treatment of interest (e.g., exposure to storm surge from Hurricanes Katrina and Rita). This requires examining the experiences of a comparison group. In our study, we define the comparison

[4]This is necessary because the starting population values in (1) are arbitrary.

group as the nearby Gulf of Mexico coastal counties and the experimental group as the disaster-affected coastline counties. Although it is unlikely that the nearby counties are identical to the disaster-affected coastline counties, a comparison of the two groups is the closest approximation of a natural experiment.[5]

For our first hypothesis concerning change in ties, we assess whether the number of all ties and the number of unique ties – ties that exist in only one of the two periods – differs between the pre-disaster and recovery periods. We focus on unique ties as opposed to all ties since the former, by definition, are indicative of a change in the migration system. To observe change, we compare the proportion of all possible ties in the pre-disaster period with those in the recovery period, where the number of all possible ties corresponds with the number of sending counties multiplied by the number of receiving counties in the specific region (less one since a county cannot be “tied” to itself). For example, for flows between disaster-affected coastline counties, there are 1,260 (36 x 35) possible ties; whereas for flows to disaster-affected coastline counties from nearby counties, there are 4,464 (36 x 124) possible ties. We test whether the difference in the proportion of unique ties is statistically significant for both in- and out-flows using a two-sample difference in proportions test for a comprehensive analysis of system contraction or expansion.

For our second and third hypotheses relating to the size of migration flows, our outcome of interest is the percent change in the size of migration in-flows to disaster-affected coastline counties (experimental group) relative to nearby counties (comparison group) between the pre-disaster and recovery periods. In these analyses, we a use regression approach to build on the descriptive results and formally test for changes (i.e., contraction and expansion) in the system, focusing on changes in the size of flows across ties. The advantage of our approach is that it produces estimates of percentage change in the size of flows across ties in the system between the pre-disaster and recovery periods.

We estimate the change in the size of in-flows to disaster-affected coastline counties and nearby counties using a modified gravity model (Greenwood 1997; Kim and Cohen 2010; Willekens 1999; Zipf 1946) containing a dummy variable for the recovery period, , t_t and controlling for changes occurring prior to the pre-disaster period by virtue of a unique intercept term, α_{ij} , for each pair of sending and receiving counties. This intercept makes the inclusion of any time-invariant variables in the model redundant; thus, distance is not and need not be included in model (4). We estimate model (4) separately for disaster-affected coastline counties and nearby counties. The parameter, λ is an estimate of the average change in the size of migration flows over time, which, when exponentiated, provides an estimate of the percent change.

$$\ln(y_{ijt})=\alpha_{ij}+\beta_1\ln(p_{it})+\beta_2\ln(p_{jt})+\lambda t_t+\varepsilon_{ijt} \quad (4)$$

[5]Sensitivity tests restricting the comparison group to nearby non-coastal counties with a FEMA disaster designation (N=64) are consistent with results reported using our preferred comparison group (all 124 nearby counties). Results are available from the corresponding author upon request.

To identify the disaster recovery effect, we employ a difference-in-difference approach (5) by including a term, k_k , denoting whether the receiving county is a disaster-affected coastline county or a nearby county. The parameter associated with the interaction between the time and group dummies, δ, is the treatment effect, and summarizes the difference in the average change in the size of in-flows to disaster-affected coastline counties relative to the change in nearby counties.

$$\ln(y_{ijtk})=\alpha_{ij}+\beta_1\ln(p_{itk})+\beta_2\ln(p_{jtk})+\lambda t_t+\delta(t_k \times k_k)+\varepsilon_{ijtk} \quad (5)$$

Given the unique intercept term, α_{ij} , inclusion of the time-invariant group term, k_k , is redundant; however the interaction of this term with the time dummy is estimable, and is the parameter of interest.

RESULTS

Changes in the migration system of the disaster-affected coastline counties

Our first task is to identify which counties were connected to disaster-affected coastline counties before Hurricanes Katrina and Rita so we can describe the pre-disaster and recovery migration systems. We examine the migration system from the perspective of disaster-affected coastline counties as the ties through which migrants flow to or from those counties and the attributes of those ties, specifically their size, both total and average, and the types of counties they connect.

To determine whether there is stability in the migration system, our first hypothesis, we compare the number of unique ties of disaster-affected coastline counties in the pre-disaster and recovery periods. If the system is perfectly stable, there will be no unique ties in either period since the ties will be common to both the pre-disaster and recovery periods. If the system is expanding there will be more unique ties in the recovery period than the pre-disaster period, and if it is contracting, there will be fewer. We find a decrease in the number of unique out-ties from disaster-affected coastline counties to all types of counties of −57.8% (Table 1, out-ties), with no significant change (-3.3%) in the number of unique in-ties to disaster-affected coastline counties (Table 1, in-ties). This suggests that the recovery migration system of disaster-affected coastline counties contracted with respect to out-ties, but not in-ties. The pattern is the same when we limit the dataset to only urban counties.

The spatial concentration of the out-flow side of the system is evident by distinguishing the ties by the proximity of the counties they connect. Change was largest and statistically significant for distant counties (−63.1%), followed by nearby counties (−43.3%). The decrease in out-ties to other disaster-affected coastline counties was also large (−34.8%) but not statistically significant. Change in the in-flow side of the system is also evident when considered this way. Unique in-ties to nearby counties grew by 33.3%, while in-ties among disaster-affected coastline counties (-34.8%) and, to a lesser extent, in-ties from distant counties (−6.8%) were eliminated. Although this change was not significant overall, when we narrow the data to only urban origin counties, which make up the majority of ties in the migration system, we observe a statistically significant increase of 41.8% in in-ties from nearby urban counties.

The significant changes in ties between types of places allow us to reject the hypothesis of stability in the migration system. The in-flow side of the system increased unique in-ties with nearby urban counties, consistent with assumptions that these were the counties most likely to have sheltered long-term displaced residents and to have provided recovery period workers. Further, we see the outflow side of the system withdrew out-ties to nearby and distant counties – likely due to population losses suffered by disaster-affected coastline counties which, in turn, reduced the likelihood of out-migration in the recovery period. These results describe a recovery migration system that was more spatially concentrated than the pre-disaster system.

Changes in the size of in-migration flows to the disaster-affected coastline counties

Our second set of hypotheses concerns the size of the in-flows to disaster-affected coastline counties in the recovery period. If recovery migration is strong, we expect to see larger in-flows in the recovery period than in the pre-disaster period, and smaller recovery period out-flows than in-flows. If recovery migration is weak, we should see smaller or no different in-flows in the recovery period than in the pre-disaster period, and larger recovery period out-flows than in-flows. The descriptive evidence shows the total flow size into disaster-affected coastline counties grew by 19.4% overall, and was larger than out-flows from these counties (144,854 versus 137,424) (Table 2).

We conclude that recovery migration was strong. In-flows from nearby counties increased the most, by 30.1%, although they were followed closely by in-flows from distant counties, which grew by 25.9% (Table 2). These increases are somewhat larger for in-flows from urban counties (32.7% and 26.4%, respectively). In contrast, and as a point of comparison, out-flows from disaster-affected coastline counties increased relatively little, by 4.6%, with the largest flows going to other disaster-affected coastline counties (8.2%) and nearby counties (9.2%), while flows to distant counties actually diminished (−1.3%). The patterns are similar for urban counties. These results are consistent with the second hypothesis that in-migration to disaster-affected coastline counties would be higher in the recovery period than in the pre-disaster period. Furthermore, we see that the spatial concentration of the migration system, evident in the test of our first hypothesis, is accompanied by the intensification of flows, especially in-flows. Such churning of migrants suggests that out-migration during the immediate disaster period was mostly temporary and intensified in-migration best characterizes the recovery period.

We illustrate these changes in the in-flow side of the migration system geographically in Figure 2, Panel 2A, which identifies tied counties for which the number of migrants changed the most between the pre-disaster and recovery periods. Change estimates produced by the multiregional migration model reflect an increase or decrease in the number of migrants between periods. Counties highlighted in the darkest shade are among the top 5 percent of counties which sent increased numbers of migrants to the disaster-affected coastline counties in the recovery period as compared to the pre-disaster period. Counties shaded in medium grey are the bottom 5 percent, which sent comparatively fewer migrants.[6] The patterns in the maps are consistent with the increase in in-ties and in-flows from nearby counties and the decrease in in-ties and smaller in-flows from distant counties (Tables 1 and 2). Only a small number of distant counties, largely southern cities, were among the top 5 percent of senders in the recovery period. The percentage change was also high in a few distant rural counties, such as places with a strong energy industry (e.g., Sweetwater County, Wyoming, and La Plata County, Colorado) from which migrants pursuing employment in the Gulf Coast's damaged oil industry may have originated. The majority of tied distant counties—e.g., counties composing the metropolitan areas of Boston, Chicago, Denver, New York, and Washington, D.C.— sent comparatively fewer migrants to disaster-affected coastline counties in the recovery period than in the pre-disaster period. Most top sending counties are clustered around the Gulf of Mexico in nearby counties or disaster-affected coastline counties. The spatial concentration of top-sending counties is what we would expect if recovery migration was strong and composed of pre-disaster residents of the disaster-affected coastline counties who relocated to nearby counties and new migrants who were connected to employment opportunities in the recovering region.

As a point of comparison, counties receiving the largest increases in out-flows from the disaster-affected coastline counties' migration system between the two periods are identified in Figure 2, Panel 2B. Recovery period out-flows from disaster-affected coastline counties to nearly all tied counties outside of the Gulf of Mexico were lower than in the pre-disaster period (medium or light grey). Instead, out-flows from disaster-affected coastline counties concentrated in other disaster-affected coastline counties and nearby counties (dark grey). There are a few exceptions, however, with larger recovery period in-flows to counties composing the southern metropolitan areas of Miami, Nashville, Oklahoma City, and Shreveport, and a few more distant metropolitan areas such as Boston, Chicago, Denver, Philadelphia, San Diego, and Seattle. Exceptions aside, we see spatial concentration and intensification of out-flows among disaster-affected coastline counties, as predicted, with only a few distant and mostly urban counties becoming important recovery period destinations.

Local spatial concentration is illustrated in Figure 3 which shows changes in the number of inflows between disaster-affected coastline counties only. Recovery period in-migration to disaster-affected metropolitan counties grew, specifically to counties forming the metropolitan areas of Corpus Christi, Houston, New Orleans and Gulfport. Rural counties hit hardest by Hurricane Rita also received larger in-flows, presumably by returning residents (Jefferson County, Texas, and Cameron and Vermilion Parishes, Louisiana). In contrast, in-migration diminished to rural Texas and Louisiana coastline counties. Although there are fewer in-ties (Table 1) and only very small increases in in-flows (Table 2) among disaster-affected coastline counties, this map demonstrates that in-flows within the recovering region were directed toward urban areas.

Results from the modified gravity regression model buttress our descriptive findings and provide more rigorous support for our contention that the migration system of the disaster-

[6]Counties highlighted in light grey were in the middle of the range or had no tie to the disaster-affected coastline counties. In either case, there was no substantial change in the estimated migrant flows between the pre-disaster and recovery periods.

affected coastline counties became more geographically concentrated and movement intensified in the recovery period by documenting change over time in the average size of migration flows between pairs of sending and receiving counties with controls for population size in sending counties. Positive λ coefficients for the experimental group in all eight models show a statistically significant increase in in-flows to disaster-affected coastline counties between the pre-disaster and recovery periods, whereas negative coefficients for the comparison group show a statistically significant decrease in in-flows to nearby counties (Table 3). Model 1 compares the growth in in-flows to disaster-affected and nearby counties from all counties and confirms the second hypothesis by showing that in-flows to disaster-affected coastline counties in the recovery period increased by 0.2%, while in-flows to nearby counties decreased by 1.1%. Models 2 through 4 show in-flows to disaster-affected coastline counties for all three regions grew in the recovery period while, in contrast, in-flows to nearby coastal counties consistently declined.

The size of the coefficients decreases as distance from disaster-affected counties increases, thereby supporting the third hypothesis that in-flows will be greater from proximate counties. In-flows from disaster-affected coastline counties and nearby counties grew by 4.0% and 2.6%, respectively between the pre-disaster and recovery periods, and by only 0.2% for distant counties. The third hypothesis poses that in-flows will be larger from urban counties, for which we find support when each of these models is duplicated for urban counties (models 5–8). In the urban counties model, the coefficients are larger than in the all counties model, with the exception of the coefficient in model 8, which is equal to its all-counties counterpart in model 2. Evidence of spatial concentration and intensification of the migration system is demonstrated most clearly in the contrast between in-flows from disaster-affected coastline counties and nearby urban counties, which grew by 5.3% and nearly 4.9%, respectively, and in-flow from distant urban counties, which grew by only 0.2%.

To isolate the disaster recovery effect, we fit a difference-in-difference model. The positive δ coefficients for each difference-in-difference model (Table 4) show that the average change in in-flows to disaster-affected counties was larger than in nearby counties. Moreover, results are consistent with our second and third hypotheses that proximate and urban counties disproportionately attract environmental migrants and, therefore, will be a strong source of recovery migration. The coefficient is larger among disaster-affected coastline counties (model 2) and nearby counties (model 3), as compared to distant counties (model 4), and even larger for urban counties (models 6, 7 and 8).

Our analysis has shown that the migration system of disaster-affected coastline counties became more spatially concentrated in the recovery period by subtracting out-ties with all regions except other disaster-affected coastline counties. Where ties were added to the system, they were mostly in-ties to nearby counties. This spatial concentration was accompanied by growth in the size of in-flows to disaster-affected coastline counties from all regions, especially from nearby and urban counties. Thus, in addition to geographic concentration and intensification, we also see an urbanization of the recovery migration system.

CONCLUSION

Coastal populations are expected to experience more intense and frequent coastal weather events and inundation resulting from climate change. Rooted in a concern for the human impacts of such environmental events, our study investigated changes in migration systems resulting from Hurricanes Katrina and Rita, two of the most severe hurricanes on record. We examine the effects of these events on U.S. migration systems to gain insights into the migratory consequences of disasters caused by extreme coastal storms, and introduce the concept of recovery migration. Recovery migration occurs when displaced residents of the disaster-affected area return and new in-migrants arrive. We propose that the migration system acts as a conduit for population recovery of disaster-affected regions, thereby moving beyond the immediate post-disaster period in which mobility is best characterized as evacuation and short-term displacement.

Before summarizing the contributions of our research we consider its limitations. The IRS flow data only measures the mobility of taxpayers and their dependents, which excludes the very poor and older populations. This bias may exaggerate mobility rates since excluded groups tend to be less mobile than employed and working-age populations. Additionally, these data do not permit us to analyze the composition of the flows, which may be equally important for recovery as the size of flows. Further, although we have augmented the IRS flow data by adding measures of county geography and urbanity, refined geographic measures or measures from additional sources could be added to further test hypotheses related to migrants' destination choice. Finally, more a caveat than a limitation, disaster responses differ across countries with and without private and governmental disaster insurance programs. In the United States, disaster-struck areas have a comparatively greater capacity to recover than those in nations lacking such programs. Hence, our findings regarding recovery migration are more generalizable to areas with private and public disaster recovery programs. Despite these limitations we feel confident that our analysis describes the dominant changes in the migration system of the Hurricane Katrina- and Rita-affected coastline counties between the pre-disaster and recovery periods.

In our investigation we focus on recovery migration and ask whether an environmental event alters the pre-existing migration system of the affected region. In doing so, we make methodological, substantive, and theoretical contributions to research on environment-related migration. Methodologically, instead of focusing on individual and household out-migration from the area affected by an environmental crisis, we use flow data between counties to model the disaster's broad impact on the complete migration system of the most severely disaster-affected coastline counties. Moreover, by leveraging the unique experimental quality and fine temporal and geographic scale offered by the IRS flow data, we are able to test confirmatory hypotheses about the human impacts of environmental events. Our findings inform the emergent literature on environment-migration relationships by lengthening the time-frame and extending the geographic scope of our understanding of this mobility, shifting focus to recovery migration, and moving the study of population-environment interactions into a new and fertile domain.

Substantively, we contribute evidence to research on environmental migration by showing how pre-disaster migration systems channel migration flows in predictable ways after an environmental event. We find that the recovery migration system of disaster-affected coastline counties became more spatially concentrated, including mostly nearby counties, especially urban counties, and only a few urban counties outside of the Gulf of Mexico and the South more generally. At the same time, the size of in-flows to disaster-affected coastline counties from these counties grew. This spatial concentration and intensification of in-flows was predicted by the principles of environmental migration destination choice. However, these principles did not anticipate our finding of increased mobility within and between disaster-affected coastline counties and nearby counties. This heightened mobility suggests migratory churning is part of the recovery as the population adjusts to changed social, economic, political, and environmental structures in a disaster-affected region.

Theoretically, we build on the general principles of environmental migration destination choice (Findlay 2011), principles with obvious roots in general migration theory (Black et al 2011). These principles propose that out-migration from areas experiencing environmental crises tends to be short-distance and reliant on connections in the pre-crisis migration system, especially ties to urban areas. Our contribution is to consider what occurs after the environmental crisis has subsided and recovery is underway, thereby shifting the focus to in-migration of former residents as well as newcomers; what we call recovery migration. By examining recovery migration, we are able to address a pressing question facing places impacted by environmental events: from where will they recover their population? The answer permits resident, planners, politicians, and scholars to understand where households who are likely to migrate to disaster-affected areas are located, information that is useful for a planful recovery. We confirm the general principles of migration destination choice by demonstrating that nearby and urban counties will become the origins of in-migrants to the crisis-affected areas in the recovery period, and extend them by showing that these in-migration streams will be larger in the recovery period if the disaster-affected area is reconstructed.

Regardless of whether the destructive power of Hurricanes Katrina and Rita was compounded by global warming, coastal erosion, or technological failures, their effects on the population of the Gulf of Mexico provide an analogue to the potential impacts of climate change (Adamo 2010). By considering analogues for climate change, we can develop more realistic and comprehensive scenarios of how climate change will affect human populations and settlements. Overall, our findings dampen alarmist concerns that climate change will produce drastic population redistribution (e.g., large numbers of poor migrants from the global South flooding the global North) while also providing a set of testable hypotheses to guide empirical research.

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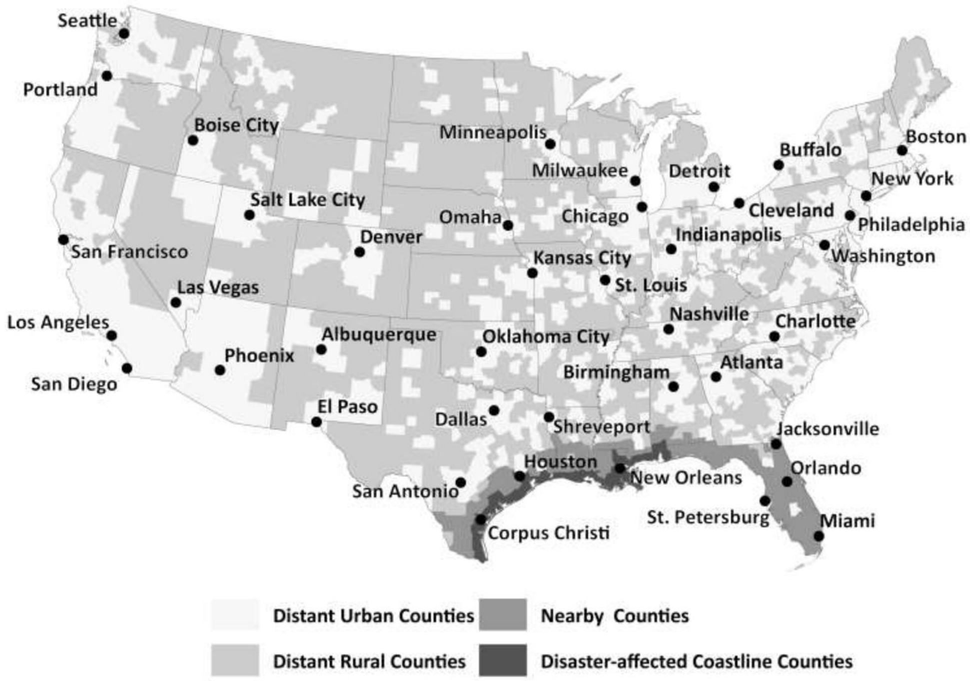

Fig. 1.
Counties by classification with reference to select cities in the United States

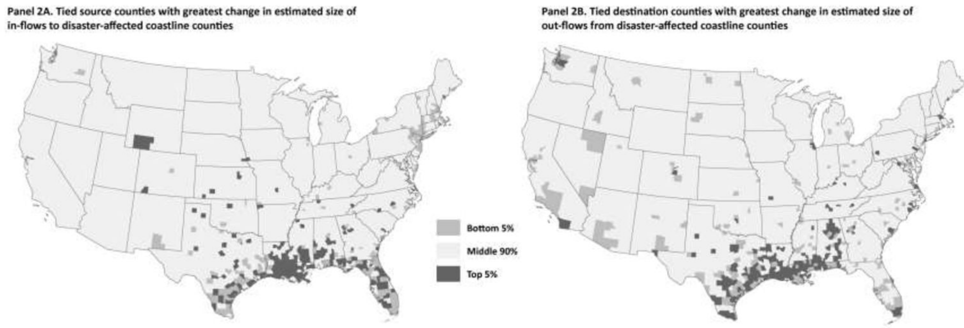

Fig. 2.

Change in size of out-flows and in-flows from disaster-affected coastline counties before and after Hurricanes Katrina and Rita estimated by multiregional migration model

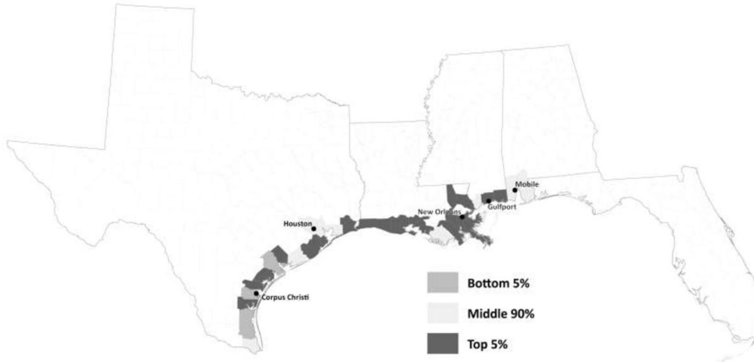

Fig. 3.
Change in in-flows to disaster-affected coastal counties before and after Hurricanes Katrina and Rita

Table 1

Number of unique out-ties and in-ties to disaster-affected coastline counties, IRS county-to-county migration flows data for tax filing years 1999–2004 (pre-disaster) and 2007–2009 (recovery)

Number of unique ties between disaster- affected coastline counties and:	Out-Ties			In-Ties		
	Pre-disaster	Recovery	% Change	Pre-disaster	Recovery	% Change
All counties	612	258	−57.8*	457	442	−3.3*
Disaster-affected coastline counties	46	30	−34.8*	46	30	−34.8*
Nearby counties	97	55	−43.3*	72	96	33.3*
Distant counties	469	173	−63.1*	339	316	−6.8*
All counties (urban)	550	224	−59.3*	395	402	1.8*
Disaster-affected coastline counties (urban)	45	29	−35.6*	45	29	−35.6*
Nearby counties (urban)	77	41	−46.8*	55	78	41.8*
Distant counties (urban)	427	153	−64.2*	295	295	0.0*

Notes: Differences estimated by two-sample difference in proportion test.

* $p < .05$

Table 2

Number of migrant households in out-flows and in-flows to disaster-affected coastline counties, IRS county-to-county migration flows data for tax filing years 1999–2004 (pre-disaster) and 2007–2009 (recovery)

Total flow size between disaster-affected coastline counties and: (Number of migrant households)	**Out-Flows**			**In-Flows**		
	Pre-disaster	**Recovery**	**% Change**	**Pre-disaster**	**Recovery**	**% Change**
All counties	131,411	137,424	4.6	121,310	144,854	19.4
Disaster-affected coastline counties	49,959	54,030	8.2	49,959	54,030	8.2
Nearby counties	28,711	31,338	9.2	23,727	30,864	30.1
Distant counties	52,742	52,056	−1.3	47,624	59,960	25.9
All counties (urban)	126,576	132,684	4.8	116,920	140,062	19.8
Disaster-affected coastline counties (urban)	49,595	53,634	8.1	49,595	53,634	8.1
Nearby counties (urban)	26,018	28,587	9.9	21,079	27,969	32.7
Distant counties (urban)	50,896	50,400	−1.0	46,247	58,459	26.4

Notes: Total out-flows are equivalent to total in-flows for disaster-affected coastline counties because the group of sending counties is the same as the group of receiving counties; the in-flows and out-flows are the migrant exchanges among this group of counties.

Table 3

Gravity model regression analysis of change over time in in-flows to disaster-affected coastline counties and nearby counties, IRS county-to-county migration flows data

Outcome: Ln (Size of Migration Flow between County-Pair)	Sending Region							
	All regions (1)	Disaster- affected coastline counties (2)	Nearby coastal counties (3)	Distant counties (4)	All regions, urban (5)	Disaster- affected coastline counties, urban (6)	Nearby coastal counties, urban (7)	Distant counties, urban (8)
Disaster-affected coastline counties (experimental group)								
Ln Population *i* (β_1)	0.070*** (0.005)	0.208*** (0.045)	0.239*** (0.043)	0.045*** (0.005)	0.125*** (0.002)	0.421*** (0.076)	0.207*** (0.056)	0.082*** (0.010)
Ln Population *j* (β_2)	−0.007*** (0.001)	−0.143*** (0.049)	−0.076*** (0.017)	−0.002** (0.001)	−0.012*** (0.003)	−0.158** (0.054)	−0.096*** (0.026)	−0.003* (0.002)
Change over time (λ)	0.002*** (0.001)	0.040*** (0.015)	0.025*** (0.007)	0.002*** (<0.001)	0.003* (0.001)	0.051*** (0.016)	0.048*** (0.012)	0.002** (0.001)
% Change over time $((e^{\lambda}-1)100)$	0.24	4.04	2.55	0.17	0.28	5.28	4.89	0.24
Nearby counties (comparison group)								
Ln Population *i* (β_1)	0.022*** (0.002)	0.031** (0.014)	0.209*** (0.020)	0.009*** (0.002)	0.084*** (0.005)	0.058** (0.025)	0.243*** (0.027)	0.072*** (0.004)
Ln Population *j* (β_2)	0.009*** (0.002)	0.186*** (0.039)	0.125*** (0.017)	0.002 (0.002)	0.019*** (0.005)	0.212*** (0.044)	0.181*** (0.025)	0.005 (0.005)
Change over time (λ)	−0.011*** (<0.001)	−0.023*** (0.006)	−0.025*** (0.003)	−0.010*** (<0.001)	−0.028*** (0.001)	−0.025*** (0.007)	−0.037*** (0.005)	−0.028*** (0.001)
% Change over time $((e^{\lambda}-1)100)$	−1.06	−2.27	−2.42	−1.00	−2.77	−2.42	−3.64	−2.75

Notes: Models estimated separately for experimental and comparison groups. Geographic distance and all other time-invariant characteristics of sending-receiving county pairs are treated by via unique intercept term, α_{ij}. Robust standard errors in parentheses. Results exclude all cases where sending county *i* = receiving county *j*.

*** p<0.01,

** p<0.05,

* p<0.10

Table 4

Difference-in-difference analysis of treatment effect on in-migration flows to disaster-affected coastline counties and nearby counties, IRS county-to-county migration flows data

Outcome: Ln (Size of Migration Flow between County-Pair)	Sending Region							
	All regions (1)	Disaster-affected coastline counties (2)	Nearby coastal counties (3)	Distant counties (4)	All regions, urban (5)	Disaster-affected coastline counties, urban (6)	Nearby coastal counties, urban (7)	Distant counties, urban (8)
Ln Population *i* (β_1)	0.033*** (0.002)	0.070*** (0.015)	0.215*** (0.018)	0.017*** (0.002)	0.093*** (0.004)	0.139*** (0.027)	0.234*** (0.024)	0.074*** (0.004)
Ln Population *j* (β_2)	−0.001 (0.001)	−0.028 (0.035)	−0.005 (0.013)	−0.001 (0.001)	−0.001 (0.002)	−0.029 (0.039)	0.001 (0.019)	−0.001 (0.002)
Change over time (λ)	−0.010*** (<0.001)	−0.001 (0.006)	−0.011*** (0.003)	−0.010*** (<0.001)	−0.027*** (0.001)	0.002 (0.007)	−0.016*** (0.005)	−0.028*** (0.001)
Treatment effect (δ)	0.015*** (0.001)	0.041*** (0.014)	0.036*** (0.006)	0.014*** (<0.001)	0.032*** (0.001)	0.043*** (0.015)	0.055*** (0.009)	0.031*** (0.001)

Notes: Geographic distance and all other time-invariant characteristics of sending-receiving county pairs are treated by via unique intercept term, a_{ij}. Robust standard errors in parentheses. Results exclude all cases where sending county *i* = receiving county *j*.

*** $p<0.01$