WORKING PAPER

Breakup of New Orleans Households after Hurricane Katrina

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ABSTRACT

The resilience of family and household structure to displacement-inducing natural disaster is investigated. Households from a survey that traces the outcomes of a population-representative sample of households in New Orleans before Hurricane Katrina are compared statistically to households from a national sample. Household breakup following Katrina was extremely high among extended-family households, exacerbated by the high prevalence of extended-family households in New Orleans before the hurricane. While the highest rates of household breakup occurred among households whose residences were made uninhabitable by the Hurricane and its aftermath, city-wide impacts on household breakup were found.

INTRODUCTION

While short-term evacuation induced by a natural disaster is a relatively common occurrence, long-term displacement of a population is extremely rare. One of the domains of impact of long-term displacement of a population is likely to be the breakup of households. Some of the population will be placed directly at risk of household breakup by being forced out of their home. Others will be placed indirectly at risk through the sudden loss of the socio-economic infrastructure and opportunity, including business and employment, in their community. Both circumstances may result in the moving out of at least one household member or the splitting up of the household. In the present study, I estimate and analyze the incidence of household breakup among the people who were living in the City of New Orleans at the time Hurricane Katrina struck at the end of August 2005. Household breakup is measured between then and 13 to 15 months later. Intactness or breakup of households is investigated irrespective of whether the individuals had returned to New Orleans following evacuation or had resettled elsewhere in the U.S. The intactness of households both in housing units or neighborhoods made inhabitable and in less affected housing units or neighborhoods is investigated. Three main research questions are addressed. First, how did the incidence of household breakup in New Orleans differ from that normally experienced in the U.S. over a similar time period? Second, were higher than normal rates of household breakup largely confined to those households from residences and neighborhoods experiencing major physical damage? Third, were both nuclear and extended New Orleans households subjected to higher than usual rates of breakup?

These questions are addressed by applying a treatment-control analytical framework to data from a survey of New Orleans households (the Displaced New Orleans Residents Pilot Study, DNORPS) and from a national panel survey of households (the Survey of Income and

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Program and Participation, SIPP) over a comparable period. In addition, Census and micro-census (American Community Survey, ACS) data are used both to evaluate the representativeness of the DNORPS and to provide more efficient estimates of the structure and character of its households before Hurricane Katrina.

LITERATURE REVIEW

In this literature review, I first address conceptual issues around the nature and measurement of population displacement and evacuation, and then describe what is known already about the evacuation of and displacement from New Orleans following Hurricane Katrina. I then go on to review literature on household breakup under disaster and normal conditions.

Evacuation versus displacement

Two terms are commonly used to describe the mass movement of people from their homes (Oliver-Smith 2006, p.3): *Evacuation* refers to the "removal of people from harm's way"; while *Displacement* refers to "the uprooting of people from a home ground." In the broader literature of large-scale population movements, natural disasters are the archetypal case of movement of the "evacuation" type, while "displacement" has usually been reserved for mass movement due to armed conflicts, land expropriations, and gradual environmental deterioration. Bates (2002) is typical in characterizing natural disasters are as "Acute disruptions …[that] produce short-term refugees from a geographically limited area" (p.469). The nature of movement out of New Orleans after Katrina, however, requires a break with existing typologies of evacuation and displacement (Picou and Marshall 2007). In terms of evacuation, the scale of Katrina's was large but not unprecedented. As recently as 2004, approximately 1.4 million people were

evacuated in advance of Hurricane Frances hitting Florida. Almost all of the residents of New Orleans left the city, following both the declaration of a mandatory evacuation and the large-scale infrastructural damage that made continued residence infeasible even among those who refused to evacuate. Nigg et al (2006, p.113) describe the evacuation of the Gulf Coast areas in the path of Hurricane Katrina as numbering 1.3 million. They remark on two aspects of the Katrina evacuation, however, that merit the term "unprecedented": the sending of evacuees to distant, out-of-state shelters; and the duration of the evacuation into "weeks or months" instead of the usual duration measured in "days or a couple of weeks at most" (p.121). Elliot and Pais (2006, p.302) report that within two weeks, temporary shelters for Hurricane Katrina evacuees had already been established in 24 states and the District of Columbia. Added to this has been the dependence of New Orleans evacuees on public institutions and polity to restore their pre-storm housing and neighborhood infrastructural services. The ability and willingness of these institutions protect or restore this infrastructure have both been challenged (Henkel, Dovidio, and Gaertner 2006; O'Neill 2008).

Even the largest of the relatively frequent major hurricanes that have struck the Gulf Coast in recent decades had relatively little long-term effect in terms of numbers of permanently displaced people. In a study of population displacement from Dade County due to Hurricane Andrew, Smith and McCarty (1996) estimated that 353,300 residents of Dade County were at least temporarily displaced from their pre-hurricane homes by Hurricane Andrew. Of these, only 39,200 people were estimated to have left the county permanently because of the storm, with as many as half of these moving only as far as to neighboring Broward County. The loss of a major employer, an air force base, may have been the main cause of this. Displacement due to Hurricane Andrew was therefore overwhelmingly short-term and local in character.

The geographic character of the evacuation of New Orleans in the wake of Hurricane Katrina clearly influenced the social geographic character of its longer-term displacement. Race and income strongly differentiated the locations of the evacuated Katrina population. Among studies describing the populations evacuated from New Orleans in the first weeks and months of 2005, Houston, Texas accounted for a disproportionate share of African Americans evacuated from New Orleans, with Houston's Reliant complex having been made available for a mass transfer of evacuees from New Orleans' Superdome and Convention Center (see also Brodie et al 2006). Frey, Singer and Park's (2007) analysis of national data in the 2006 American Community Survey (ACS) builds an important link between evacuation and longer-term displacement of New Orleans residents. They find that Houston accounted for a far larger proportion of displaced blacks than of displaced whites up to a year later. Displaced whites were much more likely to have moved within Louisiana and especially within the New Orleans metropolitan area. Frey et al's supplementary analyses of IRS data find that distant movers from New Orleans had lower incomes than did local movers. Landry et al (2007) found that lower-income evacuees to Houston were less likely to intend to return than were middle-income evacuees. The more disadvantaged characteristics of Hurricane Katrina's out-migrants are opposite to those found in regular migration processes, in which positive selection characterizes people with the highest overall and longer-distance migration propensities (Greenwood 1993). The post-Katrina findings of negatively-selected migrants, however, are consistent with the findings about population movement following other disasters (Morrow-Jones and Morrow-Jones 1991).

The Frey et al study is one of the few to provide information about the nature of displacement from New Orleans using population-representative data. A major strength of this

study is that it surveys the whole of the U.S., allowing for identification in a retrospective question on place of residence one year before the survey, individuals living in New Orleans in the year 2005. A weakness, however, is its reliance on a standard migration question "where did you live one year ago?" to infer disaster-induced movement. This question can only be used to track individuals' movements or the movement of a household that stayed together. It cannot be used to identify the event of a household breakup. The ACS public use sample of the Frey et al study, moreover, does not provide survey date within calendar year 2006, and therefore cannot be used to identify when in 2005 an individual lived in New Orleans and when (before or after Katrina threatened and then extensively destroyed the city) he or she moved.

Another major population-representative study is the Louisiana Public Health Institute's (2007) analysis of data from the 2006 Louisiana Health and Population Survey (LHPS) from 18 southern Louisiana Parishes from New Orleans up to the Baton Rouge area. The LHPS included questions on whether a move since Katrina could reasonably be attributed to the hurricane and its aftermath, either because of housing damage or loss of job. Louisiana Public Health Institute (2007) used these questions in estimating storm-induced displacement versus other reasons for out-migration. They first estimated the extent of disaster-induced moves from larger out-migration in the year to late-2006 compared to averages of annual outmigration from the same region over the previous three years. They further used an indirect estimation method to calculate total out-migration from the 18-parish area by subtracting LHPS-measured in-migration from Census Bureau estimates of net migration. The latter were subject to considerable challenges under the extremely difficult conditions for population estimation in a disaster-affected area (U.S. Census Bureau 2006a). Nevertheless, the LPHI study showed the scale of displacement a year after the storms to be extremely large, both within the region and beyond it.

They estimated 280,000 people made storm-related moves within the 18 parishes, and a further 400,000 people moved outside the 18 parishes because of the storms. Again, however, the LHPS does not allow for the identification of household breakup. The composition of pre-Katrina households that are no longer together cannot be recovered by the data in the ACS and LHPS. The prevalence and character of household change due to Hurricane Katrina and its aftermath cannot, therefore, be identified from these surveys.

Displacement and family relocation and breakup

While population-representative "displacement" studies following Hurricane Katrina have been forced by their data sources to focus on individuals, the infrequency of disasters causing long-term displacement also means that little is known from any previous natural disasters about their effects on family relocation and breakup. Disaster-induced population displacement can be expected to put pressure on the "intactness" of a household in a number of ways. In the case of a nuclear family unit this may occur, for example, through temporary separation of one parent or partner while damage to housing or neighborhood infrastructure (e.g., schools) is repaired. In some cases, the disaster may precipitate the dissolution of a marital or cohabiting unit. Economic pressures are known to increase the likelihood of marital and cohabiting union dissolution under non-disaster circumstances (White and Rogers 2000). Economic pressures due to job losses in New Orleans and difficulties finding jobs elsewhere may be expected, therefore, to have increased pressure on New Orleans couples' intactness. Karoly and Zissimopoulos (2007) find from analysis of Current Population Survey (CPS) data that unemployment rates of migrants who moved back to the areas of displacement were much lower than among migrants who remained further away. Death of family members and the psychological stresses on

individuals and families induced by disasters are potential family-disrupting effects of the storms (Galea, Nandi, and Vlahov 2005; Kaiser Family Foundation 2007; Sharkey 2007; Weisler et al 2007). In studies of the evacuation induced by Hurricane Katrina, some attention has also been given to the importance of use and maintenance of social networks that may be severely strained by the evacuation process (e.g., Fussell 2006). We further know that splitting of families occurred with some frequency in the evacuation following Hurricane Katrina (Haney, Elliot, and Fussell 2007).

Household structure before Katrina struck is also likely to have played a major role in household breakup. Nuclear families may be split at least temporarily in the case, for example, that lack of social or physical infrastructure (e.g., schools) prevented the family unit from moving back together to New Orleans. In the case an extended-family household, job losses may have a more direct effect on household breakup. For example, adult children and parents who were living together before may split due to the adult children's jobs no longer being available in the disaster-hit location, forcing them, but not their parent(s), to relocate outside the region. On the other hand, extended-family households are often formed due to strong material needs. This may either make them highly resistant to breakup when a disaster accentuates those needs, or vulnerable to being unable to continue to fulfill those needs by staying together. One of the conceptual frameworks proposed to understand the social impacts of natural disasters, including displacement, is that of "social vulnerability" (Cutter 2003). Socio-economic disadvantage, though not specifically as reflected in family and household structure, have been included among indicators of "vulnerability" of Gulf Coast communities to Hurricanes (Cutter and Emrich 2006). While this literature has developed taxonomies of risk factors, testing of it

has been extremely limited, due in no small part to the rarity of catastrophic events on the scale of Hurricane Katrina.

New Orleans has long been an economically disadvantaged community (Berube and Katz 2005). Household and family structures are both affected by, and are adaptive responses to, economic disadvantage. Two groups are more likely to be in extended-family households due to the need for resources: young adults and older people. Among younger adults, single mothers and minority single mothers in particular have been identifies as a groups that form extended-family households due to need (Hofferth 1994; Wasson and Hill 1998). Younger and middle-aged adults may also, however, provide care and economic resources to parents and therefore the direction of needs and exchange relationships within extended-family households are not uniform (Speare and Avery 1993; Choi 2003). It is useful to place elders' outcomes in response to natural disasters in the context of what is known about elder migration and its relationship to economic well-being and receipt of care in extended-family households in the non-disaster literature (Walters 2002). While elder migrants, like younger adult migrants, are generally positively selected economically, changes (especially declines) in health status sometimes serve as an impetus to migration at older-old ages, as do widowhood events. Migration and extended-family living associated with it may therefore be chosen based on increases in needs. Unmarried women, especially minority unmarried women, benefit most from living with relatives, and are consequently the most dependent on the availability of family members for their physical functioning and economic well-being (Rendall and Bahchieva 1998). The combination of minority, unmarried, and female is found to be especially disadvantageous (Angel et al 2007). Waite and Hughes (1999) show that these relationships of co-resident elder dependence hold even among younger-old (51 to 61 year old).

DATA AND METHOD

I compare the likelihood of a household breakup among households in New Orleans with a national panel sample to estimate "excess household breakup" associated with Hurricane Katrina and its aftermath for New Orleans. I use a case-control analytical framework. This includes parallel logistic regression analyses of the factors influencing breakup in New Orleans households after Katrina and in U.S. households overall in that same period, and the application of a propensity-score matching procedure that takes the New Orleans households as the "cases" and the national sample households as the "controls" in a joint analysis to provide estimates of the effect of Hurricane Katrina on the breakup of New Orleans households, I match to all individuals and separately to individuals from physically damaged and undamaged housing units and neighborhoods and in nuclear and extended-family relationships to the household head. This allows for insights respectively into the effects of physical versus socio-economic infrastructural damage and into the role of New Orleans' particular configuration of nuclear and complex household structures in the social demographic impact of Hurricane Katrina.

The "case" sample: The Displaced New Orleans Residents Pilot Study

The present study takes advantage of a unique data source, the Displaced New Orleans Residents Pilot Study (DNORPS, Sastry 2007a), which was conducted in the fall of 2006. The DNORPS design was based on a stratified, area-based probability sample of pre-Katrina dwellings in the City of New Orleans (Orleans Parish). The DNORPS defined three flood-depth strata from which units were sampled from: Low ("no-flooding," 0 feet); Medium (1-3 feet); and High (4+ feet). Within each of these strata a simple random sample was drawn. A total of 344 dwellings

were sampled for the study, 327 of which were found to be eligible for interview (the dwelling

was occupied in August 2005 by at least one resident who survived to survey date in 2006). Of

these, completed surveys were conducted for 147 households, giving an unadjusted response rate

of 45%. The response rates between strata were in the expected direction, with the no-flood

stratum having the highest response rate (51%) and the high-flood stratum having the lowest

response rate (39%). However, these response-rate differences across strata were not statistically

significant. Preliminary multivariate analyses revealed no systematic patterns of non-response,

and that the overall the quality of the data collected was high with no systematic problems with

the questions or with item nonresponse (Sastry 2007a). Sample weights are provided with the

DNORPS that first adjust for the unequal probabilities of selection between the three strata and

that second are post-stratified to the Census Bureaus estimates of the Orleans Parish 2005 mid-

year population by age, sex, and race. Because our interest is in the household, we use only the

household weights wherever weighted analysis is employed in our analyses.

Sastry (2007b) compares residence at survey date and immediately before Katrina struck

to calculate the percentage of all pre-Katrina residents of New Orleans who lived in the city in

the fall of 2006 when DNORPS was fielded. Overall, 49% of pre-Katrina residents had returned

to live in New Orleans. The most widely-accepted pre-Katrina estimate of the population of New

Orleans was the U.S. Census Bureau's July 1, 2005 estimate which placed the city's total

population at 454,863 (U.S. Census Bureau, 2006b). Together, these two estimates suggest that

the population of New Orleans in the fall of 2006 included approximately 222,900 returned

residents (plus any new residents who had not resided in the city prior to the hurricane). This

DNORPS-based population estimate is very similar to other independent estimates, including

those from the U.S. Census Bureau, which estimated the July 1, 2006 total population to be

223,000 (U.S. Census Bureau, 2007), the Louisiana Health and Population Survey, which estimated the city's total population in the fall of 2006 to be approximately 200,000 (LPHI, 2007), and the Kaiser Post-Katrina Baseline Survey, which estimated the city's total population in the fall of 2006 to be approximately 221,000 (Kaiser Family Foundation, 2007).

Sastry (2007b) additionally reports from his analyses of the DNORPS large and statistically significant differences by flood stratum in the percentage of displaced New Orleans residents who have returned to the city. In the unflooded stratum, almost three-quarters of pre-Katrina residents had returned, while in the low-flood stratum about half had returned; in the high-flood stratum, 38% of pre-Katrina residents had returned. This points to a potentially greater strain on the intactness of households from the most physically damaged neighborhoods. In addition to flood-depth stratum, information is available in the survey on the damage suffered to the residence and to the neighborhood. The DNORPS also asked the respondent to report the extent of damage to the pre-Katrina residence. Two codes, "destroyed" or "damaged [and not habitable]," allow for an "uninhabitable" designation. "Uninhabitable" refers to directly after the storm, allowing for the possibility of repairs or rebuilding to make it habitable by survey time. This allows us to identify factors that differentiate between those for whom the storm made return to the same residence either more costly or impossible.

The DNORPS includes people in households of all sizes. One-person households, however, are by definition not at risk of household breakup, and are therefore excluded from our analyses. I consider in our study only the 110 households containing at least two people in August 2005, just before the Hurricane Katrina mass evacuation. A total of 362 individuals lived in these 110 sample households. The focus of my analysis of the household breakup is on the 143 non-head adults in households of two or more people, and the likelihood that these non-head

adults were still living with the household head 13 to 15 months after Hurricane Katrina.

The moves of individual household members, from evacuation just before or just after the storm struck to the time of the survey conducted from the end of September through the end of November 2006, were asked about in several ways. First, in the roster, a check box was provided to identify whether each roster member still lived with the August 2005 Household Reference Person at survey date. I use this check box as our main source of household breakup information. Additionally, for the first five members on the roster, the following information was collected: whether or not in the pre-Katrina residence at survey date, where currently living if not the pre-Katrina residence place of evacuation, and place where the individual spent the most time since Katrina. These additional questions allow for cross-checks on the roster information on whether each individual is again living with the householder at survey date to be performed, and for corrections to be made where needed.

The "control" sample: the 2004 Panel of the Survey of Income and Program Participation
I use the 2004 panel of the Survey of Income and Program Participation (SIPP) over the 16 months from Wave 1 in 2004 to Wave 5 to compare household breakup in New Orleans in the 13 to 15 months following Katrina to overall rates and to rates for groups most similar to those in New Orleans on socio-demographic characteristics. For examples of previous analyses using the SIPP to investigate household breakup, see Speare and Avery (1993) and Mutchler and Burr (1991). To evaluate the sensitivity of our results to the SIPP households coming from a national mix of urban and rural areas and from geographical areas different from that of the New Orleans sample, I conducted analyses alternately using only the SIPP's metropolitan area households and using only households in the three Gulf Coast states of the Alabama, Louisiana, Mississippi.

After finding no substantial differences in migration and breakup between the three SIPP groups of included households (described in results below), I included only households in metropolitan areas in the final national sample. This has the advantages of matching New Orleans to a large number of similar individuals who were, like New Orleanians before Hurricane Katrina, living in households in U.S. metropolitan areas.

I code a "split" in the SIPP when either the householder or the individual (but not both) is lost to follow-up ("attrits"), or when both are followed but are living in different residences 16 months later. Out of 27,432 SIPP 2004 panel adults who were not the householder, 1,539 (5.6%) attrited when the householder remained in the survey, while 446 (1.6%) remained in the survey while their original householder attrited. These 1,985 cases where one but not both attrited accounted for two-thirds (65%) of all splits between the householder and a given individual. An additional 1,064 cases in which both the head and non-head remained in the survey but were living in different residences 16 months later accounted for the remaining 35%.

There were 4,550 (16.6%) of cases in which both the individual and the householder attrited between Wave 1 and Wave 5. These cases are excluded from the analysis. It may be that those households have a higher rate of breakup than households where either the individual or the householder was followed (recall that in most cases of household breakup coded in the SIPP, attrition of one member occurs, and breakup is recognized on the basis of not all attriting). If so, this will have the effect of downwardly biasing rates of breakup in our national estimates, to an upper bound of those 16.6% of cases in which both the individual and his or her household were lost to follow-up. This potentially biases upwards our estimates of the effects of Hurricane Katrina on household breakup. The slightly longer time between Wave 1 and 5 in the SIPP (16 months) than in the DNORPS (13 to 15 months), however, will offset this bias to some extent.

Moreover, there may also be a bias towards greater non-response for non-intact households in the New Orleans (DNORPS) sample. Therefore it is not obvious that our estimates of excess household breakup in the DNORPS compared to the SIPP will be biased either upwards or downwards. Both the absolute and relative magnitudes of bias in the SIPP and DNORPS are unfortunately difficult to estimate due to the lack of a suitable standard for comparison.

RESULTS

I first present descriptive statistics on the intactness of households of two or more people in the DNORPS, by whether the household or any of its members moved, by whether the household was in a residence that was either "habitable" or "uninhabitable" after Katrina, and by the type of household structure at baseline (nuclear versus extended, and whether this household extension is limited to vertical extension ---- adult children and parents living together). The DNORPS households are compared to households in the SIPP of the same structure (nuclear, vertical extension only, horizontally-extended households). I describe a household as having moved ("displaced") when none of the pre-Katrina household is living in the pre-Katrina residence of the household. Simple descriptive statistics are used to explore the associations of household structure and the incidence of breakup in New Orleans, and in comparison with national estimates of breakup in the SIPP.

Second, I compare the distributions of pre-Katrina household structures for New Orleans households between the DNORPS households as at August 2005 and the 2005 ACS and 2000 Census Public Release Microdata (PUMS), Orleans Parish only (U.S. Census Bureau 2007b;

University of Minnesota 2009).[1] I further compare these New Orleans households to national estimates of household structures and characteristics in the 2000 Census and in Wave 1 of the 2004 SIPP panel. These comparisons serve the joint purposes of identifying the unique features of pre-Katrina New Orleans households and checking the DNORPS' representativeness with respect to the distributions of structures of New Orleans households.

Third, I use a combination of propensity-score matching and logistic regression estimation to explore the characteristics of New Orleans individuals and households that induce higher or lower probabilities of adult household members' separating ("splitting") from the household head, and to estimate the overall effects of experiencing Hurricane Katrina on a given individual's splitting from the household reference person. Both methods are used to estimate differentials in the probability of splitting by post-storm housing habitability and by the adult individual's spousal versus extended-family relationship to the household head.

Movement from the pre-Katrina residence and breakup of the household
By our definition of "displaced" as those who had not returned to their pre-Katrina residence by survey date, all household breakup involves the displacement of at least one pre-Katrina

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[1] Ideally, the DNORPS would be compared to the 2005 distribution for the ACS before Katrina. However, the 2005 ACS PUMS includes very few post-Katrina households, and is weighted to reproduce the June "mid-year" population of individuals and of households. The similarity of the 2005 ACS PUMS results with those in the 2000 Census PUMS (described below) is also reassuring with regard to the ACS's representation of pre-Katrina household structures. The 2004 ACS PUMS unfortunately had too small a sampling fraction to allow identification of households within as small a geographical area as Orleans Parish.

household member. A household remains intact if either no household member was displaced or

if all household members were displaced but they were all living together at survey time. A

major advantage of these definitions of displacement based solely on change of residence is that

they allow the moves associated with the breakup of New Orleans households following Katrina

to be compared to a national sample that was not subject to the particular conditions of storm-

induced displacement. The patterns of moves associated with breakup of groups of all New

Orleans households, and of New Orleans households from housing units and neighborhoods that

were either habitable or uninhabitable after Katrina, may then be compared to national patterns

of movement and breakup (in the SIPP).

As throughout this analysis, sample size restrictions in the DNORPS mean that that the

number of variable categories needs to be minimized. I classify residences into "habitable" and

"uninhabitable" through a combination of their location in either the "high-flood" stratum (all

coded as "uninhabitable") versus in the "medium-flood" and "no-flood" strata and of self-

reported condition of the individual housing unit. This was in response to the question "What

was the extent of damage to your housing from Katrina and flooding?" I classified as

"uninhabitable" those housing units in medium- and no-flood strata for which the respondent

reported the residence had been destroyed or rendered uninhabitable ("Damaged so badly that

you couldn't live in it"). I classified as "habitable" those units that were undamaged or damaged

but still habitable, and located in the medium flood or no flood strata, Almost all housing units

in the "high-flood" stratum would also have qualified as "uninhabitable" based on self-reports on

the condition of their individual housing units.

For the "household breakup" outcome variable, I code households as "intact" if all pre-

Katrina members remained together at the fall 2006 survey date and "non-intact" otherwise. The

main source here is the check box for still living with the Household Reference Person at survey date.[2] I investigate different forms of breakup both by classifying households by the pre-Katrina size and structure, and through analysis of whether the entire household was "displaced" (no members of the household again in the pre-Katrina residence one year later). Individual household members' splits from the household reference person are later analyzed according to their relationship to the reference person in addition to their personal characteristics and characteristics of the household.

[TABLE 1 ABOUT HERE]

In total, I estimate from the DNORPS that 53.9% of New Orleans households with two or more people were displaced entirely, the majority of which (30.9%) remained completely intact (see Table 1). Adding to the entirely-displaced households the 13.9% of households in which at least one, but not all, household members moved, as many as two thirds (67.8%) of New Orleans households experienced the displacement of at least one individual following Hurricane Katrina.

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[2] I made corrections by inspection for probable errors in the check box based on the survey's history of moves between August 2005 and survey date by each of the up-to-five individuals for which this history was provided. Typically this involved checking the state of current residence of all household members, the state of residence immediately after evacuation, and the state of residence for most of the time since the Hurricane. Where current state of residence was the same for household members, I assumed they were living together. This treatment further ensures that excess household breakup in the DNORPS is not due to differences in the survey instrument.

Our two-category damage classification is strongly correlated with displacement, and moderately correlated with household breakup. Among "uninhabitable" residences, 75.0% were displaced entirely ---- that is no pre-Katrina members of the residence lived in it a year later. Again, the majority of these displaced households remained intact (42.7%, versus 32.3% that did not). In contrast, among households from residences and neighborhoods that remained habitable ("habitable"), only 12.5% were displaced entirely.

Household break-up can involve the displacement of at least one but not all members from the pre-Katrina residence. This phenomenon was much more common for habitable residences. While 28.3% became non-intact, 23.5% still had at least one member living in the pre-Katrina residence. For uninhabitable residences, of the 41.2% that became non-intact, only 8.9% still (or, more accurately given the time required for reconstruction, again) had at least one member living in the pre-Katrina residence.

I further compare the breakup and partial or entire displacement of households in the uninhabitable and habitable New Orleans residences with the national sample from the 2004 SIPP panel 16 months after the first survey wave. I compared SIPP estimates for all U.S. households, for metropolitan areas only, and for the three Gulf States, Louisiana and neighboring Mississippi and Alabama, only. Because the results for these three comparison groups are similar to each other, I describe only those for metropolitan areas. Overall, three quarters (75.5%) of households nationally with two or more people remained intact and in the same residence (versus 32.3% in New Orleans), and a further 10.3% of households moved as an intact unit into a new residence (versus 30.9% in New Orleans). The remaining 14.2% of households that were "non-intact" were predominantly cases of one or more household member moving out while one or more remained in the residence a year later (12.1%). Nationally, cases of

household breaking up with all members moving, but to more than one new residence, made up only 2.1% of all households of two or more people in 2004. This latter figure provides the largest contrast with our estimates for New Orleans: A quarter (23.0%) of New Orleans households had all members move but to more than one new residence.

[TABLE 2 ABOUT HERE]

Household breakup by pre-Katrina household structure

The probability of household breakup is much higher for extended-family than for nuclear-family households both in New Orleans and nationally, but it was especially so for extended-family households in New Orleans after Katrina (see Table 2). I define extended-family households to include households with at least one child of head aged 18 or over, as well as households with relatives or non-relatives of the householder other than children. While nationally 6.9% of nuclear-family households had at least one member leave over the year, the break-up rate of New Orleans nuclear-family households following Katrina (8.0%) was not statistically different. The break-up proportions of the two types of extended household, however, were twice as great in New Orleans as nationally. As many as 54.0% and 77.9% of New Orleans households I classify respectively as vertically and horizontally extended in 2005 (pre-Katrina) were non-intact in at the 2006 survey date, compared to 24.8% and 45.3% of such households nationally.

Because Katrina-induced displacement appeared to take its greatest toll on extended households, it is important to consider the prevalence and types of extended-family households in New Orleans versus nationally. We do this first in Table 2 at the household level, comparing

again to national metropolitan area estimates in the SIPP (see "distribution" columns of Table 2). Nuclear-family households account for almost three quarters (72.6%) of households of two or more individuals nationally, but just under half (47.0%) only in New Orleans. Vertically-extended households, moreover, make up as many as a third (34.3%) of New Orleans households, more than twice the national percentage (15.6%).

[TABLE 3 ABOUT HERE]

I next consider the forms of household extension in New Orleans versus nationally in more detail, taking adult non-head individuals as the units of analysis. Their distributions are compared between New Orleans and nationally in Table 3. The 2005 ACS and 2000 Census are used to compare to the DNORPS household structure for New Orleans. The 2000 Census and the 2004 SIPP are used to represent the national distributions of household structures. Results are overall very similar between data sources both in New Orleans and nationally. Only the "partner/friend/visitor" category looks very different between data sources, probably due mostly to differences in this category between the survey instruments. "Spouse" is a less prevalent non-head status in New Orleans (around 40%) than it is in the nationally (55 to 60%). This is largely compensated for by the higher prevalence of "Child of reference person," accounting for around 30% of non-head adults in New Orleans versus 20% nationally. Other forms of vertical extension are relatively uncommon in both New Orleans households (6 to 7%) and nationally (4%).

Multivariate analysis of the separating or splitting off from the pre-Katrina household head

In the above description, household breakup was considered to occur when any one pre-Katrina household member splits off from the others. I next consider individuals' splitting from the household. "Splitting" is defined in relation to the household reference person ("household head"). The same outcome variable, splitting from the household reference person, is used in both bivariate and multivariate analyses. In the bivariate analyses I estimate the simple association of splitting with being in New Orleans versus in the U.S. as a whole (limiting the U.S. population to those living in metropolitan areas). In the multivariate analyses, I estimate the increase in probability due to Hurricane Katrina of an adult experiencing a split from the household reference person. Estimates of the bivariate and multivariate associations are made separately between non-head individuals in habitable and uninhabitable housing units, and between non-heads living in three types of relationship to the head: spouse, adult child of head, and other relationship to head. In each case the comparisons are made between the DNORPS for pre-Katrina New Orleans residents and the SIPP for the national, metropolitan-area household population. Two DNORPS individuals were discarded from these analyses due to missing data on educational attainment or employment, leaving a total of 141 non-head adults in the DNORPS sample.

The New Orleans (DNORPS) sample of adult individuals in households of two or more adults is matched to a national control group on factors other than the Hurricane and subsequent flooding. I first use propensity-score matching to apply a case-control approach to the analysis of the breakup of New Orleans households. The propensity-score matching method provides strong theoretical properties based on a treatment/control framework (Imbens 2004; Morgan and Harding 2006). Under this framework, the distribution of the group that experiences the "treatment" is applied to the "control" group. The interpretation is then an estimate of an

average treatment effect *on the treated* ("ATT"). In the present study, "treatment" has two

interpretations. The first is simply having lived in New Orleans when Hurricane Katrina struck.

The second is having lived in New Orleans in a housing unit or neighborhood made

uninhabitable by Hurricane Katrina.

Unlike a multivariate regression analysis, the ATT estimates are directly comparable to

bivariate estimates of simple differences in means or proportions. In the present case, the

difference between the proportions of non-head adult individuals in New Orleans and nationally

who split from the household head is estimated after applying the distribution of characteristics

of New Orleans residents to the national sample. The interpretation is analogous to that from a

directly standardized demographic rate estimator (e.g., Smith 1992), where New Orleans

provides the "standard" population whose distribution of characteristics is applied to the national

sample of households. In place of using the distribution represented by cell proportions,

however, the ATT estimator reweights the national sample on the propensity-scores of the New

Orleans sample. The "propensity score" is just an estimate of the probability that an individual

of a given set of characteristics will be in the DNORPS sample given that he or she is in either

the DNORPS or the SIPP sample. The major advantage of the propensity score over a simple

demographic standardization estimator is that it solves the problem of dimensionality with

multiple predictor variables.   These variables in the present study are relationship to reference

person, the non-head's age, education, and employment status, the race of the household head,

and whether the housing unit is owned or rented (described in the logistic regression model

below).

Different propensity-score estimators may be used, including nearest-neighbor one-to-

one matches and several types of one-to-many matching estimators. The use here of a very large

national sample in combination with a one-to-many matching procedure results in major gains in statistical efficiency compared to a one-to-one match (Smith 1997). Also useful for statistical efficiency is the near equality in the numbers of individuals living in housing that became uninhabitable versus in housing that remained habitable, and the large proportion of extended-family households in the DNORPS sample.

Among possible matching estimators, I use the "stratification" estimator, in the STATA statistical package (Becker and Ichino 2002). This weights equally the differences between the New Orleans and the nationally sample within a given stratum containing a given range of propensity scores, with the weights given by the New Orleans sample (the "treatment" sample). The boundary points and number of strata are chosen optimally as part of the propensity-score estimation routine. I use normalized sample weights respectively of the DNORPS and SIPP in the propensity-score estimation routine. In the matching routine, standard errors are calculated either analytically or by bootstrap. Only the bootstrap incorporates design effects, and so is used here in the comparisons where statistical significance may be affected by choice of variance estimation method. I further use the "common support" option that eliminates all national sample observations that do not match to a New Orleans non-head adult.

[TABLE 4 ABOUT HERE]

Estimates of the bivariate associations of being a New Orleans resident with splitting from the household head, and of the ("treatment") effect of experiencing Hurricane Katrina on splitting from the household head among New Orleans residents, are presented in Table 4. Overall, a third (33.1%) of New Orleans non-head adults were living separately from the pre-

Katrina household head after the year and one to three months since Hurricane Katrina struck. Most of this (18.1%) may be interpreted as a consequence of Hurricane Katrina and its aftermath for New Orleans residents. Note that this "treatment effect" is smaller than the difference between the New Orleans and national proportions (33.1% - 12.9% = 20.2%), implying a larger propensity for breakup among non-head adults in New Orleans than nationally even before Hurricane Katrina. This is seen for non-heads both whose residence was made uninhabitable by Hurricane Katrina and for non-heads whose residence was still habitable. For those non-head individuals whose residence became uninhabitable, 38.2% were not living any longer with the head in late 2006. This compares with 12.9% nationally, and 24.8% of this difference is attributable to Hurricane Katrina. For non-heads who were in residences still habitable after Katrina, almost twice as many as nationally (22.8% versus 12.9%) separated from the head, though the "treatment" effect of 9.2% was only marginally significant in a two-tail test of difference from 0. The largest "treatment" effect was that for adult children of head. The 33.5% estimate is interpreted as implying that one in three adult children of head separated from the household head following Katrina, when they would not have separated from the head under "normal" circumstances. Instead of a "normal" splitting incidence of one in five, one in two adult children of head separated from the head following Hurricane Katrina. In contrast, only 2.6% of spouses are interpreted to have split from their husband or wife due to Hurricane Katrina, a magnitude not statistically different from zero. The fact that the treatment effect only half the observed difference (9.3% - 4.2%) implies that New Orleans married couples had characteristics already predisposing them more to separate than married couples nationally.

[TABLE 5 ABOUT HERE]

Finally, in Table 5 we present logistic regression estimates of models similar to those implicitly estimated by the propensity-score matching estimators of Table 4. In the logistic regression model, we see clearly the benefits of leveraging the small samples of the DNORPS with the very large samples of the SIPP. All coefficients except "Black household head" are significantly different from zero, due to the high statistical power afforded by the 23,000 SIPP observations. Of all the variables, only those for extended family relationship to head are statistically different in the DNORPS from the SIPP (results for the non-significance of the control variables interacted with DNORPS not shown). Expected control variable relationships include a lower effect of splitting among spouses with higher education than with lower education and who are employed compared to those not employed (see the Any college*spouse and Employed*spouse coefficients). This coefficient is canceled out for nonspouse heads, an expected finding given that more economic resources have been found to keep couples together (Teachman 2002; Sweeney 2002).

The main coefficients of interest are those that interact the DNORPS with relationship to household head and that interact DNORPS with "residence uninhabitable." The coefficient for "DNORPS" in the first model is only marginally significant, just as it was for the individuals from habitable residences in the propensity-score matching estimator. The statistically significant interaction of DNORPS with "residence uninhabitable," however, strengthens the finding from the propensity-score matching estimates still further. This statistically significant interaction in the logistic regression estimator means that not only are the effects of having experienced Hurricane Katrina and having one's house destroyed or otherwise made uninhabitable different from "normal" conditions, but also the effect of having one's house

destroyed or otherwise made uninhabitable on experiencing household breakup is statistically

larger than that of having lived in New Orleans when Hurricane Katrina struck but not having

had one's house destroyed. Note too that this is an effect after controlling for living in an owner-

occupied house versus renting.

In contrast, the coefficients for the interaction between living in an extended-family

relationship to the head with "DNORPS" were not statistically significant (results not shown).

That is, while we can be confident that Hurricane Katrina increased the likelihood of household

breakup relative to living in an extended-family relationship to the head under "normal"

conditions, we cannot be confident that this was not the case also for Hurricane Katrina's effect

on married couples. That is, the statistically non-significant effect of being the spouse of head in

New Orleans does not allow us to conclude that there was no real effect (compared to the real

effect found for individuals in extended-family relationships household heads). This further

suggests that low statistical power in our study is a problem for detecting effects of Hurricane

Katrina on spousal separation.

DISCUSSION

A catastrophic natural disaster such as Hurricane Katrina for the City of New Orleans will have

major impacts not only on individuals but on social structure. Focusing specifically on the

household as a key unit of social structure, I estimate that hurricane and its aftermath increased

the rate of household breakup to 2.5 times its usual level. This and other findings were derived

from data and statistical methods designed to maximize the power of the New Orleans

observations of household intactness in a pilot survey. I used propensity-score estimation with

one-to-many matches between the pilot study data from New Orleans and a large national panel

survey for household breakup by characteristics including and beyond household structure. I further used American Community Survey and Census data to anchor the pilot study estimates of New Orleans household structures.

An important sociological question is much break up may be attributed to physical destruction to the own housing unit or neighborhood versus to loss of community socio-economic infrastructure. Based on the breakup of households from still-habitable residences, I conclude that damage to the community socio-economic structure produced substantial household breakup in addition to that attributable to physical housing damage. The large number of households in which some or all people moved (two-thirds and half respectively of all households in New Orleans) points to large impacts on the socio-economic infrastructure of the community in addition to individual housing loss following Hurricane Katrina (O'Neill 2007; and see also Green, Gill, and Kleiner 2006 for post-Katrina infrastructural impacts in Biloxi, Mississippi). Socio-economic infrastructural losses include both employment and services such as schools and medical care (Liu and Plyer 2007; Yarnal 2007). In this context, point estimates from this study indicated a likelihood of household breakup from still-habitable residences in New Orleans almost twice as high as that nationally over the same period. This suggests large effects on household intactness of the damage to the socio-economic infrastructure over and above that from destruction of the physical infrastructure of habitation.

The second question I addressed was how the prevalence and nature of extended-family relationships in households preceding the disaster contributed to the high rates of household breakup. Because of both the high prevalence of extended-family households in New Orleans households preceding the disaster, and the high increments to the conditional probabilities of breakup attributed to the storms, I conclude that the prevalence and character of extended-family

households in New Orleans is crucial to understanding why household breakup occurred at such high rates, and also for the potential consequences this may have had for the New Orleans population.

In addressing the broader, adverse consequences of disaster for a population, the concept of "vulnerability" to disaster has figured prominently in typologies of risk (Cutter 2003), including specifically for the Gulf coast region (Cutter and Emrich 2006). Poor and elderly individuals are, for example, considered as particularly vulnerable under these typologies. The known greater economic vulnerability and reliance on extended-family households of elderly African-Americans (Rendall and Bahchieva 1998; Angel, Jimenez, and Angel 2007) is consistent with the applicability of such typologies to the New Orleans context, and additionally describes a mechanism to understand the dynamic consequences of vulnerability. Extended-family, or non-family, households can be expected to play a potentially large role in amplifying the adverse economic consequences of disaster-induced displacement when loss of housing is such a prevalent outcome as it was in New Orleans.

Typologies are of limited use, however, in the absence of empirical tests. Adult children turned out to be by far the largest single group to separate from the household head following Hurricane Katrina. This finding calls for a broader of investigation into outcomes of household-structure change for both adult children and their parents. In some cases, these adult children will have played crucial roles caring for and economically sustaining elderly, household-heading parents. In others, however, economic vulnerability will have been higher for the adult children than for their middle-aged and older parents (Speare and Avery 1993; Choi 2003). This is especially likely to be the case when the non-head child herself has children (Hofferth 1994), and in this case the loss of housing may have severe consequences including homelessness (Wasson

and Hill 1998).

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Table 1 Distributions of households by members' moves and household intactness, all households with two or more members

Household Intactness and whether all moved	New Orleans			National		
	All	Uninhabitable	Habitable	All	universe limited to metropolitan areas	universe limited to Gulf States*
Household intact						
No household members moved	32.3	16.1	63.9	76.1	75.5	76.4
All household members moved	30.9	42.7	7.8	9.9	10.3	8.8
Household non-intact						
All household members moved	23.0	32.3	4.7	2.0	2.1	1.7
Some household members moved	13.9	8.9	23.5	12.1	12.1	13.1
All Households	100.0	100.0	100.0	100.0	100.0	100.0
Sample N	110	62	48	26,383	19,323	1,159

Notes:
"Uninhabitable" is designated when the household respondent reports that the housing unit was destroyed or damaged so seriously as to make it
  uninabitable, or when the housing unit was in a neighborhood with a flood depth of 4 or more feet.
* Alabama, Louisiana, Mississippi

Data Sources:
New Orleans: Displaced New Orleans Residents Pilot Study (13 to 15 months from late August 2005)
National: Survey of Income and Program Participation, Wave 1 to Wave 5 (16 months from late 2004 to early 2006)

Table 2 New Orleans and national household intactness by household structure

	New Orleans		National (metropolitan areas)	
	distribution	% non-intact	distribution	% non-intact
Household structure				
nuclear	47.0	8.0	72.6	6.9
extended				
vertical only	34.3	54.0 **	15.6	24.8
horizontal	18.6	77.9 **	11.8	45.3
all households	100.0	36.8 **	100.0	14.2
Sample N	110		19,323	

Notes:
statistical significance, New Orleans difference from national sample
* p < .05
** p < .01

Data Sources:
New Orleans: Displaced New Orleans Residents Pilot Study (13 to 15 months from late August 2005)
National: Survey of Income and Program Participation, Wave 1 to Wave 5 (16 months from late 2004 to early 2006),
         metropolitan areas only

Table 3 Relationship to household head, adult nonheads in New Orleans and nationally by data source

	New Orleans			U.S.	
	2005 DNORPS	2005 ACS	2000 Census	2000 Census	2004 SIPP
Distribution of household members					
by relationship to head (age 18 and over)					
Spouse	42.7	41.8	38.4	55.8	59.8
Partner/friend/visitor	3.8	7.8	11.2	9.3	5.2
Child	31.0	29.1	28.8	19.1	20.8
Child-in-law			0.8	0.8	
Parent	2.6	3.2	2.3	2.2	2.7
Parent-in-law			0.5	0.7	
Sibling	4.4	3.3	4.0	2.5	2.4
Sibling-in-law			0.3	0.6	
Grandchild	3.5	3.1	2.7	0.9	0.8
Other relative		4.0	2.4	1.5	
Other non-relative	1.9	7.7	8.5	6.7	3.4
Other	10.0				
total	100	100	100	100	100

Note: "adult" is defined as age 18 and over

Data Sources:
DNORPS = Displaced New Orleans Residents Pilot Study, household structure in August 2005
ACS = American Community Survey, IPUMS interactive tabulation (www.ipums.org)
Census: IPUMS interactive tabulation.
SIPP = Survey of Income and Program Participation 2004 Panel, Wave 1, metropolitan areas only.

Table 4 Percentage of non-heads adults living separately from the household head after 13-16 months

	Observed Percentages Splitting from Household Head				Propensity Score Estimator of the Hurricane Katrina Effect on Splitting from the Household Head#	
	U.S.^ (SIPP[+])		New Orleans (DNORPS[+])			
					p-value DNORPS vs SIPP~	estimate	t-value
all non-heads	12.9		33.1 ***		<.001	18.1 ***	4.62
[confidence interval]	12.4	13.5	24.5	41.7			
sample N[c]	22,046		141				
non-heads, residence habitable[a]			22.8 **		0.021	9.2 *	1.85
[confidence interval]			12.3	33.2			
sample N	20,902		64				
non-heads, residence uninhabitable[b]			38.2 ***		<.001	24.8 ***	4.43
[confidence interval]			26.5	49.9			
sample N	21,363		77				
spouse of head	4.2		9.3		0.115	2.6	0.78
[confidence interval]	3.8	4.5	0.1	18.5			
sample N	12,996		58				
adult child of head	19.6		52.8 ***		<.001	33.5 ***	4.42
[confidence interval]	18.3	20.8	35.2	70.5			
sample N	4,789		45				
other relationship to head	31.8		48.6 **		0.026	17.5 **	2.31
[confidence interval]	30.1	33.6	33.0	64.1			
sample N	4,474		38				

Notes:

+ DRNORPS = Displaced New Orleans Residents Pilot Study; SIPP = Survey of Income and Program Participation

^ Non-head ndividuals living in Metropolitan Areas of the U.S.

~ All contrasts are to SIPP "all non-heads". Chi-square test of independence between surveys adjusts for clustering in families in both DNORPS and SIPP (all metropolitan areas of the U.S.), and for stratified sampling in the DNORPS. Estimates are weighted for unequal probability of selection into sample.

Uses propensity-score stratification method of matching, with normalized sample weights in the propensity-score equation. The estimate is interpreted as the additional percentage of individuals that split from the head due to experiencing Hurricane Katrina and its aftermath in New Orleans.

a. undamaged residence or damaged but still habitable, not in high flood stratum

b. residence destroyed or damaged and uninhabitable, or in high flood stratum

c. Sample N is the number of observations used in the many-to-one match of the propensity score estimator, estimated with the "common support" option. This results in inclusion of all DNORPS, but not all SIPP, observations.

* p < .10; ** p < .05; *** p < .01

Table 5 Logistic regression of splitting from the household reference person, DNORPS and SIPP pooled[+]

	coefficient	std error	coefficient	std error
Intercept	-1.7707 ***	0.096	-1.764 ***	0.096
Household socio-economic characteristics				
Black household head	-0.015	0.064	-0.010	0.064
Owner-occupied	-0.375 ***	0.052	-0.373 ***	0.052
Individual characteristics				
Age group (reference 22-29 years old)				
age 18-21	-0.296 ***	0.069	-0.300 ***	0.069
age 30-39	-0.366 ***	0.068	-0.370 ***	0.068
age 40-39	-0.643 ***	0.075	-0.644 ***	0.075
age 50-64	-0.876 ***	0.083	-0.877 ***	0.083
age 65+	-0.435 ***	0.091	-0.437 ***	0.091
Relationship to Household Head (reference: spouse)				
Adult child of household head	0.849 ***	0.098	0.838 ***	0.098
Other relationship to household head	1.533 ***	0.089	1.530 ***	0.089
Education (reference: not high school grad.)				
High School graduate	0.014	0.063	0.012	0.063
Any college	-0.242 **	0.097	-0.242 **	0.097
Any college*nonspouse	0.221 **	0.101	0.216 **	0.101
Employed	-0.601 ***	0.090	-0.602 ***	0.090
Employed*nonspouse	0.748 ***	0.102	0.751 ***	0.102
DNORPS*spouse	-		0.586	0.540
DNORPS*child of household head	-		1.631 ***	0.341
DNORPS*other relationship to household head	-		0.827 ***	0.315
DNORPS	0.606 *	0.313	-	
DNORPS*residence uninhabitable	0.923 **	0.420	-	
Likelihood Ratio	2,926.2		2,925.8	
Sample N, DNORPS	141		141	
Sample N, SIPP	22,774		22,774	

Notes:
+ DRNORPS = Displaced New Orleans Residents Pilot Study; SIPP = Survey of Income and Program Participation

Except for the relationship-to-head variables, whose interaction coefficients are presented, none of the regression
 coefficients were statistically different between the DNORPS and the SIPP when full interactions between surveys
 were modeled (results not shown).

Statistical tests of the parameters' differences from zero adjust for clustering in families in both DNORPS and SIPP
and for stratified sampling in the DNORPS. The regression model estimates are unweighted.
* p < .10; ** p < .05; *** p < .01