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Household Adjustments to Hurricane Katrina*

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Abstract: This paper examines household adjustments to Hurricane Katrina by estimating the effects of Katrina-induced damages on changes in household demographics and income distributions in the Orleans Parish between 2000 and 2012. Adjustment patterns are found to be heterogeneous across ethno-racial segments, income classes, and educational attainment. Shares of middle-income and affluent households along with educated individuals decreased in severely damaged areas relative to less damaged ones. Also the share of individuals with lower educational levels and incomes below the poverty line increased in severely damaged block groups. Furthermore, the share of the white population decreased and the share of the black population increased in damaged areas for both home owners and renters. Overall adjustment patterns suggest that resource and financially constrained population adjust by moving into previously damaged areas, while economically capable households adjust by relocating to safer areas within or outside of the parish. Given estimated increases in vulnerable segments of the population in hazardous hotspots, public efforts should focus on either revitalizing poorer neighborhoods, by investing in long-term hazard mitigation measures and improving infrastructure, with segregated housing or assisting gradual population retreat to enhance community resilience and reduce vulnerability and exposure to future catastrophic events.

Keywords: Hurricane Katrina, household adjustment, disaster recovery
JEL Codes: Q54, R23

1. INTRODUCTION

Catastrophic experiences can change the lives of disaster victims and alter the socio-economic fabric of impacted areas. Disasters often cause massive population dislocation and force households to relocate to other areas (Coffman and Noy, 2012; Lynham, Noy, and Page, 2012; Smith et al., 2006; Hornbeck, 2012; Anttila-Hughes and Hsiang, 2013). There are a number of different ways in which individuals and households adapt to natural disaster: (a) moving out of harm's way (not returning); (b) returning, but relocating to other areas within a city; and (c) returning to the same area but rebuilding and self-insuring (Smith et al., 2006). Adjustments are likely to be tied to economic capability; i.e. individuals and households who choose not to return may be those that are economically the most able to relocate. On the other hand, those who return might move to previously damaged areas because they have the economic resources to self-insure and self-protect. At the same time, households at the lower end of income distribution, who lack resources, may also move into damaged areas to exploit lower cost housing. After a catastrophic

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incident, housing prices tend to decline, as individuals have a fresh memory of the disaster and may be more averse to hazard risk (Atreya and Ferreira, 2015; Carbone, Hallstrom, and Smith, 2006; Bin and Landry, 2013; Kousky, 2010). The perception of risk also is elevated in near-miss areas, causing lower housing prices and rents (Hallstrom and Smith, 2005; Walls and Chu, 2015), which may attract low-income, less-educated, and unemployed individuals (Glaeser and Gyourko, 2005).

In all disaster-specific public assistance programs, reconstruction efforts play an important role and could dramatically reshape private adjustment patterns (Gotham, 2014). Beyond disaster-specific aid, social safety programs are often important factors in return/relocation decisions (Notowidigdo, 2011). Research indicates that reliance on social safety nets in the United States (e.g., income maintenance, unemployment insurance benefits, Medicaid) is three times greater after hurricane disasters than on traditional disaster aid and could play a far more important role in buffering disaster impacts than commonly thought (Deryugina, 2013). Private and public incentives to revitalize previously damaged areas in turn affect behavioral responses: people return if critical public infrastructure is well-established and businesses are revitalized (Baade, Baumann, and Matheson, 2007; Kousky, Luttmer, and Zeckhauser, 2006; Boustan, Kahn, and Rhode, 2012). Understanding adjustment patterns driven by past catastrophic incidents and the ways that disaster recovery efforts could reshape the socio-economic fabric of impacted areas is important and can provide guidance for public policy programs that aim at assisting resilient and smart recovery.

In this paper, we examine households' adjustments to damages caused by Hurricane Katrina in 2005, the costliest natural catastrophe in recent history, with a staggering death toll of 1,300 people and damages over $100 billion (Cutter and Gall, 2008). We explore the effects of Katrina-induced damages between post- and pre-Katrina years on changes in the shares of households with different levels of educational attainment, demographic characteristics, and income levels, as well as by the distribution of the value of housing. A seemingly unrelated regression (SUR) model is employed to capture error correlations across equations within a system, which may come from different sources such as unobserved economic conditions and policy shocks that affect the changes in household composition by various attributes (e.g., income, educational attainment, housing value, etc.) between the pre- and post-disaster periods. Planning district fixed effects are used to account for the effects of planning and zoning regulations and potentially uneven distribution of recovery efforts, as well as pre-storm socio-economic disparities that vary by planning districts in the Orleans Parish.

Our results suggest that responses are heterogeneous across racial/ethnic groups, income levels, and educational attainment. The shares of black homeowners and renters increased and the share of whites decreased in both moderately and severely damaged areas relative to less damaged block groups after hurricane Katrina in Orleans Parish. We find that the shares of households with low levels of educational attainment and low-income earners increased, while the shares of educated and of middle-income and wealthier households decreased in the damaged areas relative to less damaged ones. These findings suggest that relocation is the primary adjustment behavior for households who are economically capable of moving out of harm's way, consistent with previous findings documented in the literature. These results are consistent after accounting for differences across planning districts, likely due to pre-existing socio-economic disparities as well as uneven recovery efforts across neighborhoods in Orleans Parish after Hurricane Katrina.

We proceed as follows. Section 2 reviews the literature on adaptive behavior in response to natural disasters. Section 3 describes data. Section 4 provides the empirical framework used for estimation, and results are discussed in Section 5. Section 6 summarizes our findings, discusses policy implications, and concludes the paper.

2. ADAPTIVE BEHAVIOR TO NATURAL DISASTERS

A wealth of literature has examined direct socio-economic impacts of disasters at the national, regional, and community levels.[1] Much less is known about how affected regions, countries, communities, neighborhoods, and individuals adapt to natural disasters. Extant research suggests that countries and communities that are exposed to frequent incidents likely adapt more readily because they experience reduced damages from subsequent incidents (Nordhaus, 2010; Sadowski and Sutter, 2005, 2008; Hsiang and Narita, 2012). But these studies are unable to identify the specific adaptation channels. Limited research indicates that the quality of institutions is an important factor in enhancing disaster resilience, not only across nations (Kahn, 2005), but also across regions within a country (Barone and Mocetti, 2014). Scant literature also suggests that increased government spending can moderate adverse impacts of shocks and contribute to quick recovery in the aftermath (Davlasheridze, Fisher-Vanden and Klaiber, 2017; Deryugina, 2013; Lenze, 1997).

While these public programs are effective in mitigating the disruptive impacts of disaster after-effects, they may provide perverse incentives for individuals exposed to hazards, such as relying on public aid to develop in risky areas, and limiting/altering their adaptive behavior (Kunreuther, 2001, Lewis and Nickerson, 1989; Raschky and Weck-Hannemann, 2007; Kousky, Michel-Kerjan, and Raschky, 2013). Redevelopment patterns in the aftermath and incentives for self-protection/self-insurance behavior also may change in response to public investment in disaster protection (Kousky, Luttmer, and Zeckhauser, 2006). The investment in federal levee systems in the early 1930s in the United States was found to limit private out-migration responses from flood-prone regions (Boustan, Kahn, and Rhode, 2012). The City of New Orleans provides another good illustration of how various public protection policies could promote "unwanted " concentrations of population and the development in highly vulnerable and hazardous areas. Historically, many urban development policies were implemented after major floods or hurricanes including the construction of new levees, raising existing levees, and subsidizing insurance, just to name a few. These federal policies resulted in unintended urban sprawl and the development of swamp and marshy areas in New Orleans (Burby, 2006).

Although studies of adjustment patterns at the aggregate level provide important insights about general recovery paths, they do not capture heterogeneity in adjustments within impacted communities, as these details are often lost in the level of aggregation. To understand the heterogeneity of these effects, some elements to consider include historical perspectives, the socio-economic context of a community, and the exposure level. Among the natural disasters experienced and subsequently examined in prior studies, Hurricane Katrina unarguably was one of the largest natural catastrophes in the U.S. and deserves specific attention. Of the approximately 1.5 million individuals aged 16 and over who were evacuated as a result of Katrina, 75 percent were residents of Louisiana (Elliott and Pais, 2006; McIntosh, 2008). Many of these victims remain geographically dispersed (Deryugina, Kawano, and Levitt, 2014). A few studies have explored the economic and demographic impacts of Katrina for the entire city, but they did not explore

[1]Cavallo and Noy (2011) and Kousky (2014a) provide a comprehensive review of the disaster related economic literature.

adjustment patterns for specific areas within the city. Deryugina, Kawano, and Levitt (2014) found that Katrina had transitory effects in terms of income earning, while no discernable changes were found for decisions regarding divorce or child-bearing. Long-term household adjustments to natural disasters are not well documented within a city at a smaller spatial scale, across damaged and undamaged block groups and planning neighborhoods. Knowledge of the spatial redistribution of households of different demographic and socio-economic backgrounds in cities post-disaster is important and provides needed guidance about how different public, private, and community-level efforts can be combined to address emergent challenges and issues associated with disaster recovery. To fill this gap in the literature, we hypothesize that socioeconomic and demographic heterogeneity explains household long-term behavioral responses. Adjustment patterns within a city are influenced by the spatial distribution of impacts and resource availability, which could greatly depend on the allocation of public relief and recovery efforts across zoning and planning districts in post-Katrina New Orleans.

Economic historians studying urban recovery from catastrophes highlight that cities declining before catastrophic incidents, like New Orleans, may experience challenges to full recovery (Vigdor, 2008). The primary argument for a slow recovery is that houses in declining areas tend to be valued below their replacement costs, making it expensive to rebuild. While a city like New Orleans may not recover to its pre-disaster level, research has found that the city's slow recovery can be largely attributed to the uneven distribution of recovery funds across neighborhoods and a lack of private investment incentives in historically depressed areas (Green, Bates, and Smyth, 2007; Nance et al., 2011; Baade, Baumann, and Matheson, 2007; Gotham, 2008; 2012; 2014). Gotham and Campanella (2013) argued that impediments are due to modest changes in ethno-racial diversity and social vulnerability across the city's neighborhoods between pre- and post-Katrina years. While the historically largely segregated city has made significant efforts to rebuild and reinvest, it still remains racially and socially segregated and further predisposed to future disastrous vulnerability.

In terms of return and migration behavior, studies following Katrina victims within a year or two after the incident showed that low-income individuals and the black population with low levels of education were less likely to return relative to the white population (Groen and Polivka, 2008). Consistent with these findings, Landry et al. (2007) suggested that residents with higher income and who owned homes were more likely to return. On the contrary, Elliot and Pias (2006) found that among a group of 1,200 survivors, lower-income home owners were more likely to return compared to affluent homeowners. While survey results remain inconsistent, a long line of studies suggest that long-term adjustments are tied to financial and economic capability, and a lack of resources may present an impediment to return behavior for economically disadvantaged groups in the population. However, due to lower housing rents and a temporarily depressed housing market, these segments of the population may move into previously damaged areas with limited self-insurance/self-protection responses. Understanding disaster-induced migration is important because these adjustments (e.g., permanent out-migration, forced displacement, relocation, and limited adaptive behavior) may reshape the socio-economic composition of the impacted areas in the long-term. Hornbeck (2012) suggested that the persistent and long-lasting impact of the Dustbowl in the Midwest was due to permanent loss of population and diverted in-migration into the impacted counties.[2] Evidence from the 1927 Mississippi flood and levee break also indicates

[2]Studies suggest that small island economies remain vulnerable to hurricanes and tsunamis for extended periods and never rebound due to permanent population loss (Lynham, Noy and Page, 2012; Coffman and Noy, 2012; Silbert and Useche, 2011).

increased out-migration of the black population from flooded counties in the South and sectoral reallocation of labor (Hornbeck and Naidu, 2014).

Methodologically, our paper closely follows the approach by Smith et al. (2006) who studied households' long-term adjustments to Hurricane Andrew in Dade County, Florida. The main finding of that study was that adjustments were primarily driven by financial ability to rebuild and relocate; however, the study did not account for the differences in adjustment driven by recovery and public relief efforts across neighborhoods. Our paper is an extension of extensive sociological research conducted in post-Katrina New Orleans and, in particular, of the studies by Gotham and Campanella (2013) and Nance et al. (2011) on ethno-racial and income disparity in pre- and post-Katrina New Orleans. An important extension is that we employ an empirical model to study adjustment patterns at the block group level in response to damages caused by Hurricane Katrina, as opposed to merely comparing pre- and post-incident differences in economic and demographic indicators. Additionally, we explore adjustment not only across race/ethnicity and income levels, but also across different levels of educational attainment and the distribution of housing by value and tenure. To isolate the effects of damages from the effects of public recovery efforts, we further control for differences in adjustments across New Orleans's 13 planning districts that are likely due to pre-existing socio-economic disparities and discrepancies in public recovery and planning efforts, highlighted by scholars in prior literature (Gotham and Campanella, 2013; Nance et al., 2011). To capture an error correlation for each set of equations by household category, which may come from unobserved economic conditions and public policies that influence changes in income, educational attainments, racial composition, and housing values, between pre- and post-Katrina periods, we employed the seemingly unrelated regressions, or SUR, model developed by Zellner (1962). When error terms are correlated in a system of different equations, the classical least squares estimates from a single equation model, a common estimation strategy employed to study disaster adjustments, leads to inefficient results; however, SUR can produce unbiased and efficient estimates by jointly estimating the set of equations (Zellner, 1962).

3. DATA DESCRIPTION

Data for this study came from a variety of different sources. Demographic and socio-economic variables at the block group level in Orleans Parish for the years 2000 and 2012 were drawn from Census Summary Files 1 and 3 (U.S. Census Bureau, 2013a; 2013b).[3] Similar to the framework of Smith et al. (2006), we calculate the share of households with various characteristics, including race/ethnicity, gender, and educational attainment, as well as the distribution of houses in different value brackets and housing tenure by ethnicity/race in 2000 (pre-disaster) and 2012 (post-disaster). Using this data, we can calculate the changes in these variables over the two periods. Back-to-back comparison of summary tables ensured that the variables reported in 2000 were compatible with those in the American Community Survey (ACS) 2012 tables. The majority of the tables were identical. Some economic variables, such as distribution of income and housing value, had more categories in 2012 than in 2000, and those categories were collapsed to match the 2000-level categories. In addition, there were changes in the block group boundaries between 2000 and 2012. The number of block groups had increased from 418 to 495 in that time. Sets of area

[3] Pre-2005 Census Block Group level data are available only for decennial census years, which ceased after 2000. Since single-year data at the block group level is not available after 2000, we use five year ACS data from 2008 to 2012 to represent the five year average during this time period. In the text, 2012 data is referred to as 2008-2012 five year ACS data.

weights based on 2000-level block group areas were applied to the model variables to make observations consistent across years.[4]

In categorizing the damage variables, we used average flood-depth data by block group obtained from the Louisiana Geographic Information Center (LAGIC, 2016).[5] Given that flood depth and property damage may exhibit a nonlinear relationship, similar to Gotham and Campanella (2013), we created four different categories of damages: (i) low damage with flood depth less than 0.5 feet; (ii) medium-low damage with mean flood depth between 0.5 and 3 feet; (iii) medium-high damage with flood depth between 3 and 5 feet; and (iv) extensive damage with mean flood depth equal or greater than 5 feet. Figure 1 shows the final distribution of block groups by each damage category. Approximately, 161 block groups were delineated as extensively damaged areas with mean flood depth at 5 feet or over. A total number of 101 and 102 block groups were identified with low- and high-medium flood depth in the sample, respectively. Low or no water depth levels ("less damaged areas") were associated with 121 block groups and this category represents the reference category. We verified damage distribution with other damage indicators reported for Orleans Parish, including individual house damage assessment percentages, as well as zip-code level damages measured by dollar value reported by FEMA.[6]

Flood zone areas were calculated using FEMA advisory base flood-alleviation maps for Orleans Parish (FEMA, 2013). For each census block group, we calculated the share of AE flood zone areas by intersecting floodplain maps with census block group maps. As discussed, the AE floodplain zone captured existing flood risk and helped us uncover heterogeneity in adjustments to *ex-ante* flood risk information indicated by those areas subject to inundation by the 1-percent-annual-chance flood event. Insurance is commonly mandated for houses located in 100-year floodplains if they are financed by federally regulated or insured lenders. Table 1 reports the summary statistics of all the variables for this analysis.

Finally, planning district data for the City of New Orleans were obtained from the Data Center (2016a), which provides a multitude of data and resources about southeast Louisiana. The New Orleans City Planning Commission created 13 unique planning districts complied from "unofficial neighborhoods" of the city in 2006 in response to Katrina's devastation. The Comprehensive Zoning Ordinance (CZO) governs and sets urban design standards and regulations for each zoning district and regulates the management of land use permits, height limits, and setback requirements, along with other operational rules (City of New Orleans, 2016). Figure 1 depicts these planning districts.

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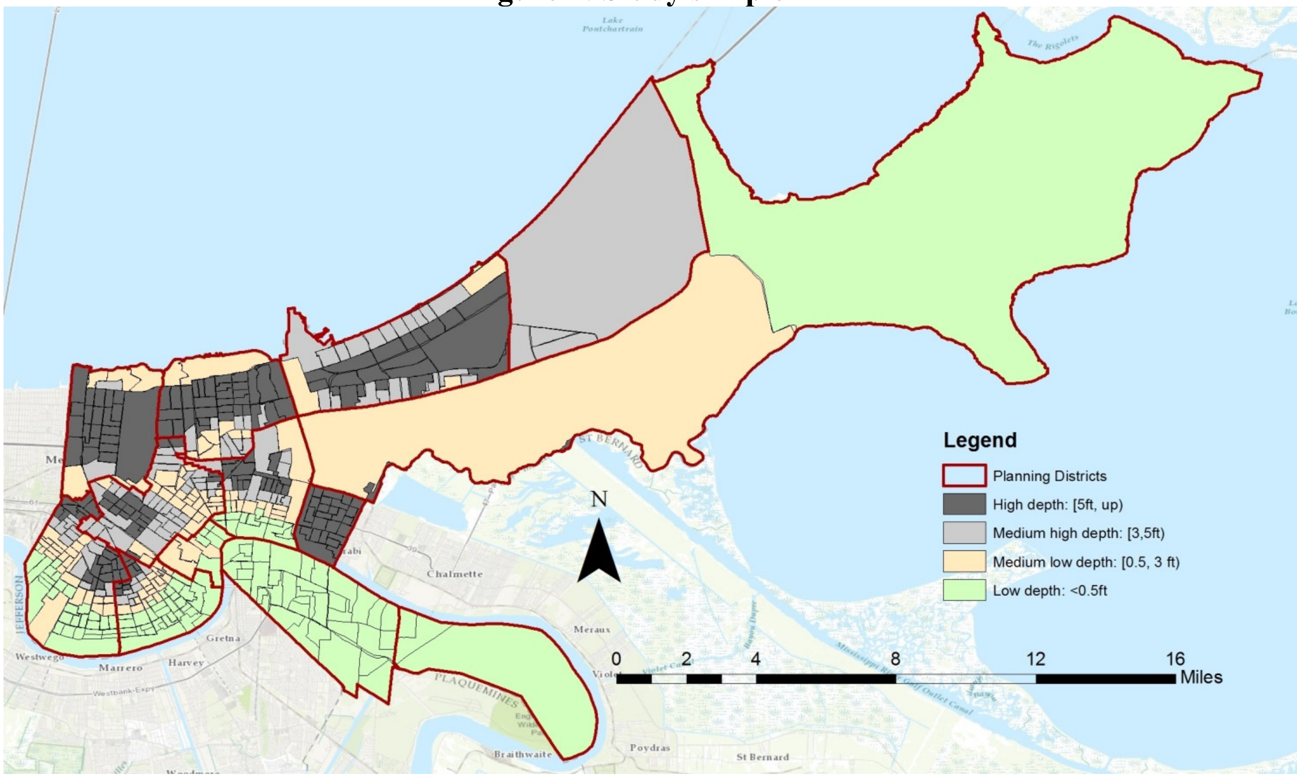
[4] We also conducted a sensitivity test by using area weights based on 2012 block groups. Results are consistent. Results using the alternative area weight are available upon request.

[5] The authors are grateful to Dr. Joshua Kent for sharing Katrina flood water depth data

[6] Individual housing damage data were available from the City of New Orleans website (City of New Orleans, 2013). This dataset reported damage percentages for each residential home. Damage data contained "overall percent" of the house being damaged as well as percent of damages by housing attributes such as foundation and basement, roofing, interior, floor, electrical, and other parts. Relying on this data, however, was deemed questionable given the strong incentives to misreport damages and, in particular, to report them at lower than the 50percent level. This is because houses with damages of 50percent or more were required to be raised above the highest adjacent grade, or 3 feet if in levee-enclosed areas (Kates et al., 2006). Complying with these requirements was associated with substantial reconstruction costs, which appeared to exceed in most parts housing assistance relief given at the pre-disaster value of the property. To further validate the distribution of damages across block groups used in our model, we also used the distribution of damages from FEMA's zip-code level damage assessment. The results of these models were comparable to the ones presented in the paper and are available from the authors upon request.

Figure 1: Study sample



Source: LAGIC (2016); Authors.

4. EMPIRICAL MODEL

This section describes an empirical approach employed to examine households' adjustments to Katrina-induced damages. The model is specified in Equation (1)

$$(1) \qquad y_{j,t=2012}^{k} - y_{j,t=2000}^{k} = \beta_0 + \beta_1 y_{j,t=2000}^{k} + \beta_2 D_j + \beta_3 Risk_j + \mu_Z + \epsilon_j$$

where $y_{j,t}^{k}$ represents the proportion of households of type k in census block group j in time period t. Household type k includes race/ethnicity (e.g. whites, blacks, Hispanics or Latinos), educational attainment, income class, housing value, and housing tenure. D_j is the vector of indicator variables corresponding to three different categories of damages: (i) medium-low; (ii) medium-high; and (iii) high. Low flood depth is omitted as the reference group. Each of these categories equals one if the average flood depth level in the block group is within the flood depth bin defined in the data description section, but zero otherwise. By examining adjustments in response to various categories of damages, we are able to capture heterogeneous responses driven by hurricane-induced damages relative to less-damaged block groups (an omitted category in the model). $Risk_j$ is the flood risk represented by the area of AE floodplain zones. AE floodplains are called special flood hazard areas and are subject to a 1 percent-annual-chance of flood. The parameter associated with the flood risk variable (β_3) captures the perception of a household's *ex-ante* flood risk, as well as the potential effect of flood insurance requirements for properties financed by federally regulated or insured lenders and located in these flood hazard zones.

Table 1: Summary Statistics

Variable Name	Shares in 2000 Mean	Std. Dev	Min	Max	Change between 2012 and 2010 Mean	Std. Dev	Min	Max
High School degree or less	0.509	0.223	0.036	0.987	-0.051	0.225	-0.926	1.397
Some College	0.243	0.082	0	0.486	0.030	0.194	-0.374	1.760
College Degree	0.142	0.109	0	0.484	0.038	0.211	-0.337	3.849
Graduate Degree	0.106	0.113	0	0.581	0.032	0.192	-0.523	3.436
College Degree & Higher	0.248	0.211	0	0.895	0.069	0.374	-0.648	7.286
Income, less than 15K	0.322	0.181	0	0.864	-0.066	0.217	-0.819	2.397
Income, 15-25K	0.162	0.074	0	0.368	-0.006	0.143	-0.343	0.819
Income, 25-35K	0.132	0.064	0	0.463	-0.008	0.134	-0.350	0.710
Income, 35-50K	0.136	0.071	0	0.404	-0.005	0.133	-0.304	0.894
Income, 50-75K	0.120	0.078	0	0.397	0.024	0.132	-0.316	0.860
Income, 75-100K	0.052	0.052	0	0.309	0.030	0.103	-0.215	1.135
Income, 100-125K	0.026	0.037	0	0.35	0.026	0.099	-0.350	1.335
Income, 125K & up	0.050	0.093	0	1	0.048	0.173	-0.710	3.025
White	0.306	0.335	0	1	0.034	0.445	-0.975	8.788
Black	0.653	0.350	0	1	0.001	0.317	-1.000	2.612
Asian	0.014	0.045	0	0.481	0.005	0.080	-0.481	1.467
Other race	0.024	0.028	0	0.155	0.008	0.097	-0.143	1.399
White, owner occupied	0.370	0.364	0	1	0.013	0.470	-0.955	9.115
Black, owner occupied	0.604	0.373	0	1	0.004	0.320	-1	2.543
White, renter occupied	0.314	0.350	0	1	0.006	0.419	-1	7.353
Black, renter occupied	0.651	0.368	0	1	-0.007	0.377	-1	2.395
Latino, owner occupied	0.026	0.046	0	0.346	0.010	0.077	-0.3	0.592
Latino, renter occupied	0.035	0.055	0	0.5	0.011	0.114	-0.5	1.125
Total, owner occupied	0.459	0.235	0	1	0.032	0.372	-0.899	6.104
Total, renter occupied	0.507	0.234	0	1	0.000	0.291	-0.979	3.639
Total, vacant	0.123	0.088	0	0.655	0.114	0.183	-0.655	1.208
House value, less than 40K	0.113	0.163	0	1	-0.061	0.192	-1	1.421
House value, 40-100K	0.537	0.300	0	1	-0.345	0.311	-1	1.211
House value, 100-250K	0.263	0.257	0	1	0.220	0.451	-1	2.427
House value, 250-400K	0.048	0.095	0	0.497	0.138	0.229	-0.395	2.050
House value, 400-500K	0.014	0.043	0	0.409	0.022	0.087	-0.242	1.129
House value, 500K & up	0.025	0.083	0	0.615	0.058	0.263	-0.563	5.221
Share of AE zones	0.246	0.289	0	1				
Dummy for low depth	0.249	0.433	0	1				
Dummy for medium-low depth	0.208	0.406	0	1				
Dummy for medium-high depth	0.210	0.408	0	1				
Dummy for high depth	0.332	0.471	0	1				

Notes: Total number of sample observations is 483. All model dependent variables represent the share of households in a specified category out of the total number of households, weighted by block group area in the year 2000. AE zones represent shares of special flood hazard areas subject to 100-year flood inundation out of total block group area.

The model also includes 13 different neighborhood planning district (z) dummy variables represented by μ_Z. These district indicators control for differences across districts that are time invariant including differences in public recovery responses, post-disaster planning and regulations related to land-use permits and heights; and setback requirements by each planning district. ϵ_j is a random error term and is assumed to be normally distributed. Error terms may be correlated within each planning district because of unique socio-economic profiles, unified public recovery efforts, and local risk management within planning districts. We thus cluster errors by planning districts. Furthermore, we estimate multiple models presented in equation (1) that differ from each other by dependent variable. The omitted information entered into the error terms across equations within a system of the same household type (e.g., type by income bracket, educational attainment, ethnicity and race, etc.) is likely to be correlated due to common unobserved shocks to households of the same type. For example, for a set of equations by income bracket, the unobservable characteristics that influence changes in the share of households by income class between 2000 and 2012 could come from common economic conditions and public policies. To account for error correlations across equations within the system and to improve efficiency of the model, we used seemingly unrelated regression (SUR) models (Zellner, 1962; Wooldridge, 2010).

5. RESULTS

Tables 2 through 9 report regression results for models defined in equation (1); column headings indicate the change in the dependent variable of interest. All models include initial values of the dependent variable for the year 2000, three different categories of damage variables, as well as areas of AE floodplains and the 13 Planning District dummies.[7]

5.1 Adjustment by Race/Ethnicity and Tenure

Results associated with the racial/ethnic composition of households by housing tenure are reported in Table 2. We see in this table that the number of both black homeowners and renters has increased significantly across all three damage categories relative to less damaged block groups. On the contrary, the number of white homeowners and white renters decreased in severely and moderately damaged areas relative to less damaged block groups. The share of Hispanic homeowners also declined in damaged block groups, while a statistically significant decline in the share of Hispanic renters is only found in medium-high damaged block groups.

Table 2: Owner & Renter Occupied Homes, by Race

	Proportion, White		Proportion, Black		Proportion, Hispanic	
	Owner Occupied	Renter Occupied	Owner Occupied	Renter Occupied	Owner Occupied	Renter Occupied
Medium damage, low	-0.306**	-0.271**	0.201***	0.171***	-0.043***	-0.013
	(0.149)	(0.124)	(0.058)	(0.064)	(0.009)	(0.016)
Medium damage, high	-0.376***	-0.355***	0.180***	0.221***	-0.028**	-0.035**
	(0.145)	(0.118)	(0.057)	(0.066)	(0.014)	(0.017)
High damage	-0.351***	-0.301***	0.251***	0.210***	-0.023*	-0.020
	(0.128)	(0.107)	(0.067)	(0.068)	(0.012)	(0.019)
AE zone	-0.064	-0.038	-0.134**	-0.069	0.028*	-0.022
	(0.081)	(0.072)	(0.062)	(0.062)	(0.017)	(0.019)
Initial	-0.370***	-0.443***	-0.301***	-0.387***	-0.701***	-0.827***
	(0.072)	(0.074)	(0.054)	(0.057)	(0.074)	(0.075)
Planning District	Y	Y	Y	Y	Y	Y
χ^2 (12)	721.37***	347.56***	2045.98***	599.34***	337.06***	3791.97***
N	472	472	472	472	472	472
RMSE	0.459	0.404	0.288	0.339	0.066	0.099
R^2	.051	.078	.174	.189	.262	.251
χ^2	81.12***	121.39***	118.99***	123.27***	214.08***	201.56***

* p<.1; ** p<.05; *** p<.01; bootstrapped standard errors in parenthesis (rep. 1,000). Column headings correspond to the dependent variable used in the estimation and represents the difference between 2012 and 2000. Initial value indicates that models include initial values of dependent variables. Letter Y indicates that the model includes planning district dummies. Chi-square (12) is the statistic associated with joint significance test of planning district dummies; includes constant term.

[7] As a robustness check, models without initial values of the dependent variable on the right hand side (RHS) were also estimated and the results are largely consistent.

The effect of *ex-ante* flood risk as captured by AE flood zones remains insignificant for white homeowners and for renters of all race/ethnic groups. Black homeowners tend to avoid these risky flood zones, as shown by the significantly negative coefficients associated with the AE zone variable, while Hispanic homeowners increased in AE flood-zones, suggested by positively significant, however marginal, coefficient associated with AE zone in the model.

We used planning-district fixed effects to capture differences in adjustment due to potentially uneven distribution of recovery efforts across these districts. In Table 3 we report coefficients associated with different planning districts from models presented in Table 2 for black and white homeowners and renters.[8] The coefficients reported for individual planning districts are interpreted relative to omitted district. We omitted the New Aurora district because is a district that was almost fully repopulated about 90-99 percent of district residents is now receiving mail at their district homes (The Data Center, 2016b).

Table 3: Adjustments of Housing Tenure by Planning Districts and Race

	White		Black	
	Homeowner	Renter	Homeowner	Renter
French Quarter/CBD	0.440***	0.521***	-0.347***	-0.409***
	(0.139)	(0.089)	(0.050)	(0.104)
Central City/Garden District	0.274***	0.388***	-0.347***	-0.393***
	(0.060)	(0.056)	(0.049)	(0.050)
Uptown/Carrollton	0.467**	0.583***	-0.363***	-0.445***
	(0.182)	(0.153)	(0.049)	(0.051)
Midcity	0.369***	0.469***	-0.396***	-0.451***
	(0.125)	(0.107)	(0.078)	(0.075)
Lakeview	0.585***	0.642***	-0.540***	-0.609***
	(0.187)	(0.161)	(0.085)	(0.090)
Gentilly	0.249*	0.293***	-0.223***	-0.214***
	(0.129)	(0.106)	(0.063)	(0.070)
Bywater	0.253***	0.403***	-0.319***	-0.379***
	(0.098)	(0.079)	(0.095)	(0.069)
Lower 9th Ward	0.282***	0.330***	-0.316***	-0.542***
	(0.108)	(0.094)	(0.076)	(0.200)
New Orleans East	0.227*	0.342***	-0.053	-0.152
	(0.118)	(0.101)	(0.126)	(0.165)
Village de l'Est Area	0.575***	0.487***	-0.342***	-0.021
	(0.123)	(0.102)	(0.054)	(0.066)
Viavant/Venetian Isles	0.394***	-0.111*	-0.481***	-0.381***
	(0.083)	(0.059)	(0.051)	(0.042)
Algiers	0.026	0.126***	0.020	-0.028
	(0.040)	(0.040)	(0.057)	(0.069)
N	472	472	472	472
RMSE	0.459	0.404	0.288	0.339
R^2	.051	.078	.174	.189
χ^2	81.12***	121.39***	118.99***	123.27***

* p<.1; ** p<.05; *** p<.01; bootstrapped standard errors in parenthesis (rep. 1,000). Column headings correspond to the dependent variable used in the estimation and represents the difference between 2012 and 2000. Omitted district in New Aurora; district-specific coefficients are interpreted relative to omitted district. The coefficients for damage, AE zones and initial values for dependent variables are suppressed as they are presented in Table 2; includes constant term.

[8]The full set of results associated with planning district fixed effects for all models presented in the paper are available from the authors upon request.

As suggested by the coefficients associated with individual planning districts, New Aurora has the largest share of black homeowners and renters, and shares of this group are significantly lower in almost all districts relative to New Aurora. On the other side, shares of white homeowners have increased in almost all planning districts relative to the New Aurora District. These ethno-racial adjustments across planning districts conform in general to the ethno-racial composition of post-Katrina New Orleans as a whole. As highlighted in Gotham and Companella (2013), while repopulation and rebuilding in New Orleans have been slow and the city still remains a primarily black city, post-Katrina New Orleans has a greater proportion of white individuals (both homeowners and renters) than before the incident.

Table 4 reports regression results related to changes in the only racial composition of the population due to the devastation induced by Hurricane Katrina and shows an adjustment pattern similar to that reported in Table 2. Positive and significant coefficients associated with medium-low and high damage variables in the model for the proportion of the black population suggest that this segment of the population has increased significantly across these categories in damaged block groups relative to less damaged ones. Furthermore, this racial/ethnic group, along with Asians, also appears to avoid AE flood zones. We find a statistically significant decline in the proportions of both the white and Asian population in severely damaged block groups relative to less damaged areas, and no significant changes among other race/ethnicity.

Changes in total housing stock are presented in Table 5. They indicate no statistically significant changes in owner-occupied and renter-occupied housing units across medium-low and medium-high damaged and less damaged block groups between pre- and post-Katrina conditions. But we did find a statistically significant increase in vacant homes in heavily damaged block groups, which suggests lack of overall return behavior of population in these heavily devastated block groups.

Table 4: Racial Population Adjustment

	White	Black	Asian	Other Race
Medium damage, low	-0.185*	0.131**	-0.022***	-0.016
	(0.104)	(0.061)	(0.007)	(0.011)
Medium damage, high	-0.232**	0.124	-0.013*	-0.009
	(0.091)	(0.094)	(0.007)	(0.012)
High damage	-0.206***	0.179*	-0.001	0.007
	(0.080)	(0.093)	(0.011)	(0.016)
AE zone	-0.044	-0.085*	-0.023*	-0.013
	(0.069)	(0.048)	(0.012)	(0.022)
Initial	-0.112*	-0.251***	-0.117	-0.811***
	(0.065)	(0.052)	(0.507)	(0.136)
Planning District	Y	Y	Y	Y
χ^2 (12)	113.80***	65.07***	3175.67***	214.73***
N	483	483	483	483
RMSE	0.433	0.287	0.068	0.093
R^2	.053	.180	.274	.079
χ^2	26.83*	105.61***	182.07***	39.89***

* $p<.1$; ** $p<.05$; *** $p<.01$; bootstrapped standard errors in parenthesis (rep. 1,000). Column headings correspond to the dependent variable used in the estimation and represents the difference between 2012 and 2000. Initial value indicates that models include initial values of dependent variables. Letter Y indicates that the model includes planning district dummies. Chi-square (12) is the joint significance test of planning district dummies; includes constant term.

Table 5: Housing Tenure

	Vacant	Owner-Occupied	Renter-Occupied
Medium damage, low	-0.007	-0.090	0.029
	(0.028)	(0.089)	(0.064)
Medium damage, high	0.025	-0.139	0.021
	(0.027)	(0.088)	(0.062)
High damage	0.110***	-0.102	0.049
	(0.034)	(0.091)	(0.054)
AE zone	-0.070*	-0.011	-0.130***
	(0.039)	(0.064)	(0.045)
Initial	-0.813***	-0.146	-0.450***
	(0.110)	(0.110)	(0.083)
Planning District	Y	Y	Y
χ^2 (12)	273.21***	389.62***	32.65***
N	482	482	482
RMSE	0.163	0.363	0.274
R^2	.205	.042	.112
χ^2	134.12***	18.99	72.08***

* *p*<.1; ** *p*<.05; *** *p*<.01; bootstrapped standard errors in parenthesis (rep. 1,000). Column headings correspond to the dependent variable used in the estimation and represents the difference between 2012 and 2000. Initial value indicates that models include initial values of dependent variables. Letter Y indicates that the model includes planning district dummies. Chi-square (12) is the joint significance test of planning district dummies; includes constant term.

5.2 Adjustment by Educational Attainment and Income

In Table 6 we report adjustments by educational attainment. Results indicate that the share of individuals with a high school degree or less increased in medium-low damaged areas relative to less damaged areas, however the effect is only significant at 10 percent significance level. Similarly, our findings confirm that less educated individuals tend to move into heavily damaged census block groups. On the contrary, the shares of the population with college and graduate degrees as well as combined college degrees and higher significantly decreased across all types

Table 6: Educational Attainment

	Prop. with High School and less	Prop. with some college	Prop. with College Degree	Prop. with graduate degree	Prop. with college degree and higher
Medium damage, low	0.093*	-0.004	-0.147**	-0.109**	-0.255**
	(0.052)	(0.036)	(0.058)	(0.048)	(0.104)
Medium damage, high	0.065	0.010	-0.158***	-0.129**	-0.286***
	(0.065)	(0.047)	(0.051)	(0.052)	(0.100)
High damage	0.121**	0.066	-0.160***	-0.132***	-0.291***
	(0.059)	(0.049)	(0.052)	(0.049)	(0.097)
AE zone	-0.119***	-0.070*	-0.011	0.019	0.008
	(0.040)	(0.041)	(0.032)	(0.032)	(0.059)
Initial	-0.303***	-0.889***	-0.456***	-0.474***	-0.458***
	(0.072)	(0.109)	(0.113)	(0.119)	(0.114)
Planning District	Y	Y	Y	Y	Y
χ^2 (12)	2019.10***	346.72***	183.59***	48.76***	87.04***
N	483	483	483	483	483
RMSE	0.200	0.178	0.206	0.190	0.371
R^2	.219	.150	.500	.014	.011
χ^2	136.60***	108.90***	71.44***	65.67***	72.32***

* *p*<.1; ** *p*<.05; *** *p*<.01; bootstrapped standard errors in parenthesis (rep. 1,000). Column headings correspond to the dependent variable used in the estimation and represents the difference between 2012 and 2000. Initial value indicates that models include initial values of dependent variables. Letter Y indicates that the model includes planning district dummies. Chi-square (12) is the joint significance test of planning district dummies; includes constant term.

of damaged block groups relative to less damaged areas. AE flood zones exert a significantly negative effect only on the share of the population with a lower level of educational attainment.

Results presented in Table 7 show adjustments for households across different income brackets. Significant declines, indicated by negative and significantly significant coefficients associated with the damage variables in these models, are found for the shares of households with incomes $50,000 and higher in the damaged areas. This suggests that shares of both middle-income and affluent households have declined in heavily and moderately damaged areas relative to less damaged areas. Damage coefficients for low-income earners indicate the opposite effect; a statistically significant effect is only estimated for households with an income between $15,000 and $20,000. Households earning between $25,000 and $35,000 also increased in a statistically significant sense but only in the medium-high damaged areas. While the risk information conveyed by AE flood zones were largely statistically insignificant for almost all income groups, households in the lowest income category (below 15K) appeared to avoid AE flood zones.

5.3 Housing Adjustment

Table 8 reports regression coefficients from different variants of models in which the number of housing units varies by house value. The results reveal that the shares of homes with values of $40,000 to $100,000 increased in damaged block groups in a statistically significant manner, with the highest increase observed in medium-low damaged areas relative to less-damaged block groups. The share of homes valued below $40,000 and between $100,000 and $250,000 also show a statistically significant increase in medium-high damaged and high damaged block groups, relative to less damaged block groups, although no statistically discernable changes were observed in medium-low damaged areas. On the contrary, the share of homes in the $250,000-$400,000 and $400,000-$500,000 value brackets show a statistically significant decrease in all damaged block groups, while the shares of homes valued at $500,000 and above decreased in medium high and severely damaged areas in post-Katrina New Orleans. Changes across the house value distribution generally confirm the hypothesis that disasters adversely affect housing value and can have prolonged effects on housing markets. The effects of flood

Table 7: Distribution of Households by Income Level

	Less than 15K	15K – 24,999	25K – 34,999	35K-49,999	50K-74,999	75K – 99,999	100K-124,999	125K and up
Medium damage, low	0.057	0.045**	0.023	0.005	-0.056***	-0.046***	-0.060**	-0.083**
	(0.058)	(0.018)	(0.018)	(0.013)	(0.021)	(0.017)	(0.026)	(0.042)
Medium damage, high	0.027	0.065**	0.016	0.018	-0.057**	-0.039**	-0.054*	-0.116***
	(0.055)	(0.026)	(0.017)	(0.019)	(0.023)	(0.018)	(0.031)	(0.040)
High damage	0.07	0.055**	0.048**	0.026	-0.019	-0.050**	-0.036	-0.118***
	(0.049)	(0.023)	(0.021)	(0.023)	(0.026)	(0.020)	(0.033)	(0.042)
AE zone	-0.079**	-0.025	-0.038	-0.023	-0.034	0.012	-0.031	0.018
	(0.038)	(0.025)	(0.027)	(0.030)	(0.026)	(0.018)	(0.024)	(0.027)
Initial	-0.477***	-0.762***	-0.977***	-0.889***	-0.918***	-0.669***	-1.037***	-0.197
	(0.096)	(0.101)	(0.090)	(0.094)	(0.074)	(0.110)	(0.162)	(0.169)
Planning District	Y	Y	Y	Y	Y	Y	Y	Y
$\chi 2$ (12)	650.32***	1181.96***	82.00***	110.57***	657.84***	88.86***	305.66***	115.53***
N	482	482	482	482	482	482	482	482
RMSE	0.19	0.129	0.116	0.118	0.115	0.1	0.091	0.167
R^2	.233	.186	.244	.203	.234	.092	.149	.063
χ^2	142.87***	108.57***	161.17***	133.50***	170.13***	77.50***	124.70***	47.72***

* p<.1; ** p<.05; *** p<.01; bootstrapped standard errors in parenthesis (rep. 1,000). Column headings correspond to the dependent variable used in the estimation and represents the difference between 2012 and 2000. Initial value indicates that models include initial values of dependent variables. Letter Y indicates that the model includes planning district dummies. Chi-square (12) is the joint significance test of planning district dummies; includes constant term.

Table 8: Distribution of Housing Units by Value

	Less than 40K	40K-100K	100K - 250K	250-400K	400K-500K	500K and up
Medium damage, low	0.004	0.136***	0.080	-0.149***	-0.048***	-0.121
	(0.012)	(0.042)	(0.053)	(0.049)	(0.019)	(0.076)
Medium damage, high	0.030*	0.073*	0.142**	-0.217***	-0.057***	-0.147**
	(0.017)	(0.041)	(0.059)	(0.052)	(0.019)	(0.067)
High damage	0.048*	0.099**	0.197***	-0.174***	-0.060***	-0.139**
	(0.025)	(0.045)	(0.069)	(0.060)	(0.018)	(0.063)
AE zone	-0.041	0.025	-0.137**	-0.022	0.007	-0.020
	(0.045)	(0.042)	(0.056)	(0.047)	(0.015)	(0.041)
Initial	-0.909***	-0.780***	-1.068***	-1.018***	-0.913***	0.233
	(0.053)	(0.064)	(0.094)	(0.267)	(0.094)	(0.265)
Planning District	Y	Y	Y	Y	Y	Y
$\chi 2$ (12)	79.43***	408.15***	236.57***	193.16***	49.89***	32.31***
N	478	478	478	478	478	478
RMSE	0.126	0.212	0.293	0.214	0.080	0.251
R^2	.568	.532	.575	.125	.136	.091
χ^2	624.90***	567.03***	679.01***	137.78***	204.60***	47.07***

* $p<.1$; ** $p<.05$; *** $p<.01$; bootstrapped standard errors in parenthesis (rep. 1,000). Column headings correspond to the dependent variable used in the estimation and represents the difference between 2012 and 2000. Initial value indicates that models include initial values of dependent variables. Letter Y indicates that the model includes planning district dummies. Chi-square (12) is the joint significance test of planning district dummies; includes constant term.

zones on changes in the distribution of housing by house value do not show many statistically significant differences, except for homes valued between $100,000 and $250,000, for which the share appears to decline in AE zones.

6. DISCUSSION AND CONCLUSION

Findings reported in this paper provide important insights regarding households' adjustment patterns in Orleans Parish due to the devastation wrought by Hurricane Katrina in 2005. Our analysis indicates heterogeneity in adjustments across populations with different levels of educational attainment, racial/ethnic backgrounds, and income levels. Estimated adjustment patterns consistently suggest that lower-income and more resource-constrained households tend to move into damaged areas, likely due to lower rental and cheaper housing prices. Increases in the shares of less-educated individuals, households at the lower tail of the income distribution, and a general increase in low-valued housing after Hurricane Katrina in the most damaged areas suggest these patterns. Furthermore, adjustments across racial segments confirm mobility constraints for both black homeowners and renters. This is no surprise, given that the large concentration of black households are below the poverty line in Orleans Parish (Cutter et al., 2006).

Our results also suggest that flood risk information, as captured by AE flood zones which are areas subject to 100-year flood inundation, has few effects on adjustments across household types that are statistically detectable. Still, we found that the shares of the population with a high school diploma-only as well as high school dropouts, along with households earning less than $15,000, and black homeowners, declined in AE zones in a statistically significant fashion. Perhaps mandatory flood insurance and floodplain management standards applied in these areas drive away households who are financially constrained.

Comparing Katrina's impact with other previously recorded catastrophic incidents is very challenging due to not only the scale of devastation that potentially generated different responses, but also the pre-disaster socio-economic profile of Orleans Parish. The study of Smith et al. (2006)

comes closest in examining empirical adjustments to 1992's Hurricane Andrew in Miami-Dade County, Florida, the second costliest U.S. hurricane in history. While the scale of the impacts, overall socio-economic profiles, and the amenity/disamenity landscapes of the impact of the two hurricanes on the different counties are heterogeneous, adjustments across damaged block groups are somewhat consistent when it comes to economically disadvantageous and resource constraint households as well as less educated individuals. Consistently, middle-income households also moved away from damaged areas after Hurricane Andrew. Unlike the findings of Smith et al. (2006), who observed no changes in the share of wealthy households in Miami-Dade County after Hurricane Andrew, however, we found that Orleans Parish experienced a post-Katrina decline in the share of affluent households in damaged areas, which indicated that financial capability likely affected their relocation more than did rebuilding behavior.

When discussing the future of Orleans Parish and, particularly, the City of New Orleans, scholars underscore several mistakes in the public policy arena that can potentially lead to future levels of social vulnerability, similar to those that resulted in the catastrophic devastation in the first place. Some social programs and recovery policies, such as the Road Home program, have reinforced housing segregation, a lack of ethno-racial diversity, and social inequalities across neighborhoods (Nance et al., 2011; Gotham, 2014; Gotham and Campanella, 2011; Gotham and Greenberg, 2008). Related concerns have been raised about the efficacy of privatizing many disaster-related public services and urban recovery efforts after numerous reported failures of the Road Home program in New Orleans, managed by a private contractor (Gotham, 2012; Gotham and Greenberg, 2008). In addition, tensions over the roles of state and local governments in allocating public resources and federal disaster relief funds and deciding on the city's rebuilding and redevelopment patterns, as well as cultural differences—all deeply rooted reasons for historical schism—appear to have persisted in the post-Katrina era, slowing the city's recovery (Burns and Thomas, 2008).

The threat of rising sea levels and other climate-induced hazards pose growing challenges for many coastal communities, including Orleans Parish (Kousky and Cooke, 2010; Kousky, 2014b; IPCC, 2012; Walsh et al., 2014; Mendelsohn et al., 2012). Adjustments across damaged block groups, as confirmed by our research, and in particular an estimated increase of poorer, less-educated, and predominantly African-American population in previously damaged areas, indicate that some vulnerable hotspots may still remain after Hurricane Katrina.

Exploiting neighborhood and location-specific sources of resilience, such as neighborhood associations, capitalizing on emergent networks and ties with external agencies and nonprofit organization after major events, and using existing social capital may be far more important than traditional public disaster aid for rapid recovery of some of the historically segregated communities in Orleans Parish (Nance et al, 2011; Gafford, 2010). Public efforts could also aid and specifically focus on either revitalizing socially vulnerable and poorer neighborhoods with segregated housing, or assisting gradual retreat of the vulnerable population from hazardous hotspots in order to improve community resilience and reduce vulnerability and exposure from future natural disasters.

New Orleans has permanently lost population, likely those who are more mobile such as educated and wealthy individuals. A decline in human capital may have enduring socio-economic implications for Orleans Parish and provide a positive spillover to other areas experiencing an influx of high-skilled labor. Understating spillover effects of brain drain/gain will be an interesting future extension of the present study.

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