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Recovery Migration to the City of New Orleans after Hurricane Katrina: A Migration Systems Approach

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Abstract

Hurricane Katrina's effect on the population of the City of New Orleans provides a model of how severe weather events, which are likely to increase in frequency and strength as the climate warms, might affect other large coastal cities. Our research focuses on changes in the migration system – defined as the system of ties between Orleans Parish and all other U.S. counties – between the pre-disaster (1999–2004) and recovery (2007–2009) periods. Using Internal Revenue Service county-to-county migration flow data, we find that in the recovery period Orleans Parish increased the number of migration ties with and received larger migration flows from nearby counties in the Gulf of Mexico coastal region, thereby spatially concentrating and intensifying the in-migration dimension of this predominantly urban system, while the out-migration dimension contracted and had smaller flows. We interpret these changes as the migration system relying on its strongest ties to nearby and less damaged counties to generate recovery in-migration.

Keywords

Migration; migration systems; environment; New Orleans; Hurricane Katrina; climate change

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A growing proportion of the world's population lives in coastal cities, increasing the number of people who are vulnerable to hurricanes, typhoons, and other coastal events that are predicted to increase in number and strength as the climate warms (Adamo 2010; McGranahan et al. 2007). New Orleans became emblematic of urban disaster vulnerability after Hurricane Katrina struck the city on August 29, 2005. Nearly 80% of the 452,000 residents in the City of New Orleans – whose borders are the same as Orleans Parish[1] – evacuated on their own in anticipation of Katrina's landfall (McCarthy et al. 2006). The mandatory evacuation order issued on August 28th required that all residents leave the city. Katrina's storm surge breached the levee system, flooding 80% of the below-sea-level city. "Dewatering" took six weeks and was prolonged when Hurricane Rita added rain to the floodwaters on September 25 (Kates et al. 2006). After residents were allowed to return, the

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[1]Louisiana parishes are equivalent to counties. We use the "City of New Orleans" and "Orleans Parish" interchangeably since they identify the same place.

city's population recovered gradually, reaching only about half its pre-Katrina size by mid-year 2006 and about three-quarters by mid-year 2012 (Frey et al. 2007; U.S. Census 2013). Widespread housing damage delayed residents' returns; 71.5% of the 188,251 housing units in Orleans were damaged, with 55.9% having major or severe damage (U.S. Department of Homeland Security 2006). In the immediate aftermath of Katrina, politicians, urban planners, and residents faced the uncertainty of how New Orleans would recover its population.

In this article, we take a migration systems approach to understand how the population of New Orleans recovered. We ask two foundational questions about population recovery: How did the migration system change after Hurricane Katrina? And, were the most important sources for population recovery after the disaster also the most important destinations for migrants before the disaster? Our research is novel in two ways. First, we focus on New Orleans's migration system – a place-based perspective which complements more typical approaches of explaining disaster-driven migration at the household- or individual-level (e.g. Fussell et al. 2010; Gray and Mueller 2012; Groen and Polivka 2010). Second, we focus on how a migration system changes in response to an exogenous shock — a contrast to most migration systems research which focuses on identifying the system and mechanisms perpetuating it (e.g. Fawcett 1989; Kritz et al. 1992; Massey et al. 1998). Both focal shifts allow us to discern how places recover population after a disaster. Our results show that population recovery occurs through a spatial concentration and intensification of the migration system, and lead us to expect that other severely disaster-affected coastal cities can anticipate population recovery through similar changes in their migration systems.

A systems perspective on Hurricane Katrina and the City of New Orleans

In a systems perspective, the entire migration system is the object of study (Lee 1966; Fawcett 1989). The central orientation is that when one place within the system experiences a change--i.e., a weather-related disaster--the effect of that change is 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 elements of a migration system are the ties connecting places, which are the basis for measuring the size and attributes of migrant flows between them (Mabogunje 1970). The process element is the dynamics governing the ties, and includes the migratory decisions of individuals and households (Bakewell 2013a: 15). Labor markets, social networks, and political, economic, social, and environmental changes inform the processes underlying the migration system. Ties, flows, and their attributes and relationships interact to perpetuate and reinforce the system by encouraging migration and other types of exchanges along certain pathways and discouraging it along others (Mabogunje 1970: 12; Kritz et al. 1992). Although much research focuses on stability within migration systems (DeWaard et al. 2012; Kritz et al. 1992; Massey et al. 1998), our work resembles studies of factors altering migration systems (Bakewell 2013a; Bennett and Haining 1985; Bennett et al. 1985; de Haas 2010; Fawcett 1989; Plane 1987; Plane and Rogerson 1986). We are concerned with how the migration system changed after Hurricane Katrina, specifically in terms of the size of in-migration flows to the city and the sources of those flows.

Most migration systems are driven by labor migration in which populations are redistributed from areas with poor economic opportunities to those with greater opportunities (e.g., Greenwood 1997). Underlying such a system is the decision-making of individuals who weigh the costs and benefits of a potential move, and move when perceived gains exceed costs (e.g., Sjaastad 1962; Todaro 1976). In this human capital framework, the benefits and costs of moving are both economic--i.e., real and anticipated earnings and living standards--

and social --i.e., proximity to kith and kin and place-based amenities. The costs of moving are reduced by the information and assistance offered by social networks (Lansing and Mueller 1967; Nelson 1959). Before Hurricane Katrina, these factors drove New Orleans's migration system, which was characterized by out-migration due to slow economic growth (Frey 2012; Winkler et al. 2013). After the disaster displaced all of New Orleans's population and wrought extensive housing damage, we expect that the drivers of the migration system were radically altered.

The mechanisms driving environmental migration are multi-causal (Black et al 2011). Hazard type and individuals' vulnerability interact to produce a range of migratory responses (Black et al. 2013; Piguet et al. 2011). Rapid-onset environmental events typically result in short-term and short-distance migrations, while slow-onset environmental changes produce more progressive migrations including seasonal labor migration and permanent out-migration (Laczko and Aghazarm 2009). Moreover, social statuses, such as gender and socio-economic resources, affect which individuals and households are more vulnerable to hazards' impacts (Cutter et al. 2003; Fothergill and Peek 2004; Hunter and David 2011). The range of migratory responses affected by the hazard's impact also shapes the nature of population recovery, which can include temporary out-migration (i.e., displacement), permanent out-migration, return migration, or remaining in place.

In the case of Hurricane Katrina, the displaced population chose to either return to New Orleans, thereby contributing to population recovery, or to resettle elsewhere. Similarly, potential newcomers to New Orleans had the choice of migrating toward recovery-led opportunities, thus also contributing to population recovery. Human capital considerations inform these migration decisions, which incorporate costs associated with housing or job opportunities and social networks in New Orleans. Consequently, displaced residents with place-based capital may have returned to minimize loss, while relocation may have been preferable for those lacking capital (Andrienko and Guriev 2004; Black et al. 2013). The key point, and central to our first question, is that this environmental event rearranged the mechanisms driving the system and, in turn, changed the migration system of Orleans Parish.

We anticipate the nature of changes in the migration system from the generalization that migration responses to rapid-onset environmental events are typically short-term and short-distance (Black et al. 2013; McLeman and Hunter 2010; Piguet et al. 2011). Findlay (2011: S51–S52) derives principles governing migrants' destination choices as follows: once the decision to migrate has been made in response to an environmental change or event, most migrants prefer to move relatively short distances, to places where they already have ties that allow them to exchange their human, social, and cultural capital, and to stay within their nations' own boundaries (Findley 1994; Gray and Mueller 2012; Henry et al. 2004). This suggests that displaced New Orleans residents would have relocated to nearby urban areas to which they were already connected, and which were likely to have been destinations for out-migrants in the pre-disaster period. Therefore, if they were to return to New Orleans, in-flows would originate in these counties. We expect that such a change would geographically concentrate the migration system and produce larger in-flows in the recovery period than existed in the pre-disaster period.

Return migration of displaced residents is not the only type of move constituting recovery migration. Disasters also present attractive opportunities to new in-migrants (Fussell 2009; McLeman and Smit 2006). Pais and Elliott (2006: 1420–1422) contend that pro-growth coalitions of politicians, planners, land developers, and city boosters organize to rebuild "bigger and better." Federal disaster recovery funds and other types of economic investments attract new in-migration, especially with employment opportunities in construction or other recovery-related enterprises. New in-migrants are likely to originate in places tied to the disaster-affected region prior to the disaster since migration systems are also defined by the flows of goods and services as well as people. With our data, newcomers and returning residents are indistinguishable. Thus we describe all in-migration flows in the recovery period as recovery migration given their contribution to the repopulation of the disaster-affected area.

Derived from a migration systems logic which emphasizes the enduring connections between places, our second question asks whether the places connected to New Orleans through out-migration before Hurricane Katrina became sources of in-flows in the recovery period. Pre-Katrina out-ties are evident from U.S. Census (2000) data showing that between 1995 and 2000, the top destinations for out-migrants from Orleans Parish were other parishes within the metropolitan statistical area (Jefferson, St. Tammany and St. Bernard) and other urban parishes in Louisiana (E. Baton Rouge, W. Feliciana, Lafayette, Iberville, Tangipahoa) (Table 1). Urban counties in Texas (Harris, Dallas and Tarrant, home to the cities of Houston, Dallas, and Fort Worth, respectively) were also common pre-disaster destinations, as were counties in the Atlanta metropolitan area (DeKalb, Fulton, and Cobb). Only small percentages of New Orleans's out-migrants left for more distant destinations, such as Los Angeles County, California, Cook County, Illinois (Chicago), and New York County, New York.

There is no comparable data on the sources of in-migration flows to New Orleans between 2005 and 2010. The 2010 decennial census did not collect migration data[2] and other sources only provide information on where New Orleanians evacuated in the first year after Katrina. Data from disaster assistance applications show evacuees relocated to all fifty states, with most concentrating in cities (Johnson et al. 2008; Koerber 2006). Evacuees tended to relocate near to New Orleans: 46% were within 100 miles, while only 5% moved more than 400 miles away (Weber and Peek 2012: 3). Given the concentration of evacuees in places near to New Orleans, we anticipate that the in-flows that made New Orleans one of the fastest growing U.S. counties from 2007 through the end of the decade originated in these nearby places (United States Census Bureau 2011).

Data and Methods

We describe the existence and magnitude of migration flows using the Internal Revenue Service (IRS) Statistics of Income Division (SOI) County-to-County Migration Data files. This database identifies movers by matching IRS returns in adjacent years and comparing filing addresses. The data report only household income and broad age groups and undercount older and very poor populations. Despite these limitations, researchers agree the IRS migration data are an excellent source of information for tracking changes in internal migration in the United States (Engels and Healy 1981; Isserman et al. 1982). The Current Population Survey indicates that 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). While some researchers have developed procedures to adjust for the undercount of the poor and older population in the IRS data (i.e., Plane 1999), there is no clean way of making such adjustments and this is just one limitation common to migration estimates (Raymer et al. 2013). Ultimately, the IRS data are the best data available for estimating inter-county migration flows, and are ideal for our study because they capture annual migration flows that pre-date and follow the 2005 hurricane season in the style of a natural experiment. Evacuation behavior is not our interest, and is better measured by the

[2]The annual American Community Survey replaced the decennial census long-form data (known as Summary File 3) that provided economic, social, and migration data on the US population. The migration measures differ between the two sources.

American Community Survey (e.g., Koerber 2006), the Current Population Survey (e.g., Groen and Polivka 2010) or specialized surveys (e.g., Sastry 2009). These surveys are not adequate for our analysis given their limited geographic representation or time frame.

We focus our analysis on the years before and after the hurricanes for conceptual and practical reasons. Conceptually, we are interested in the pre-disaster migration system, measured with the 1999–2004 data, and the recovery migration system, measured with the 2007–2009 data. Migration during the omitted years (2005–2006) was likely temporary and therefore not captured by the IRS data which measures permanent changes of residence. Furthermore, the quality of the IRS data during those years was poor due to a decline in filing rates and therefore not comparable to the pre-disaster or recovery periods (Johnson et al. 2008). Our approach of averaging across individual tax filing years within the pre-disaster (1999–2004) and recovery (2007–2009) periods produces annualized estimates, thereby negating possible problems associated with imbalanced samples and other year-to-year fluctuations.

We identify three geographic regions by combining definitions used in a U.S. Census report on coastline population trends (Wilson and Fischetti 2010) with Federal Emergency Management Agency (FEMA) disaster declarations (Figure 1). We focus on counties' relationship to water since the storm surge accompanying a hurricane brings powerful waves into coastline areas and pushes water through rivers and other water ways, destroying and damaging buildings and infrastructure. We refer to these three regions as *disaster-affected coastline counties*, *nearby counties*, and *distant counties*.

1. disaster-affected coastline counties: In the U.S. Census report, counties adjacent to coastal waters or territorial seas are designated coastline counties and are a subset of coastal counties. Coastal counties have at least 15% of their 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 FEMA. We label these disaster-affected coastline counties, among which is Orleans Parish;

2. nearby coastal counties: 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.; and

3. distant counties in the continental U.S.: 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.

Our study concerns the connections between places rather than places themselves. We start by examining the existence of ties between Orleans Parish and other counties and, if a tie exists, the magnitude of the migration flow, a characteristic of the tie. Further, we distinguish ties and flows into or out of Orleans Parish because the meaning of the flow depends on its directionality (Rogers 1990). Flows from Orleans Parish to all types of U.S. counties describe the out-migration dimension of the migration system, and identify where residents had networks that might have helped them to evacuate and relocate. The in-migration dimension of the system is described by flows into Orleans Parish from all other counties. To ensure confidentiality of the data the IRS only reports county-to-county flows of 10 or more households. Consequently, we can observe the most stable ties in the migration system but we do not capture the entire system *per se*.

After describing the migration system, we turn to the analysis of the risk of county-to-county migration and, thus, controls for population size. Characterizing flows requires modeling migration systems in such a way as to simultaneously consider the population of persons "at risk" of migrating in each and every sending county. We generate two matrices of county-to-county migration probabilities between each and every county in the lower 48 states in the pre-disaster period, **Q(0)**, and recovery period, **Q(1)**. These matrices take the following generic form:

$$\mathbf{Q}=\begin{bmatrix} \frac{M_{i,i}}{P_i} & \frac{M_{i,j}}{P_i} & \cdots & \frac{M_{i,k}}{P_i} & \frac{M_{i,NOLA}}{P_i} \\ \frac{M_{j,i}}{P_j} & \frac{M_{j,j}}{P_j} & \cdots & \frac{M_{j,k}}{P_j} & \frac{M_{j,NOLA}}{P_j} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \frac{M_{k,i}}{P_k} & \frac{M_{k,j}}{P_k} & \cdots & \frac{M_{k,k}}{P_k} & \frac{M_{k,NOLA}}{P_k} \\ \frac{M_{NOLA,i}}{P_{NOLA}} & \frac{M_{NOLA,j}}{P_{NOLA}} & \cdots & \frac{M_{NOLA,k}}{P_{NOLA}} & \frac{M_{NOLA,NOLA}}{P_{NOLA}} \end{bmatrix}$$

As one example, for sending county *i*, the first row of the matrix above, $M_{i,NOLA}$ is the number of households migrating from county *i* to Orleans Parish ("NOLA" for short), while P_i represents (by assumption) those at risk of emigrating from county *i* (to any receiving county).

$$P_i=M_{ii}+\sum_{j=1}^{k}M_{i,j}+M_{i,NOLA}, \quad i \neq j$$

where $M_{i,i}$ refers to the number of non-migrant households in county *i*, and $M_{i,j}$ refers to the number of migrant households from county *i* to county *j*. Although it could have been implied in the term $\sum_{j=1}^{k}M_{i,j}$, we include a separate term $M_{i,NOLA}$ denoting the number of households moving from county *i* to NOLA in an effort to highlight the link to NOLA.

The matrix above takes into account both the directionality of flows (i.e., there is no "net" migration) and the exposure to the risk of migration in each sending county (i.e., there are no probabilities of in-migration, only those of out-migration which accurately reflect the risks of movement). The last column in the matrix above can therefore be interpreted as a distribution of the risk of *migrating to* Orleans Parish from each sending county. Hereafter, we refer to this distribution as "in-flows" to Orleans Parish. The final row of the matrix above can similarly be interpreted as a distribution of the risk of *migrating from* Orleans Parish. Hereafter, we refer to this distribution as "outflows" from Orleans Parish. In examining the distributions of out-flows and in-flows, we ignore the final element in the matrix above, $\frac{M_{NOLA,NOLA}}{P_{NOLA}}$, i.e., non-migrant households in Orleans Parish.

Results

The disaster following Hurricane Katrina radically altered New Orleans's migration system. The contraction of the out-migration dimension is evident from the decrease in the number of out-ties (or destination counties) from 194 to 136 between the pre-disaster and recovery periods, with only 129 ties common to both periods (Table 2). The in-migration dimension of the system expanded, increasing the number of in-ties (or sending counties) from 186 to 216, although it contracted as well since only 167 ties were common to both periods. The addition and subtraction of unique ties — ties that exist in only one period — indicate where the greatest change in the system occurred. New Orleans's unique out-ties decreased dramatically from 65 to 7 between the two periods, with the loss of all ties to other disaster-affected coastline counties and the majority of ties to nearby and distant counties in the recovery period. In contrast, although New Orleans had only 19 unique in-ties in the pre-disaster period, these more than doubled to 49 in the recovery period, with the largest increase in in-ties to nearby counties. These changes suggest that the Orleans Parish migration system became more spatially concentrated by decreasing all out-ties and increasing in-ties, especially those from nearby counties.

Not only were nearby counties more likely to have in-ties to New Orleans in the recovery period, but the magnitude of the flows into New Orleans were larger from these counties in the recovery period as well. Overall, the percent change in in-flows was 72% between the disaster and recovery periods (Table 2). The percentage increase in flow size was greatest (139%) for nearby counties, which increased their average size from 793 to 1,897 households. However, flows from these counties were still smaller than those from both disaster-affected coastline counties, which increased from 4,271 to 6,599 households (54%), and distant counties, which increased from 2,144 to 3,883 households (81%). Simultaneously, the size of out-flows from Orleans Parish decreased by 28% overall, although out-flows to nearby counties diminished the least. In short, in-flows intensified from all counties, most especially from nearby counties, whereas out-flows diminished, less so to nearby counties. In reference to our first question about change in New Orleans's migration system, we show that the system changed through spatial concentration of both in-ties and out-ties, and intensification of in-flows in the recovery period.

Our second question concerns whether the most important destinations in the pre-disaster migration system became the most important origin counties for in-flows in the recovery period. We answer this by geographically locating counties with both pre-disaster out-ties and recovery in-ties as well as with unique recovery in-ties (Figure 2). The 172 counties with out-ties in the pre-disaster period and in-ties in the recovery period (black) are concentrated in the immediate area around New Orleans, and become sparser through the Midwest and South, with only a few in the West and Northeast. The 22 counties with in-ties to New Orleans in the pre-disaster period but not in the recovery period (light grey) tend to be more distant. The 44 counties that only had in-ties to New Orleans in the recovery period (medium grey) are visible in several states, but mostly states near the Gulf of Mexico. The greatest increase in the magnitude of in-flows was from counties with both pre-disaster out-ties and recovery period in-ties. This is evident from Figure 3, which identifies counties with flows to Orleans Parish that were greater than the average annual flow of 22 households (black); counties with less than average but still positive in-flows (dark grey); and counties with a negative flow of households from Orleans, labeled out-migration(light grey). Nearly all of the positive in-flows to Orleans are from counties that had both pre-disaster out-ties and recovery period in-ties, evident in Figure 2. These were the critical counties in the City of New Orleans's migration system that intensified in-flows in the recovery period. Thus, we answer our second question affirmatively: out-migrant destination counties in the pre-disaster period tended to also be in-migrant origin counties in the recovery period.

So far our research has shown the types and locations of counties to which New Orleans was tied in the pre-disaster and recovery periods, and the magnitude of flows to and from Orleans carried by those ties. From this we have seen that Orleans Parish's migration system became more spatially concentrated and in-flows intensified in the recovery period, with counties connected by pre-disaster out-ties and recovery period in-ties playing a critical role in the repopulation of the city. We also found (not shown here) that in both the pre-disaster and the recovery migration systems about 95% of New Orleans's in- and out-ties corresponded to other urban counties, making it an overwhelmingly urban migration system. In the following section, we illustrate these conclusions about changes in the migration system by identifying some of the specific places that make up the system.

In Table 3 we compare the magnitude of flows for the top 20 counties with the largest out-flows from Orleans Parish in the pre-disaster period and the top 20 counties with the largest in-flows to Orleans Parish in the recovery period – 16 counties fell in both categories. Most nearby counties had both large pre-disaster out-flows and recovery period in-flows (Panel A). Within the New Orleans MSA, Jefferson, St. Tammany, St. Charles, and St. John the Baptist Parishes all had similar or larger recovery period in-flows relative to the pre-disaster out-flows. Notably, although most of these parishes are disaster-affected coastline counties, they did not suffer highly damaging storm surges. As such, they were attractive temporary residences for displaced households who were able to return in the recovery period and sources of in-migrants to Orleans to participate in the recovery economy.

Nearby urban counties – Harris, East Baton Rouge, Dallas, Tangipahoa, Lafayette, and Tarrant – shared this role. Some distant counties – Los Angeles, Fulton, Cook, and DeKalb – sent slightly more households in the recovery period than they received in the pre-disaster period, while others that were important recipients of in-flows in the pre-disaster period – New York, San Diego, and Cobb (Panel B) – did not. A few regional counties that were not important destinations for out-flows from New Orleans in the pre-disaster period – Travis, Shelby, Bexar, and Ascension (Panel C) – sent sizable flows in the recovery period. Finally, disaster-affected coastline counties that experienced tremendous storm surges – St. Bernard, Plaquemines, and Harrison – sent smaller in-flows to Orleans in the recovery period than they received in the pre-disaster period. These results confirm our earlier analysis and extend it by showing which of the nearby counties in the City of New Orleans's migration system became more important components of the migration system in the recovery period, and which of the distant counties and the disaster-affected coastline counties became less important for population recovery.

However, the flow sizes compared in Table 3 are influenced by the origin counties' population sizes. To adjust for this we compare the top 20 counties with the largest out-flow probabilities in the pre-disaster period and those with the largest in-flow probabilities in the recovery period. This comparison makes the importance of nearby coastal counties even clearer (Table 4). The nine top receiving counties in the pre-disaster period that were also top sending counties in the recovery period were all nearby suburban and urban parishes in Louisiana, which typically sent households at higher rates in the recovery period than they received in the pre-disaster period (Panel A). Most of the eleven top receiving counties in the pre-disaster period that were not top sending counties in the recovery period were distant counties, with the exception of two – Harris County, Texas and Harrison County, Mississippi (Panel B). These counties contain large cities, Houston and Gulfport, respectively, to which New Orleans had long been sending migrants. Finally, 19 of the top 20 sending counties in the recovery period were nearby counties, a few of which — Lafourche, Terrebonne, Hancock — were disaster-affected coastline counties (only Adams County is not "nearby" in our classification but is spatially close) (Panel C). This confirms that the source counties for recovery migration were all more likely to be nearby to Orleans; they include suburban parishes, other urban parishes in Louisiana, and even disaster-affected coastline counties, all of which were likely to have sheltered long-term displaced residents and to have sent new in-migrants to New Orleans as part of the recovery in-migration.

Discussion

Concern over an increase in the number of weather-related coastal disasters associated with global warming has resulted in a growing literature on disaster-driven migration. Most research on this topic focuses on temporary or permanent out-migration of individuals and households from disaster-affected areas and, to a lesser extent, on the destinations of those out-migrants. In contrast, we are interested in the disaster-affected place and how the migration system adapts in order to recover the population of that place. This recovery migration is a combination of both returning residents and new in-migrants.

In the case of New Orleans, the destinations of displaced residents were identifiable with data even up to a year after Hurricane Katrina (Johnson et al. 2008; Koerber 2006), but what was not well understood was the role these destinations played in the pre-disaster migration system and their contribution to recovery migration as long as four years after the disaster. This place-based approach contributes to two different literatures. First, with respect to the disaster and migration literature, it shifts the unit of analysis from the individual to the place and asks how places recover their population. Second, it shifts the focus of migration systems theory away from the structure and durability of migration systems to the ways in which the dynamics of the system are changed by an exogenous shock (Bakewell 2013a), for example environmental events or changes.

We found that after the disaster, New Orleans' migration system increased in-ties with and received larger flows from nearby counties in the Gulf of Mexico coastal region, thereby spatially concentrating and intensifying the in-migration dimension of the system. Most of these were counties that had received out-migrants from Orleans in the pre-disaster migration system. A few of the more distant counties remained in the migration system, and although in-flows from the most important of distant larger cities remained sizable, their probabilities of in-migration hardly compared to the probabilities of in-migration from nearby counties. While disaster-affected coastline counties contributed large in-flows in the recovery period, the magnitude of flows depended on the amount of damage they experienced. Our research shows that Orleans's migration system relied on its strongest ties to nearby and less damaged counties to recover its population.

Our analysis has limitations. First, the IRS data only measure the mobility of taxpayers and their dependents, which undercounts the very poor and older populations. However, it is unlikely to strongly affect the identification of ties in the migration system or the magnitude of flows since these excluded groups tend to be less mobile. Second, because many taxpayers from disaster-affected counties failed to file in the two years after the storm, we elected not to analyze data from tax filing years 2005 and 2006. However, because we use only years when tax filing rates had returned to normal levels, our groups are comparable. Finally, while we are able to describe changes in the system, we are not able to discern returning households from new in-migrant households to New Orleans in the recovery period. Anecdotal evidence indicates that the post-disaster population of New Orleans consists mainly of pre-Katrina residents and a small proportion of new residents, but no available data demonstrates their relative proportions. Therefore, we label this post-disaster in-migration "recovery migration" to emphasize its contribution to the recovery of the City's size, though not necessarily the return of its pre-Katrina residents.

Our findings contribute to a growing literature on migration responses to disasters, at the population-level (as opposed to individual-level) and from a systems perspective. Like others, we find heightened mobility after hurricanes (e.g., Curtis, et al 2012; Myers et al. 2008; Schultz and Elliott 2012) and disasters more generally (e.g., McLeman and Smit 2006; McLeman and Hunter 2010). But this mobility is not random: it occurs within the existing migration system, and displaced households follow well-traveled pathways to family and friends in familiar places (McHugh 1987:187). Counties connected to disaster-affected areas, especially nearby counties, produce flows of return residents and new in-migrants as the affected county recovers. The implications of our case extend beyond disaster response. Our method and data allow us to link coupled human and natural systems at a common spatial scale (Liu et al. 2007), offering a better understanding of population and environment interactions and for projections of migration scenarios (Curtis and Schneider 2011).

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Figure 1.

Map of the three types of regions: disaster-affected coastline counties, nearby coastal counties, and distant counties with references to major cities.

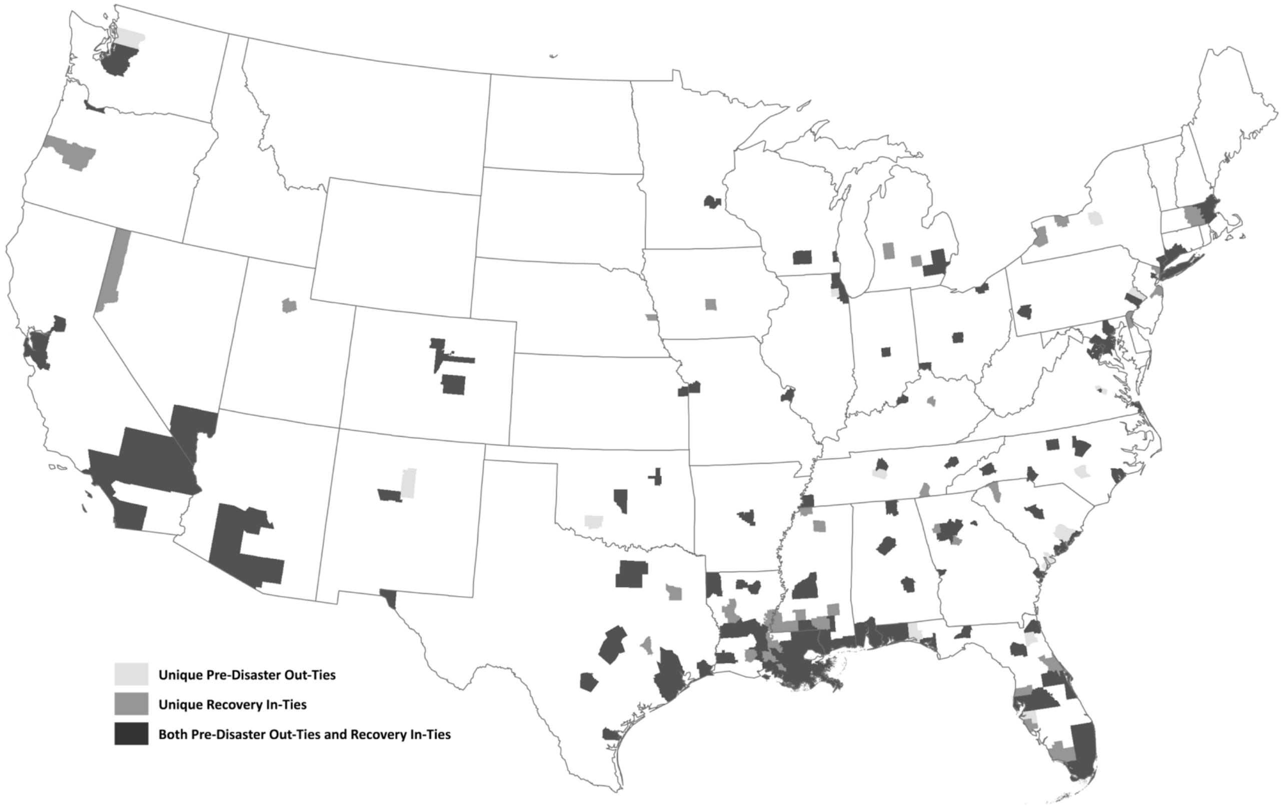

Figure 2.
Map showing change in existing ties between pre-disaster and recovery periods.

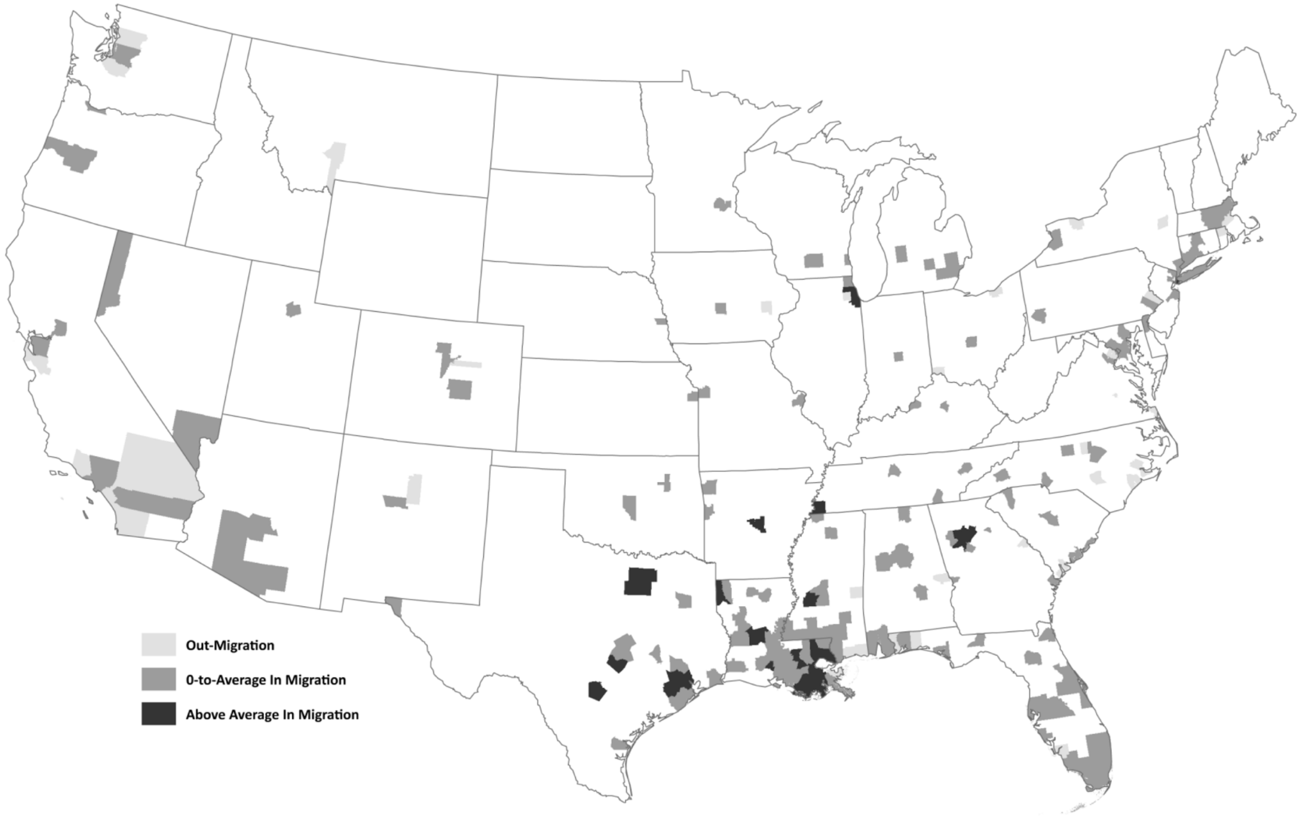

Figure 3.
Map showing the balance of the size of flows to the City of New Orleans in the recovery period.

Table 1

Top receiving counties for New Orleans out-migrants between 1995 and 2000.

County	State	% of out-migrants
Jefferson	Louisiana	22.0%
St. Tammany	Louisiana	6.6%
East Baton Rouge	Louisiana	3.2%
Harris	Texas	2.4%
St. Bernard	Louisiana	2.1%
Dallas	Texas	1.3%
Los Angeles	California	1.3%
West Feliciana	Louisiana	1.2%
Harrison	Mississippi	1.0%
Lafayette	Louisiana	1.0%
DeKalb	Georgia	1.0%
Cook	Illinois	1.0%
Iberville	Louisiana	0.9%
Tarrant	Texas	0.9%
Fulton	Georgia	0.9%
Pearl River	Mississippi	0.9%
New York	New York	0.8%
Tangipahoa	Louisiana	0.8%
San Diego	California	0.8%
Cobb	Georgia	0.8%
All other US counties		49.3%

Source: Census 2000.

Table 2

Total number and number of unique out-times and in-ties and flow sizes for Orleans Parish (annual averages in each period)

	Out-ties or flows			In-ties or flows		
Number of Ties	**Pre-disaster**	**Recovery**	**% Change**	**Pre-disaster**	**Recovery**	**% Change**
All counties	194	136	−29.9	186	216	16.1
Disaster-affected coastline counties	21	19	−9.5	20	21	5.0
Nearby counties	37	26	−29.7	29	46	58.6
Distant counties	136	91	−33.1	137	149	8.8
Number of Unique Ties	Pre-disaster	Recovery	% Change	Pre-disaster	Recovery	% Change
All counties	65	7	−89.2	19	49	157.9
Disaster-affected coastline counties	2	0	−100.0	0	1	-
Nearby counties	14	3	−78.6	1	18	1700.0
Distant counties	49	4	−91.8	18	30	66.7
Flow Size (Number of Migrant Households)	Pre-disaster	Recovery	% Change	Pre-disaster	Recovery	% Change
All counties	9,675	7,010	−27.6	7,208	12,379	71.7
Disaster-affected coastline counties	6,202	4,478	−27.8	4,271	6,599	54.5
Nearby counties	939	854	−9.1	793	1,897	139.2
Distant counties	2,534	1,678	−33.8	2,144	3,883	81.1

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Table 3

Top receiving counties in pre-disaster period and sending counties recovery period: Magnitude of ties

County	State	County type	Out-flow (pre-)	In-flow (recovery)	Δ
Panel A. Top receiving and sending counties					
Jefferson (New Orleans MSA)	Louisiana	Coastline	4,076	4,154	78
St. Tammany (New Orleans MSA)	Louisiana	Coastline	751	925	174
St. Bernard (New Orleans MSA)	Louisiana	Coastline	340	100	−240
Harris (Houston MSA)	Texas	Coastline	322	925	603
East Baton Rouge (Baton Rouge MSA)	Louisiana	Nearby	282	877	595
Dallas (Dallas-Fort Worth-Arl. MSA)	Texas	Distant	138	279	141
Los Angeles (Los Angeles MSA)	California	Distant	124	134	10
Plaquemines (New Orleans MSA)	Louisiana	Coastline	122	88	−34
St. Charles (New Orleans MSA)	Louisiana	Coastline	102	134	32
Fulton (Atlanta MSA)	Georgia	Distant	99	159	60
St. John The Baptist (New Orleans MSA)	Louisiana	Coastline	99	148	49
Cook (Chicago MSA)	Illinois	Distant	96	126	30
DeKalb (Atlanta MSA)	Georgia	Distant	84	115	31
Tangipahoa	Louisiana	Coastline	68	103	35
Lafayette	Louisiana	Nearby	63	142	79
Tarrant (Dallas-Fort Worth-Arl. MSA)	Texas	Distant	58	133	75
Panel B. Top receiving counties					
New York (New York MSA)	New York	Distant	91	82	−9
San Diego (San Diego MSA)	California	Distant	81	69	−12
Harrison (Gulfport Biloxi MSA)	Mississippi	Coastline	68	48	−20
Cobb (Atlanta MSA)	Georgia	Distant	62	76	23
Panel C. Top sending counties					
Travis (Austin MSA)	Texas	Distant	57	102	45
Shelby (Memphis MSA)	Tennessee	Distant	44	99	55
Bexar (San Antonio MSA)	Texas	Distant	38	97	59

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County	State	County type	Out-flow (pre-)	In-flow (recovery)	Δ
Ascension (Baton Rouge MSA)	Louisiana	Nearby	29	83	54

Note: Coastline refers to “disaster-affected coastline counties”; nearby refers to “nearby counties”; and distant refers to “Distant counties.”

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Table 4

Top receiving counties in pre-disaster period and sending counties recovery period: Migration probabilities

County	State	County type	Out- flow (pre-)	In-flow (recovery)	Δ
Panel A. Top receiving and sending counties					
Jefferson (New Orleans MSA)	Louisiana	Coastline	2.63	2.61	−0.01
St. Tammany (New Orleans MSA)	Louisiana	Coastline	0.48	0.65	0.17
St. Bernard (New Orleans MSA)	Louisiana	Coastline	0.22	1.21	0.99
East Baton Rouge (Baton Rouge MSA)	Louisiana	Nearby	0.18	0.57	0.38
Plaquemines (New Orleans MSA)	Louisiana	Coastline	0.08	1.13	1.05
St. Charles (New Orleans MSA)	Louisiana	Coastline	0.07	0.70	0.63
St. John The Baptist (New Orleans MSA)	Louisiana	Coastline	0.06	0.93	0.86
Tangipahoa	Louisiana	Coastline	0.04	0.27	0.23
Lafayette	Louisiana	Nearby	0.04	0.18	0.14
Panel B. Top receiving counties					
Harris (Houston MSA)	Texas	Coastline	0.21	0.07	−0.14
Dallas (Dallas-Fort Worth-Arlington MSA)	Texas	Distant	0.09	0.03	−0.05
Los Angeles (Los Angeles MSA)	California	Distant	0.08	0.00	−0.08
Fulton (Atlanta MSA)	Georgia	Distant	0.06	0.05	−0.02
Cook (Chicago MSA)	Illinois	Distant	0.06	0.01	−0.06
New York (New York MSA)	New York	Distant	0.06	0.01	−0.05
DeKalb (Atlanta MSA)	Georgia	Distant	0.05	0.04	−0.01
San Diego (San Diego MSA)	California	Distant	0.05	0.01	−0.05
Harrison (Gulfport Biloxi MSA)	Mississippi	Coastline	0.04	0.08	0.03
Cobb (Atlanta MSA)	Georgia	Distant	0.04	0.03	−0.01
Tarrant (Dallas Fort Worth MSA)	Texas	Distant	0.04	0.02	−0.02
Panel C. Top sending counties					
St. Helena (Baton Rouge MSA)	Louisiana	Nearby	0.01	0.37	0.37
St. James	Louisiana	Nearby	0.01	0.31	0.30
Ascension (Baton Rouge MSA)	Louisiana	Nearby	0.02	0.23	0.21

County	State	County type	Out- flow (pre-)	In-flow (recovery)	Δ
Lafourche (Houma-Thibodaux MSA)	Louisiana	Coastline	0.02	0.22	0.19
Washington	Louisiana	Nearby	0.02	0.19	0.17
Iberville (Baton Rouge MSA)	Louisiana	Nearby	0.00	0.19	0.19
Pike	Mississippi	Nearby	0.01	0.19	0.17
Terrebonne (Houma-Thibodaux MSA)	Louisiana	Coastline	0.02	0.19	0.16
Hancock (Gulfport-Biloxi MSA)	Mississippi	Coastline	0.04	0.18	0.15
Adams	Mississippi	Nearby	0.00	0.18	0.18
Pearl River	Mississippi	Nearby	0.03	0.16	0.14

Note: Probabilities are multiplied by 100 to facilitate interpretation in percentage terms.

Note: Coastline refers to “disaster-affected coastline counties”; nearby refers to “nearby counties”; and distant refers to “Distant counties.”