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Stage Migration within and through Migration Systems: Implications for Population Recovery in New Orleans after Hurricane Katrina

Jack DeWaard†
Department of Sociology, Minnesota Population Center, University of Minnesota

Katherine J. Curtis
Department of Sociology, University of Wisconsin-Madison

Elizabeth Fussell
Population Studies, Brown University

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†Correspondence should be directed to:
Jack DeWaard
Department of Sociology, University of Minnesota
909 Social Sciences, 267 19th Ave South, Minneapolis, MN, 55455, USA
e-mail: jdewaard@umn.edu

Abstract

In this paper, we apply a migration systems perspective to understand how places affected by natural disasters recover their populations through in-migration when in-migration is delayed on account of post-disaster impediments (e.g., housing and property damage) in disaster-affected areas. Specifically, we consider and test the idea that post-disaster impediments spawn innovation in migration systems in the form of indirect, or "stage," migration flows toward and, over time, to disaster-affected areas through intermediary destinations. Taking as our case Orleans Parish over a five-year period after Hurricane Katrina, we show that stage migration played a potentially significant role in the ability of Orleans Parish to recover its population after Hurricane Katrina. We close by discussing the implications, limitations, and extensions of our work.

Keywords Migration • Migration systems • Natural Disasters • Population • New Orleans • Hurricane Katrina

Introduction

Two recent studies by Curtis et al. (2014) and Fussell et al. (2014) applied a migration systems perspective to understand how places affected by natural disasters recover their populations through in-migration. While places affected by natural disasters do not always recover their populations (McLeman 2011), among those that do, whether fully or in part, a key finding from these studies is that the pre-disaster migration ties of disaster-affected areas to other places in the system are important sources of post-disaster in-migration to and, thus, population recovery in disaster-affected areas. In the case of New Orleans after Hurricane Katrina, a central focus in these studies and the focus of this paper, Orleans Parish recovered about three-quarters of its pre-Katrina population by 2010 due to positive net-migration (Frey et al. 2007; McCarthy et al. 2006; U.S. Census Bureau 2011).[1] Importantly, many of the destinations for migrants from Orleans Parish before Hurricane Katrina (e.g., Harris County, Texas, where Houston is located) were sending areas for migrants to Orleans Parish after Hurricane Katrina (Fussell et al. 2014). In this way, a migration systems perspective is useful for understanding how places affected by natural disasters recover their populations given its emphasis on the pre-disaster migration ties of disaster-affected areas.

With respect to our work in this paper, an interesting observation that is made in the studies above is that post-disaster "impediments" (e.g., "[w]idespread housing damage" (Fussell et al. 2014:306)) can delay in-migration to and, thus, population recovery in disaster-affected areas (Green et al. 2007:311; see also Elliot 2014; Kates et al. 2006; Pais and Elliott 2008). This observation is intriguing because it raises an important question about how migration systems, and ultimately the actors therein (Bakewell 2013), respond when particular avenues of migration within the system are impeded. In a migration system, places are connected to one another by migration flows (Mabogunje 1970; Plane and Rogerson 1986; Zlotnik 1992). In an extreme case, if the flow of migrants to a particular place j is impeded, then there is zero migration to j.[2] However, taking seriously the idea that "the entire migration system is the object of study" (Fussell et al. 2014:306), there is potentially more to this story.

Because places in a migration system are connected to one another by migration, they are also, at least in theory (Conway 1980), indirectly connected through one another via intermediary destinations. This feature (i.e., transitivity) raises the prospect that, if the flow of migrants to a particular place j is impeded, one potential response of the migration system might be to redirect flows toward and, at some later point in time, to j through one or more intermediary destinations. In this way, the very impediment that delays in-migration to j may, at the same time, catalyze migration toward and, over time, to j, with these indirect flows representing a response or innovation in the migration system. Clearly, this requires viewing the migration system not merely as a collection of flows between pairs of places, but, rather, as a more integrated network, what Mabogunje (1970:3) originally described as a "complex of interacting elements." It likewise requires viewing migration within and through the system over time.

Additionally, as Bakewell (2013:1) rightfully pointed out in his recent "relaunch of migration systems" theory, characterizations of migration systems of the sort described above require

[1] The City of "New Orleans" and "Orleans Parish" refer to the same place. Hereafter, for consistency, we use the latter. Parishes in Louisiana are the equivalent of U.S. counties.

[2] In a less extreme case, the size of the migration flow to j might be less than it would otherwise be in the absence of the impediment, but not zero.

consideration of the motivations, decisions, and behaviors of actors (e.g., individuals, households, etc.) who ultimately drive change within the system. Toward providing such an account, we begin with Findlay's (2011) observation that actors who are displaced by natural disasters, whether voluntarily or by mandate, prefer not to have emigrated in the first place. In a post-disaster context in which population displacement has occurred, evidence suggests that pre-disaster preferences not to have emigrated manifest themselves in the form of strong attachments to "home" and desires to eventually return there (Chamlee-Wright and Storr 2009:628). However, because home has been adversely affected by a set of environmental hazards[3], it likely carries the scars of extensive damage to housing and property, infrastructure, and services, not the mention the sometimes slow pace of efforts to repair and rebuild disaster-affected areas in contexts that are politically and emotionally charged and contested (Kates et al. 2006; Pais and Elliott 2008). As a result, returning home may not [yet] be an option. In a cost-benefit framework (Greenwood 1995; McCarthy et al. 2006; Sjaastad 1962), the costs of migrating home are simply too great to incur; thus, migration to the disaster-affected area does not occur, at least at this particular moment in time.

However, as Bakewell (2013; see also Emirbayer and Mische 1998) also pointed out, actors are not passive. Actors possess agency, are resourceful, and, ultimately, are innovators. Accordingly, in response to impediments to migrating home, rather than remain in their current place of residence, actors might, instead, seek to reposition themselves (e.g., closer to home and property, employment opportunities and work, family and friends, etc.) in preparation for migrating home to the disaster-affected area at some point in the future. This repositioning is called "step-wise" migration, where steps correspond to intermediary destinations, and the final step corresponds to the disaster-affected area (Conway 1980:7). In theory, at each step, the benefits of migrating should outweigh the costs of not migrating. Over time, and through a process of step-wise migration, actors eventually migrate home as conditions in the disaster-affected area improve. Importantly, this idea can be extended to accommodate actors living outside of the disaster-affected area who did not experience the disaster. One example might be persons looking to capitalize on demands for labor (e.g., in construction) in the disaster-affected area who engage in step-wise migration toward (e.g., closer to, around, etc.) the disaster-affected area in search of work, with a subsequent migration to the disaster-affected area taking place once conditions permit (Fussell 2009; Green et al. 2007).

At the level of place, which is the focus of this paper, the migration decisions and behaviors of actors result in "stage by stage pattern[s] of aggregate-level migration flows," or "stage migration," a term that was originally coined to characterize rural-to-urban migration flows "*towards*…major urban centers" (Conway 1980:7, emphasis ours; see also Hägerstrand 1957; Skeldon 1977). The aim of this paper is to consider and test the idea that post-disaster impediments of the sort described above (and again below) spawn innovation in migration systems in the form of stage migration flows toward and, over time, to disaster-affected areas through intermediary destinations as a means of population recovery.

Hypotheses and Case

[3] This is the definition of *disaster* used by numerous research and relief organizations, including the Center for Research on the Epidemiology of Disasters (CRED), Doctors Without Borders, the Federal Emergency Management Agency (FEMA), the Intergovernmental Panel on Climate Change (IPCC), the International Federation of Red Cross and Red Crescent Societies (IFRC), the Office of U.S. Foreign Disaster Assistance (USAID), and the United Nations (U.N.), to name only a few.

From the preceding discussion, we think that stage migration flows toward and, over time, to disaster-affected areas through intermediary destinations (hereafter, stage in-migration) play a potentially important role in how places affected by natural disasters recover their populations. Guided by the idea that [at least some] actors respond to impediments in disaster-affected areas in the form of step-wise migration, we expect that stage in-migration flows to disaster-affected areas should be pronounced in the post- (versus pre-) disaster period. Focusing on the difference in stage in-migration flows between the pre- and post-disaster periods is important for two reasons. First, stage in-migration is not unique to post-disaster periods, and can be viewed over any length of time for which sufficient data points exist; thus, in order to determine whether stage in-migration is particularly pronounced in the post-disaster period, it is necessary to difference out pre-existent (i.e., pre-disaster) stage in-migration. Second, stage in-migration is not comparable across time points within the post-disaster period because the potential number of stages increases with the amount of time since the start of the post-disaster period. To see this, it is necessary to provide a definition of stage migration.

In this paper, we define stage migration as a migration flow from sending area i to receiving area j that involves one or more intermediary destinations k, such that $i \neq j \neq k$. Assuming that time t is the beginning of the post-disaster period, between time t and time $t+n$ (hereafter, we will refer to each time interval using the time term at the start of the interval; so, in this case, "at time t"), stage migration between sending area i and receiving area j is not possible since only one time interval has elapsed since the start of the post-disaster period. Over two time intervals, t and $t+n$, stage migration between sending area i and receiving area j is possible, and, moreover, can involve one, and only one, intermediary destination. We might write this flow as follows, where s refers to stage migration: $m_{t,t+n}^{ij.s}$. Over three time intervals, stage migration between sending area i and receiving area j potentially involves two intermediary destinations, written in the following way: $m_{t,t+2n}^{ij.s}$. Clearly, $m_{t,t+n}^{ij.s}$ and $m_{t,t+2n}^{ij.s}$ are not directly comparable because they potentially encompass different numbers of stages, and therefore summarize stage migration over different lengths of time in the post-disaster period.

The above focus on stage in-migration flows to disaster-affected areas in the post- (versus pre-) disaster period naturally raises questions about the possibility of stage out-migration flows from disaster-affected areas. While stage in-migration flows are the focus of this paper, we think that it is important to also consider stage out-migration flows in order show that post-disaster impediments, of the sort described above, do *not* result in elevated stage out-migration flows from disaster-affected areas. If stage out-migration flows from disaster-affected areas in the post-disaster period are not higher than those in the pre-disaster period, then we can be more confident that stage in-migration flows to disaster affected areas are, indeed, a response to post-disaster impediments, which delay in-migration flows to disaster-affected areas in the immediate aftermath of disasters (Fussell et al. 2014).

We test the two hypotheses above by examining stage in-migration flows to and out-migration flows from Orleans Parish over a five year period (2006-2010) after Hurricane Katrina. To provide some context on the gradual nature of population recovery in Orleans Parish after Hurricane Katrina, prior to Hurricane Katrina, the population of Orleans Parish was roughly constant, having increased by 1.79 percent between 2000 and 2005 (U.S. Census Bureau 2011). After Hurricane Katrina made landfall on August 29, 2005, the population of Orleans Parish declined from 494,765 persons in April of that year to 230,172 persons by April of 2006. Between 2006 and 2010, the population of Orleans Parish increased by more than 51 percent to

347,858 persons, about three-quarters of its pre-Katrina size. Importantly, population recovery was gradual over the post-Katrina period. Of the 113,657 residents gained between 2006 and 2010, about 34 percent were recovered between 2006 and 2007. Twenty-nine percent were recovered between 2007 and 2008, 23 percent between 2008 and 2009, and 14 percent between 2009 and 2010. Although it is beyond the scope of this paper, it is also important to note that there were pronounced compositional differences with respect to who migrated (or not) to Orleans Parish during this time (Finch et al. 2010; Frey et al. 2007; Fussell et al. 2010; Groen and Polivka 2010; Sastry 2009), not to mention those who migrated from Orleans Parish (or not) during Hurricane Katrina (Elliott and Pais 2006; Koerber 2006).

With respect to post-disaster impediments, Fussell et al. (2014:306) noted that "[w]idespread housing damage delayed residents' returns" to Orleans Parish. In addition to housing damage, Green et al. (2007:11; see also Berggren and Curiel 2006) detailed a number of substantial and "widespread impediments" to in-migration. These included, for example, extensive damage to property and structures other than housing, labor shortages in industries vital to recovery efforts (e.g., construction), repairs and improvements to existing levees that do not necessarily reduce the risk of future breaches and flooding, and a service sector operating well above capacity with limited resources. Other research has further documented the importance of political conflict and consensus in how these impediments were experienced and addressed at the local, state, and national levels, as well as the emotional toll taken on actors (Chamlee-Wright and Storr 2009; Kates et al. 2006; Pais and Elliott 2008). With respect to the aims of this paper, the key point is that these impediments delayed in-migration to and, thus, population recovery in Orleans Parish. However, as we discussed above, we think that these impediments also catalyzed innovation in the U.S. migration system in the form of stage in-migration flows to Orleans Parish as a potential means of population recovery over time.

Data and Methods

Following Curtis et al. (2014) and Fussell et al. (2014), we analyze the U.S. migration system of county-to-county flows, focusing particularly on direct and indirect (i.e., stage) migration flows to and from Orleans Parish. While it would be ideal to analyze county-to-county data aggregated up from the actual migration histories of actors as they migrate between counties over time, unfortunately, such data do not exist. While data containing the actual migration histories of actors over time are available (e.g., in the Panel Study of Income Dynamics (PSID)), these lack sufficient sample sizes to estimate place-to-place migration flows for a system comprised of 3,141 U.S. counties (Nowok et al. 2006). For this reason, we use publicly available data on county-to-county migration flows from the Statistics of Income Program at the Internal Revenue Service (IRS) (Gross 2005). These data afford the opportunity to analyze the entire U.S. migration system of county-to-county flows; however, they also come with a tradeoff. Because these data do not contain information on the actual migration histories of actors over time, it is not possible to disentangle stage migration that actually happened after Hurricane Katrina from the broader set of "all possible [stage] migration paths" (Conway 1980:10). Accordingly, in this paper, we analyze the latter. Consequently, our estimates of stage in-migration to and out-migration from Orleans Parish likely represent upper bounds.

The IRS migration data are in the form of counts of county-to-county migration flows between all counties in the United States. To generate these estimates, the IRS matched tax returns in consecutive years and noted whether the tax-filing addresses matched; thus, these estimates capture the county-to-county migrations of tax returns (roughly equivalent to households) and tax exemptions (roughly equivalent to individuals). Following prior research (Curtis et al. 2014; Fussell et al. 2014; Vachon 2014), we focus our analysis on the former set of household migration flows given that migration is frequently a household-level strategy in response to uncertainty and risk (Stark and Bloom 1985). Because the IRS data are derived from tax returns, they underrepresent those who do not file, most notably the poor and the elderly (Gross 2005). That said, a study by Molloy et al. (2011) using data from the Current Population Survey (CPS) showed that 87 percent of household heads in the United States file tax returns annually, thereby providing strong evidence that these data are suitable for analyzing population-level trends (see also Engels and Healy 1981; Isserman et al. 1982). This point is particularly important when one considers that there exist no comparable data before, during, and after Hurricane Katrina made landfall. Although estimates of county-to-county migration flows produced by the U.S. Census Bureau come close, these are problematic because the timing criteria for identifying migrants changed between the 2000 Decennial Census and the 2007-2011 American Community Survey (ACS), thus raising issues of comparability.[4] While the IRS data are available annually, Johnson et al. (2008) showed that IRS match rates declined in Orleans Parish and in surrounding parishes between 2005 and 2006 on account of absent and late tax filings due to Hurricane Katrina.[5] We therefore exclude the IRS data for the 2005 period from our analysis, and focus our analysis on the post-Katrina period (2006-2010). We compare migration during this period to migration that occurred before Hurricane Katrina (2004).

Given the size of the migration system considered in this paper[6], in Figures 1 and 2, we illustrate our approach to estimating stage migration flows using a hypothetical example of migration flows between three counties (i, j, and k) in three time intervals (1, 2, and 3). We begin in Figure 1 by displaying three matrices ($\mathbf{M(1)}$, $\mathbf{M(2)}$, and $\mathbf{M(3)}$) containing counts of migrant and non-migrant households. Three matrices ($\mathbf{P(1)}$, $\mathbf{P(2)}$, and $\mathbf{P(3)}$) containing the corresponding transition probabilities are also displayed.

---FIGURE 1 ABOUT HERE---

In each matrix, sending counties are listed as rows, and receiving counties are listed as columns. Thus, in the first time interval, of the 100 households in county i, 45 did not migrate, 15 migrated to county k, and 40 migrated to county j. The corresponding transition probabilities are 0.450, 0.150, and 0.400, respectively. As is evident, over time, the populations of counties i and k declined, while the population of county j increased. For the purposes of this illustration, we might therefore think of county j as a disaster-affected county that is gradually recovering its population over time, with the beginning of first time interval signifying the start of the post-disaster period.

[4] Estimates from the Decennial Census identify migrants using place of residence at the time of the census and five years prior, while ACS estimates use place of residence at the time of the survey and one year prior. The ACS also switched to counting migrants using a two-month rule for defining residence, replacing the rule of usual residence, (i.e. where persons lived/slept) in the Decennial Census.
[5] The IRS periodicizes their estimates using a two-year window, where, for example, for the period 2005-2006, 2005 is the year in which migration occurred and 2006 is the tax filing year. Hereafter, we refer to each period using the former year, the year in which migration actually occurred.
[6] 3,141 counties plus three residual categories, for a total of 9,865,881 potential migration flows:
9,865,881 = [3,141 + 3 potential sending areas] x [3,141 + 3 potential receiving areas].

Between times *1* and *3*, the population of county *j* increased from 100 households to 150 households. At the end of the third time interval, the population of county *j* was 160 households (160 = 20 + 20 +120).

Because the IRS data do not afford the ability to track the actual migration histories of households as they migrate between counties over time, our approach to estimating stage migration utilizes the transition probabilities in Figure 1. As shown in Figure 2, we begin by calculating the joint probabilities of county-to-county migration for each pair of counties between time *1* and times *2* and *3*.

---FIGURE 2 ABOUT HERE---

The joint probabilities of county-to-county migration between time *1* and times *2* and *3* are contained in the $\mathbf{P(1-2)}$ and $\mathbf{P(1-3)}$ matrices, respectively, where:

$$\mathbf{P(1-2)} = \mathbf{P(1)P(2)} \quad (1)$$

$$\mathbf{P(1-3)} = \mathbf{P(1)P(2)P(3)} \quad (2)$$

Next, we display the number of migrant and non-migrant households between time *1* and times *2* and *3*. Hereafter, we will refer to these as *cumulative* migration counts. Cumulative migration counts are contained in the $\mathbf{M(1-2)}$ and $\mathbf{M(1-3)}$ matrices, and are calculated by multiplying the size of the starting populations in counties *i*, *j*, and *k* at the beginning of the first time interval (100 households in each county, as shown in Figure 1) by the joint probabilities of county-to-county migration in (1) and (2). Thus, for example, we see that, of the 100 households in county *i* at time *1*, 26 households did not migrate between time *1* and time *2*, 25 households migrated to county *k*, and 49 households migrated to county *j*. The corresponding figures between time *1* and time *3* are 23 households, 24 households, and 53 households, respectively.

We then proceed to disaggregate the joint probabilities of county-to-county migration to isolate the stage migration component for each pair of counties by applying our earlier definition of stage migration, which was that a migration flow from sending area *i* to receiving area *j* is a stage migration flow if it involves one or more intermediary destinations *k*, such that *i≠j≠k*. To illustrate, between time *1* and times *2* and *3*, the joint probabilities of migrating from county *i* to county *j* are:

$$p_{1,2}^{ij} = p_1^{ii}p_2^{ij} + p_1^{ik}p_2^{kj} + p_1^{ij}p_2^{jj} \quad (3)$$

$$\begin{aligned} p_{1,3}^{ij} = {} & p_1^{ii}p_2^{ii}p_3^{ij} + p_1^{ii}p_2^{ik}p_3^{kj} + p_1^{ii}p_2^{ij}p_3^{jj} \\ & + p_1^{ik}p_2^{ki}p_3^{ij} + p_1^{ik}p_2^{kk}p_3^{kj} + p_1^{ik}p_2^{kj}p_3^{jj} \\ & + p_1^{ij}p_2^{ji}p_3^{ij} + p_1^{ij}p_2^{jk}p_3^{kj} + p_1^{ij}p_2^{jj}p_3^{jj} \end{aligned} \quad (4)$$

Subsequently applying our definition of stage migration, there is one stage migration pathway from county *i* to county *j* in (3) and five stage migration pathways in (4).

$$p_{1,2}^{ij.s} = p_1^{ik}p_2^{kj} \quad (5)$$

$$p_{1,3}^{ij.s} = p_1^{ii}p_2^{ik}p_3^{kj} \quad (6)$$
$$+p_1^{ik}p_2^{ki}p_3^{ij} + p_1^{ik}p_2^{kk}p_3^{kj} + p_1^{ik}p_2^{kj}p_3^{jj}$$
$$+p_1^{ij}p_2^{jk}p_3^{kj}$$

Probabilities of stage migration are displayed for all pairs of counties in the $\mathbf{P}^s(\mathbf{1}-\mathbf{2})$ and $\mathbf{P}^s(\mathbf{1}-\mathbf{3})$ matrices. Given our definition of stage migration, there can be no stage migration between counties *i* and *j* if *i*=*j*; thus, the main diagonals in the $\mathbf{P}^s(\mathbf{1}-\mathbf{2})$ and $\mathbf{P}^s(\mathbf{1}-\mathbf{3})$ matrices are blank. Subsequently multiplying the size of the populations in counties *i*, *j*, and *k* at the beginning of the first time interval by the probabilities of stage migration, we arrive at counts of stage migration flows, $\mathbf{M}^s(\mathbf{1}-\mathbf{2})$ and $\mathbf{M}^s(\mathbf{1}-\mathbf{3})$, between time *1* and times *2* and *3*, as shown at the bottom of Figure 2. To provide an interpretation, focusing on county *j*, between time *1* and time *2*, the cumulative number of households that migrated to *j* was 98 (98 = 49 + 49). Of these 98 households, 10 (10 = 5 + 5), or about 10.2 percent, migrated to *j* via a stage migration pathway involving one intermediary destination. The corresponding stage migration figures between time *1* and time *3* were 24 (24 = 12 + 12) households, or 22.6 percent (22.6 = 24 / 106 * 100) of cumulative migration flows to *j*.

In the this paper, we estimate the size of stage migration flows to and from Orleans Parish between the start of the post-Katrina period (2006) and each subsequent year (2007, 2008, 2009, and 2010). Between 2006 and 2007, the number of potential intermediary destinations between a given county in the United States and Orleans Parish is one; whereas, between 2006 and 2010, up to four intermediary destinations are possible. To the extent that our estimates of stage migration flows in the post-Katrina period can be considered meaningful (e.g., pronounced or not), it necessary to compare them to estimates of stage migration flows prior to Hurricane Katrina. To generate estimates of stage migration flows in the pre-Katrina period, we use the IRS county-to-county migration flow data in 2004, the year before Hurricane Katrina, to approximate several stage migration processes characterized by different numbers of potential intermediary destinations, and thus lengths of time.

In Table 1, we display the joint probability matrices used to estimate cumulative in-migration flows to and out-migration flows from Orleans Parish in the pre- and post-Katrina periods. These matrices compare to the $\mathbf{P}(\mathbf{1}-\mathbf{2})$ and $\mathbf{P}(\mathbf{1}-\mathbf{3})$ matrices shown earlier in Figure 2.

---TABLE 1 ABOUT HERE---

In conjunction with information on population size in each U.S. county at the start of the pre- and post-Katrina periods, we use these matrices to arrive at counts of stage in-migration flows to and out-migration flows from Orleans Parish following the set of steps in (3)-(6).

Our analysis is organized as follows. First, we present estimates of total annual, cumulative, and stage migration flows to and from Orleans Parish in the post-Katrina period. This is followed by presenting estimates of the difference in total annual, cumulative, and stage migration flows to and from Orleans Parish between the pre- and post-Katrina periods. Finally, we test the two hypotheses detailed earlier concerning stage in-migration flows to and out-migration flows from Orleans Parish in the context of gravity models of county-to-county stage migration. The model for stage in-migration flows is:

$$\ln\left(m_{t,t+n}^{ij.s}\right) = \alpha + \beta_1 \ln(Population_i) + \beta_2 \ln(Distance_{ij}) + \delta Period_p + \varepsilon \quad (7)$$

where $m_{t,t+n}^{ij,s}$ is the size of the stage in-migration flow from county i to county j (j = Orleans Parish), $Population_i$ is the size of the population in county i, $Distance_{ij}$ is the geographic distance between county i and Orleans Parish, and $Period_p$ is a dummy indicator for whether the period refers to the post-Katrina period (1) or the pre-Katrina period (0). The coefficient, δ, provides an estimate of whether and by how much stage in-migration flows to Orleans Parish in the post-Katrina period differed from stage in-migration flows in the pre-Katrina period.

The model for stage out-migration flows takes a similar form:

$$\ln\left(m_{t,t+n}^{ij,s}\right) = \alpha + \beta_1 \ln(Population_j) + \beta_2 \ln(Distance_{ij}) + \delta Period_p + \varepsilon \quad (8)$$

Here, i = Orleans Parish, and j refers to any other U.S. county. In this model, the coefficient, δ, provides an estimate of the difference between stage out-migration flows from Orleans Parish between the pre- and post-Katrina periods.

Because we estimate the size of stage migration flows to and from Orleans Parish between the start of the post-Katrina period (2006) and each subsequent year (2007, 2008, 2009, and 2010), the models in (7) and (8) are estimated separately for each span of time in the post-Katrina period, relative to a comparable span of time in the pre-Katrina period (see Table 1). Thus, for example, we estimate the model in (7) for stage in-migration flows to Orleans Parish between 2006 and 2007, another model for stage in-migration flows between 2006 and 2008, and so on. We do the same for stage out-migration flows from Orleans Parish using the model in (8).

Results

In Figure 3, we display estimates of total annual, cumulative, and stage migration flows to and from Orleans Parish in the post-Katrina period.

---FIGURE 3 ABOUT HERE---

Starting with annual migration, in-migration flows to Orleans Parish ranged from a high of 18,408 households in 2006 to a low of 12,799 households in 2010. Out-migration flows from Orleans Parish also declined, at least between 2006 and 2009, going from 10,702 households to 8,536 households, before increasing to 9,342 households in 2010. From these figures, it is clear that net-migration in Orleans Parish was consistently positive over the post-Katrina period, ranging from a high of +7,706 households in 2006 to a low of +3,457 households in 2010. As we noted earlier, positive net-migration ultimately contributed to population recovery in Orleans Parish (Frey et al. 2007; McCarthy et al. 2006; U.S. Census Bureau 2011).

Turning from annual migration to cumulative migration flows, it is important to note our usage of dashed (versus solid) lines in the latter figures in Figure 3. Dashed lines are used to communicate that two series displayed are not properly time series since they encompass different lengths of time since 2006, the start of the post-Katrina period. That is, each data point displayed summarizes cumulative migration flows since 2006. Between 2006 and 2007, a total of 31,044 households migrated to Orleans Parish, while some 15,486 households migrated from Orleans Parish. Differences between cumulative in-migration flows to and out-migration flows from Orleans Parish hold throughout the post-Katrina period (i.e., cumulative net-migration was consistently positive). By 2010, a total of 55,888 households had migrated to Orleans Parish over the post-Katrina period, while some 24,678 households migrated from Orleans Parish.

The estimates of cumulative migration are used generate estimates of stage in-migration flows to and out-migration flows from Orleans Parish, as shown earlier in (3)-(6). In Figure 3, stage migration flows comprised a small, but still non-zero, portion of cumulative migration flows over the post-Katrina period. Between 2006 and 2007, stage in-migration flows to Orleans Parish numbered 3,128 households, accounting for about 10.1 percent of cumulative in-migration flows. Stage out-migration flows from Orleans Parish were smaller between 2006 and 2007, totaling 2,173 households and accounting for 14.0 percent of cumulative out-migration flows. Over the entire post-Katrina period, 2006-2010, some 13,483 households migrated to Orleans Parish via one or more intermediary counties in the United States, while 6,814 households migrated from Orleans Parish in a similar manner. In percentage terms, stage in-migration flows accounted for 24.1 percent of cumulative in-migration flows to Orleans Parish, while stage out-migration flows accounted for 27.6 percent of cumulative out-migration flows.

In order to get better sense of whether in-migration flows to and out-migration flows from Orleans Parish were particularly pronounced in the post-Katrina period, it is necessary to compare these to similar estimates for the pre-Katrina period. These comparisons, in the form of differences between the pre- and post-Katrina periods, are displayed in Figure 4.

---FIGURE 4 ABOUT HERE---

Beginning with annual migration, in-migration flows to Orleans Parish were consistently higher in the post- (versus pre-) Katrina period, while out-migration flows from Orleans Parish were consistently lower. However, by 2010, both in-migration and out-migration flows were approaching pre-Katrina levels. Cumulative in-migration flows to Orleans Parish were also elevated in the post- (versus pre-) Katrina period, while cumulative out-migration flows from Orleans Parish were quite a bit lower. Between 2006 and 2010, cumulative in-migration flows from Orleans Parish totaled 55,888 households; the corresponding figure for the pre-Katrina period was 38,319 households, for a difference of +17,570 households. Likewise, over the entire post-Katrina period, cumulative out-migration flows from Orleans Parish totaled 24,678 households; the corresponding figure for the pre-Katrina period was 49,887 households, for a difference of -25,209 households.

The graphs for stage in-migration flows to and out-migration flows from Orleans Parish provide initial descriptive evidence for our two hypotheses advanced earlier. Stage in-migration flows to Orleans Parish were higher in the post- (versus pre-) Katrina period. Between 2006 and 2007, 3,128 households migrated to Orleans Parish via one intermediary destination, versus 2,346 households in the pre-Katrina period, for a difference of +782 households. Between 2006 and 2010, the corresponding figures were 13,483 households in the post-Katrina period and 10,361 households in the pre-Katrina period, for a difference of +3,121 households. Although these differences are not large considering the magnitudes of the differences in cumulative in-migration before and after Hurricane Katrina, they are nonetheless positive, as initially hypothesized. The differences for stage out-migration flows between the pre- and post-Katrina periods are negative, which is consistent with our second hypothesis.

In Table 2, we display the results of significance tests used to determine if stage in-migration flows to and out-migration flows from Orleans Parish were significantly different between the pre- and post-Katrina periods.

---TABLE 2 ABOUT HERE---

As a general observation about the coefficients for population size and geographic distance in Panels A and B in Table 2, these are in the expected directions. In gravity models of migration, it is expected, and a common finding, that population size should be positively associated and geographic distance negatively associated with the size of migration flows. The positive association between population size and the size of migration flows is often framed in one of two ways. First, larger populations typically give rise to larger migration flows; this is one potential explanation for the results for population size in sending counties displayed in Panel A. Second, migration flows are typically directed at more populated areas for a number of reasons (e.g., economic opportunities, social networks, etc.); this is one potential explanation for the results for population size in receiving counties displayed in Panel B. With respect to geographic distance, scholars routinely cite the economic and psychic costs associated with migration, which are theorized to increase as a function of the distance between sending and receiving areas (Greenwood 1995; Sjaastad 1962).

With respect to the coefficients for the post- (versus pre-) Katrina period in Table 2, these are in the expected directions, and each is statistically significant. Between 2006 and each of the other four years in the post-Katrina period, stage in-migration flows were larger than those in the pre-Katrina period, on average. Likewise, stage out-migration flows in the post-Katrina period were smaller than those in the pre-Katrina period, on average. To provide a more intuitive sense of the magnitudes of these differences, in Figure 5, we display the exponentiated coefficients, which express the difference in stage migration flows between the pre- and post-Katrina periods in percentage terms.

---FIGURE 5 ABOUT HERE---

Between 2006 and 2007, stage in-migration flows were an average of 4.8 percent (4.8 = (exp(0.047) – 1) * 100) larger than those in the pre-Katrina period. Similar estimates between the start of the post-Katrina period and 2008 and 2009 are +7.1 percent and +8.7 percent, respectively, relative to stage in-migration flows to Orleans Parish in the pre-Katrina period. Over the entire observation window, 2006-2010, stage in-migration flows were an average of 8.0 percent higher in the post- (versus pre-) Katrina period. These results are consistent with our hypothesis that stage in-migration flows are a response or innovation in the migration system that is unique to post- (versus pre-) disaster periods. As we noted in our opening remarks, following Fussell et al. (2014:206) and others, we think that the reason that stage in-migration flows to Orleans Parish were especially elevated in the post- (versus pre-) Katrina period was on account of post-disaster impediments, which “delayed” in-migration to Orleans Parish in the immediate aftermath of Hurricane Katrina. As our results show, these delays catalyzed stage migration flows toward and, over time, to Orleans Parish through intermediary destinations.

The results displayed for stage out-migration flows from Orleans Parish are consistent with this story. Stage out-migration flows were considerably smaller in the post- (versus pre-) Katrina period, on average. Between 2006 and 2007, the difference was -3.1 percent. Over the entire post-Katrina period, 2006-2010, the difference was -22.2 percent. Presumably, stage out-migration flows from Orleans Parish were smaller in the post-Katrina period because there were no (or fewer) impediments to out-migration. Thus, there was less of need in the migration system to redirect out-migration flows towards and, over time, to other counties in the United States through intermediary destinations.

Discussion

Adopting a migration systems perspective (Bakewell 2013; Mabogunje 1970), in this paper, we considered the idea that post-disaster impediments (e.g., damage to housing and property, etc.) can delay in-migration to and, thus, population recovery in disaster-affected areas (Fussell et al. 2014). However, we argued that these impediments, rather than simply delay in-migration flows to disaster-affected areas, can also catalyze responses or innovations in migration systems in the form of stage migration flows toward, and at a later point in time, to disaster-affected areas through intermediary destinations (Conway 1980). In considering the migration motivations, decisions, and behaviors of actors, especially those who have been displaced from their homes during natural disasters, we think there are strong reasons for why actors would choose to migrate toward and eventually to disaster-affected areas through intermediary destinations. In so doing, it becomes evident that understanding exactly how disaster-affected areas recover their populations through in-migration requires considering not only how places in a migration system are connected to one another by migration (Curtis et al. 2014; Fussell et al. 2014), but also how places are connected through one another via intermediary destinations. In this way, the entire migration system, rather than just flows between pairs of places, is implicated in the ability of disaster-affected areas to recover their populations through in-migration.

The above reflection serves to highlight two important contributions of our work. First, at a theoretical level, we sought to connect research on migration systems theory with earlier theoretical work on step-wise and stage migration. Although, to our knowledge, these two theoretical bodies of research have not been linked explicitly, they have much in common. Migration systems theory starts with the interconnected nature of places (Mabogunje 1970), and stresses the importance of actors—their motivations, decisions, and behaviors—in the process (Bakewell 2013). Research on step-wise and stage migration likewise differentiates between actors and places, and provides the necessary tools and terminology for considering how (i.e., the different ways that) migration "happens" in a migration system (Conway 1980; Hägerstrand 1957; Skeldon 1977). Connecting these two literatures is particularly important when one considers that studies of migration systems are often little more than an inventories and summaries of migration flows between pairs of sending and receiving areas (Bakewell 2013), with little if any consideration of dynamics of movement within the system over time. Our work provides a necessary first step for this theoretical integration.

The second contribution of this paper is more substantive in nature. While the hazards associated with many environmental events (e.g., rainfall, wind speeds, etc.) are often local phenomena, the ability of places adversely affected by them to recover is not. How places are connected to other places is ultimately another way of saying that places are dependent on one another. While we conceptualized and measured this dependency with respect to migration flows and population recovery, clearly, this is but one example. Other examples might include flows of capital, information, goods and services, and so on. In a world that is rapidly changing with respect to the frequency, type, and severity of natural disasters, it is therefore important to consider these dependencies, and, ultimately, the collective nature of preparing for, withstanding, and responding to natural disasters.

Our work in this paper, however, is not without its share of limitations. First, although we took an innovative approach to estimating stage migration flows, as we discussed, our approach was ultimately necessary because we lacked detailed information on the migration histories of actors over space and time. Accordingly, our estimates of stage migration flows to and from Orleans Parish likely represent upper bounds because they capture "all possible migration paths" (Conway 1980:10). If actual (versus all possible) stage migration flows to and from Orleans Parish are less than what we have estimated, then this raises questions about whether stage migration flows were, in fact, pronounced in the post (versus pre-) Katrina period, and, ultimately, the relevance of stage migration for understanding population recovery in disaster-affected areas.

The above limitation is accompanied by a second, which is that we did not make explicit in our analysis the underlying mechanism at work, which concerns the role of post-disaster impediments in disaster-affected areas. Instead, adopting the framework of a natural experiment, and based on the observations of others (Fussell et al. 2014; Green et al. 2007), we started with the assumption that post-disaster impediments did, in fact, delay in-migration to Orleans Parish after Hurricane Katrina. Ultimately, data provided by the U.S. Census (2011) on population growth in Orleans Parish over the post-Katrina period are consistent with a story of delayed in-migration to and, thus, population recovery in Orleans Parish. However, this aside, it might still be the case that post-disaster impediments had nothing to do with these trends. An alternative explanation might involve the types of places to which persons displaced by Hurricane Katrina were evacuated and migrated to. Perhaps these places exerted substantial "pull" effects (e.g., available housing, employment opportunities, amenities, etc.) on actors who were considering migrating to Orleans Parish, thereby delaying in-migration to Orleans Parish in a way that had little to do with post-disaster impediments of the sort described above.

These limitations aside, we believe that we have made an important contribution to research applying a migration systems perspective to understand how places affected by natural disasters recover their populations through in-migration. Going forward, future research in this area might consider the following potential extensions of our work. First, although we focused on places that recover their populations after natural disasters, whether fully or in part, another interesting question, and one that could also be explored using a migration systems perspective, is the set of conditions under which places fail to recover their populations via migration (McLeman 2011). A central focus here might be the conditions under which in-migration to disaster-affected areas is deterred entirely, as opposed to delayed. Another question concerns the types of places that actors displaced by natural disasters migrate to, and, with respect to the work of this paper, the pathways by which actors reach these destinations. Finally, it goes without saying that natural disasters in the form of hurricanes, let alone a single hurricane in the form of Hurricane Katrina, do not exhaust the diversity of environmental hazards and their effects. Accordingly, future research might also consider this heterogeneity with respect to different types of natural disasters (e.g., floods, sea level rise, etc.) (Curtis and Schneider 2011), the pace of onset (e.g., rapid versus slow) and desistance (Laczko and Aghazarm 2009), etc.

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Table 1. Joint Probablity Matrices of County-to-County Migration: Pre- and Post-Katrina

	Pre-Katrina	Post-Katrina
1 Year	**P(2004)**	**P(2006)**
2 Years	**$P(2004)^2$**	**P(2006-07)**
3 Years	**$P(2004)^3$**	**P(2006-08)**
4 Years	**$P(2004)^4$**	**P(2006-09)**
5 Years	**$P(2004)^5$**	**P(2006-10)**

Table 2. Stage Migration Flows to and from Orleans Parish

Panel A. Stage In-Migration Flows to Orleans Parish

Outcome: Natural Log of County-to-County Stage In-Migration Flow to Orleans Parish

	2006-2007	2006-2008	2006-2009	2006-2010
Constant	-1.750*	-2.324*	-2.614*	-2.760*
	(0.042)	(0.053)	(0.059)	(0.063)
Natural Log Population:	0.265*	0.373*	0.440*	0.488*
Sending County	(0.002)	(0.003)	(0.003)	(0.003)
Natural Log Distance	-0.042*	-0.069*	-0.093*	-0.115*
	(0.006)	(0.007)	(0.008)	(0.008)
Post-Katrina Period = 1	0.047*	0.069*	0.083*	0.077*
(Pre-Katrina Period = 0)	(0.007)	(0.008)	(0.009)	(0.010)

Panel B. Stage Out-Migration Flows from Orleans Parish

Outcome: Natural Log of County-to-County Stage Out-Migration Flow from Orleans Parish

	2006-2007	2006-2008	2006-2009	2006-2010
Constant	-1.256*	-1.618*	-1.805*	-1.920*
	(0.041)	(0.053)	(0.060)	(0.065)
Natural Log Population:	0.234*	0.324*	0.384*	0.428*
Receiving County	(0.002)	(0.003)	(0.003)	(0.003)
Natural Log Distance	-0.075*	-0.110*	-0.137*	-0.158*
	(0.005)	(0.007)	(0.008)	(0.009)
Post-Katrina Period = 1	-0.031*	-0.113*	-0.186*	-0.251*
(Pre-Katrina Period = 0)	(0.007)	(0.009)	(0.010)	(0.010)

Figure 1. Hypothetical System of Migration Flows Among Three Counties in Three Time Intervals

$$\mathbf{M(1)} = \begin{array}{c} \\ i \\ k \\ j \end{array} \begin{array}{c} \begin{array}{ccc} i & k & j \end{array} \\ \begin{bmatrix} 45 & 15 & 40 \\ 15 & 45 & 40 \\ 25 & 25 & 50 \end{bmatrix} \end{array} \begin{array}{c} \Sigma \\ 100 \\ 100 \\ 100 \end{array} \qquad \mathbf{P(1)} = \begin{array}{c} \\ i \\ k \\ j \end{array} \begin{array}{c} \begin{array}{ccc} i & k & j \end{array} \\ \begin{bmatrix} 0.450 & 0.150 & 0.400 \\ 0.150 & 0.450 & 0.400 \\ 0.250 & 0.250 & 0.500 \end{bmatrix} \end{array} \begin{array}{c} \Sigma \\ 1.000 \\ 1.000 \\ 1.000 \end{array}$$

$$\mathbf{M(2)} = \begin{array}{c} \\ i \\ k \\ j \end{array} \begin{array}{c} \begin{array}{ccc} i & k & j \end{array} \\ \begin{bmatrix} 30 & 25 & 30 \\ 25 & 30 & 30 \\ 20 & 20 & 90 \end{bmatrix} \end{array} \begin{array}{c} \Sigma \\ 85 \\ 85 \\ 130 \end{array} \qquad \mathbf{P(2)} = \begin{array}{c} \\ i \\ k \\ j \end{array} \begin{array}{c} \begin{array}{ccc} i & k & j \end{array} \\ \begin{bmatrix} 0.353 & 0.294 & 0.353 \\ 0.294 & 0.353 & 0.353 \\ 0.154 & 0.154 & 0.692 \end{bmatrix} \end{array} \begin{array}{c} \Sigma \\ 1.000 \\ 1.000 \\ 1.000 \end{array}$$

$$\mathbf{M(3)} = \begin{array}{c} \\ i \\ k \\ j \end{array} \begin{array}{c} \begin{array}{ccc} i & k & j \end{array} \\ \begin{bmatrix} 20 & 35 & 20 \\ 35 & 20 & 20 \\ 15 & 15 & 120 \end{bmatrix} \end{array} \begin{array}{c} \Sigma \\ 75 \\ 75 \\ 150 \end{array} \qquad \mathbf{P(3)} = \begin{array}{c} \\ i \\ k \\ j \end{array} \begin{array}{c} \begin{array}{ccc} i & k & j \end{array} \\ \begin{bmatrix} 0.267 & 0.467 & 0.267 \\ 0.467 & 0.267 & 0.267 \\ 0.100 & 0.100 & 0.800 \end{bmatrix} \end{array} \begin{array}{c} \Sigma \\ 1.000 \\ 1.000 \\ 1.000 \end{array}$$

Figure 2. Hypothetical System of Migration Flows Among Three Counties in Three Time Intervals: Cumulative and Stage Migration

$$\mathbf{P(1\text{-}2)} = \begin{array}{c} \\ i \\ k \\ j \end{array} \begin{array}{c} \begin{array}{ccc} i & \quad k & \quad j \end{array} \\ \begin{bmatrix} 0.264 & 0.247 & 0.489 \\ 0.247 & 0.264 & 0.489 \\ 0.239 & 0.239 & 0.523 \end{bmatrix} \end{array} \qquad \mathbf{P(1\text{-}3)} = \begin{array}{c} \\ i \\ k \\ j \end{array} \begin{array}{c} \begin{array}{ccc} i & \quad k & \quad j \end{array} \\ \begin{bmatrix} 0.235 & 0.238 & 0.527 \\ 0.238 & 0.235 & 0.527 \\ 0.227 & 0.227 & 0.545 \end{bmatrix} \end{array}$$

$$\mathbf{M(1\text{-}2)} = \begin{array}{c} \\ i \\ k \\ j \end{array} \begin{array}{c} \begin{array}{ccc} i & \quad k & \quad j \end{array} \\ \begin{bmatrix} 26 & 25 & 49 \\ 25 & 26 & 49 \\ 24 & 24 & 52 \end{bmatrix} \end{array} \qquad \mathbf{M(1\text{-}3)} = \begin{array}{c} \\ i \\ k \\ j \end{array} \begin{array}{c} \begin{array}{ccc} i & \quad k & \quad j \end{array} \\ \begin{bmatrix} 23 & 24 & 53 \\ 24 & 23 & 53 \\ 23 & 23 & 55 \end{bmatrix} \end{array}$$

$$\mathbf{P^s(1\text{-}2)} = \begin{array}{c} \\ i \\ k \\ j \end{array} \begin{array}{c} \begin{array}{ccc} i & \quad k & \quad j \end{array} \\ \begin{bmatrix} & 0.062 & 0.053 \\ 0.062 & & 0.053 \\ 0.074 & 0.074 & \end{bmatrix} \end{array} \qquad \mathbf{P^s(1\text{-}3)} = \begin{array}{c} \\ i \\ k \\ j \end{array} \begin{array}{c} \begin{array}{ccc} i & \quad k & \quad j \end{array} \\ \begin{bmatrix} & 0.094 & 0.120 \\ 0.094 & & 0.120 \\ 0.140 & 0.140 & \end{bmatrix} \end{array}$$

$$\mathbf{M^s(1\text{-}2)} = \begin{array}{c} \\ i \\ k \\ j \end{array} \begin{array}{c} \begin{array}{ccc} i & \quad k & \quad j \end{array} \\ \begin{bmatrix} & 6 & 5 \\ 6 & & 5 \\ 7 & 7 & \end{bmatrix} \end{array} \qquad \mathbf{M^s(1\text{-}3)} = \begin{array}{c} \\ i \\ k \\ j \end{array} \begin{array}{c} \begin{array}{ccc} i & \quad k & \quad j \end{array} \\ \begin{bmatrix} & 9 & 12 \\ 9 & & 12 \\ 14 & 14 & \end{bmatrix} \end{array}$$

Figure 3. Total Annual, Cumulative, and Stage Migration Flows to and from Orleans Parish: Post-Katrina

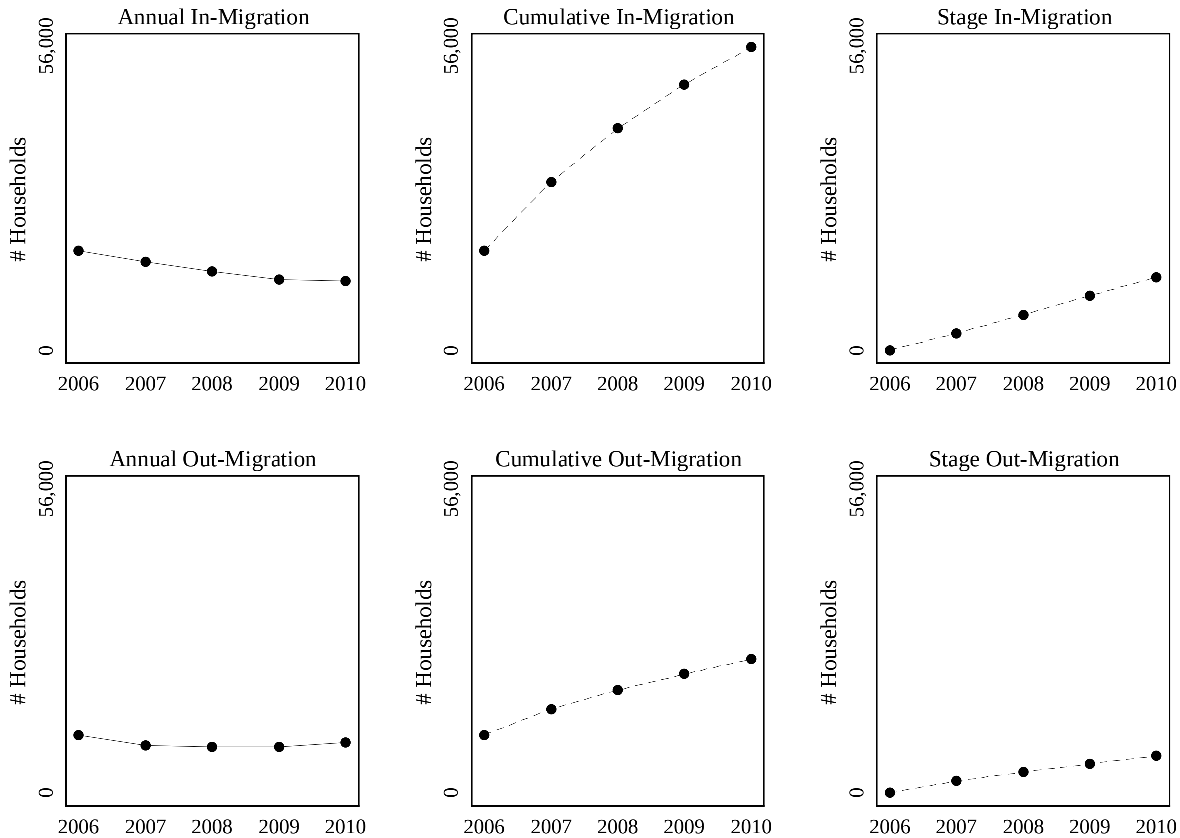

Figure 4. Difference in Total Annual, Cumulative, and Stage Migration Flows to and from Orleans Parish: Pre-Versus Post-Katrina

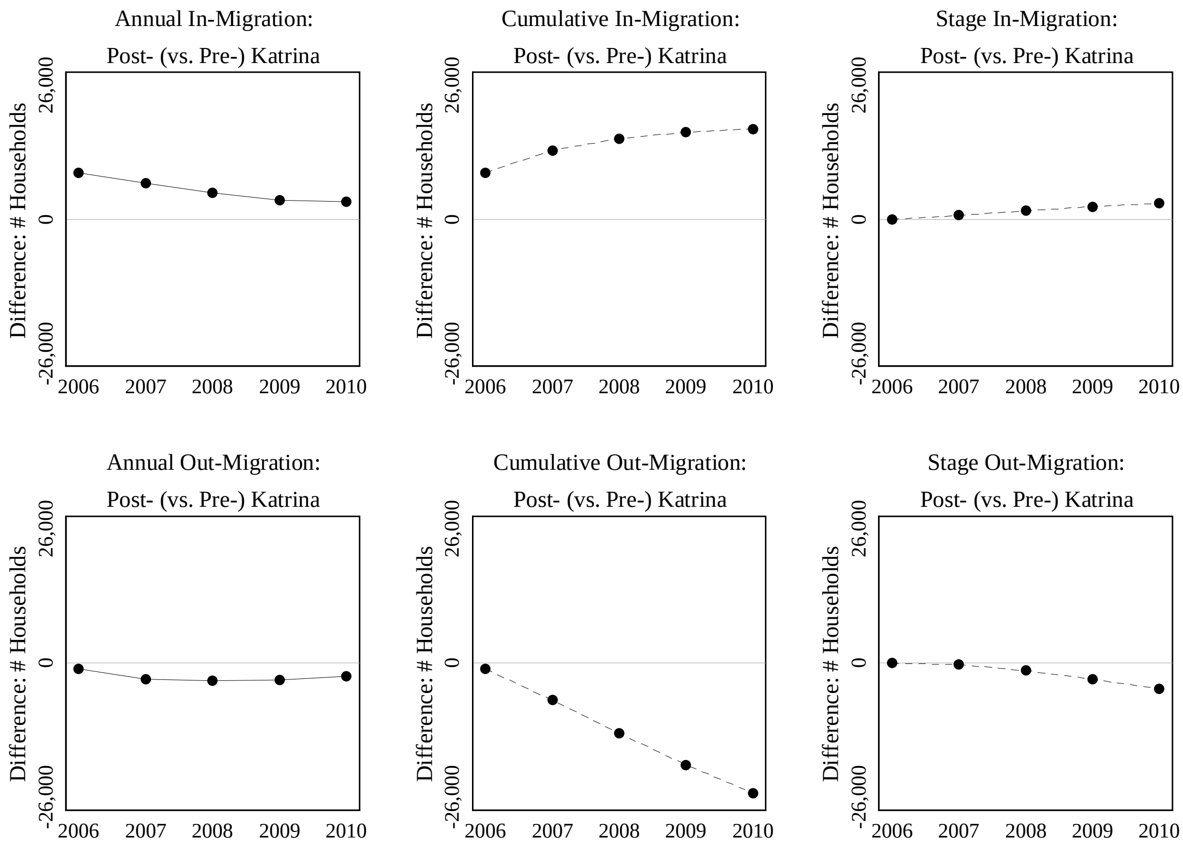

Figure 5. Percentage Difference in Stage Migration Flows to and from Orleans Parish: Pre- Versus Post-Katrina