The Impact of Rebuilding Grants and Wage Subsidies on the Resettlement Choices of Hurricane Katrina Victims*

Jesse Gregory
University of Michigan
jessgreg@umich.edu

Abstract

Following Hurricane Katrina, the Louisiana Road Home program provided cash grants directly to individual homeowners to offset repair costs and to encourage rebuilding. I develop a dynamic discrete choice model of New Orleans homeowners' post-Katrina choices regarding residential locations, home repairs, home sales, and amounts to borrow or save, and I derive and implement a maximum likelihood estimator for the model's structural parameters. Using simulations I find that the Road Home program significantly increased the fraction of homes rebuilt within four years of Katrina, mostly by relaxing financing constraints for borrowing constrained households who would have strongly preferred to rebuild even in the absence of a subsidy if the associated costs could have been spread out over time. I find that location preferences are highly heterogeneous, and most households are far enough from the margin with respect to their preferred location that even large location subsidies induce few households to change locations. These findings suggest that disaster-related subsidies to dangerous locations generate substantially smaller economic distortions than would be predicted by spatial equilibrium models with homogeneous agents.

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Policymakers designing disaster relief packages face a difficult tradeoff. The desire to assist disaster victims must be weighed against the fear that subsidizing people to live in dangerous areas will generate moral hazard with regard to households' location decisions. The size of the economic distortion caused by this type of moral hazard depends on the extent to which individuals' and households' location choices are influenced by financial incentives. If each household is nearly indifferent between many different residence locations, then disaster policies that subsidize residence in a particular location will generate large distortions. If most households strictly prefer one location, then it is possible for disaster relief programs to increase the welfare of residents in disaster-affected areas without generating large distortions. A full appraisal of the impact of disaster-relief policy on social welfare must consider the direct impact of disaster relief on victims' welfare and the extent to which the programs distort individuals' location decisions.

This paper develops and estimates a dynamic discrete choice model of New Orleans homeowners' post-Hurricane Katrina resettlement choices. In the model, households make choices regarding residential locations, home repairs, home sales, and amounts to borrow or save. The model's parameters describe households' preferences over consumption and residence locations and describe households' ability to borrow. The model is estimated using a unique dataset that combines data from the recently fielded Displaced New Orleans Residents Survey with administrative records from the Orleans Parish property database. The model is identified by variation across households in the financial incentive to rebuild provided by the Louisiana Road Home rebuilding grant program and by variation in the relative labor wages available in New Orleans versus away from New Orleans for workers in different occupations. I use the estimated model to measure the impact of post-Katrina relief programs on households' short term resettlement choices and to quantify a key component of the deadweight loss associated with a guarantee of future relief.

The estimated model finds that households in this population have a strong preference for living in New Orleans on average; there is substantial variation across households in the strength of that location preference; and large population subgroups face borrowing constraints. The model finds that the government's Road Home program, which paid cash rebuilding grants to individual homeowners, increased the fraction of homes rebuilt during the first four years following Katrina by 11%. This impact occurred primarily by relaxing borrowing constraints for households that would have strongly preferred to rebuild even in the absence of the subsidy if the associated costs could have been smoothed.

Estimates suggest that heterogeneity in location preferences is substantial enough that most households are far from the margin with respect to their preferred location. This pattern implies that the elasticity of location choices with respect to financial incentives is low, as few households switch locations in response to a location subsidy. For this reason, simulations find that a guarantee of relief in the event of a future disaster generates a deadweight loss that is at most 3% of the policy's expected cost.

Several recent studies have estimated explicit dynamic behavioral models to measure the responsiveness of migration choices to financial incentives. Kennan and Walker (2011) estimate a dynamic discrete choice model of optimal migration and find that labor flows are responsive to variation in wages across space. Several related studies have considered variations on Kennan and Walker's model to investigate particular aspects of migration.[1] This paper contributes to that literature in several important ways.

This paper is the first to estimate a dynamic structural model of migration that explicitly includes the asset accumulation choice and allows for the possibility of borrowing constraints. Borrowing constraints will affect the migration choices of any population that faces large up-front costs to moving. In the disaster context, those costs reflect the price of home repairs. The model would be equally well-suited to investigate migration choices, for example, among homeowners with negative mortgage equity, or other populations that face up-front costs to moving.[2]

This paper also contributes to this literature by estimating a dynamic structural migration model using directly observable sources of variation in location-specific financial incentives. Other studies in this literature have relied heavily on variation in the individual-location match component of workers' wages, which must be inferred statistically from panel wage data, to identify the influence of earnings opportunities on migration. Because I replicate several key findings of the existing literature using a different and more transparent source of identification, my study provides an out-of-sample validation for the main conclusions of the existing literature.

The responsiveness of individual migration choices to financial incentives is of general interest beyond the disaster-policy context. For example, the manner in which local or regional labor markets adjust to labor demand shocks depends critically on the willingness of affected workers to relocate (Topel 1986; Blanchard and Katz, 1992; Bound and Holzer, 2000).[3] If workers' location choices are not strongly influenced by financial incentives, then localized labor demand shocks will have large wage effects that persist until capital re-adjusts. If workers quickly relocate in response to financial incentives, then localized labor demand shocks will have short lasting wage effects and larger effects on the size of local populations.

The responsiveness of individual migration choices to financial incentives also figures prominently in the broader literature that examines the economic distortions caused by place-based policies.[4] If, as in classic models of spatial equilibrium (Rosen, 1979; Roback, 1982), workers are fully mobile and share homogeneous location preferences, the deadweight loss associated with a tax or subsidy to a given location

[1] Gemici (2011) develops a model in which married couples must consider the potential labor earnings of both household members across locations. Bishop (2007) applies a computational innovation that allows her to model migration with enough geographic detail that migration choices become informative about preferences for spatially delineated amenities.

[2] It has been documented (Chan, 2001; Ferreiraa, Gyourko, Tracy, 2010) that declining home equity is associated with reduced mobility, but the relative importance of the several mechanisms that could account for this phenomenon is unknown.

[3] Blanchard and Katz (1992) consider a model in which fully mobile (in the long run) workers and firms arbitrage away shocks to local employment and wages, and the long-run employment effects of such shocks depend on the relative speed with which workers and firms relocate. Bound and Holzer (2000) consider differences across race, education, and experience subgroups in the impact of labor demand shocks on wages, focusing on differences across groups in the elasticity of migration with respect to financial incentives as the primary explanation for these differences.

[4] Glaeser and Gottlieb (2008) review the economics of place-making policies.

depends entirely on the elasticities of local labor demand and local housing supply (Albouy, 2009). Because long-run labor demand and housing supply are quite elastic, this sort of model suggests that local policies generate large distortions. On the other hand, if workers' preferences for locations are heterogeneous, then the long-run supply elasticity of residents to locations is finite (Moretti, 2011; Busso, Gregory, and Kline 2011), and local policies will generate smaller distortions.

This study also contributes to the literature that examines the economic consequences of disasters and the more narrow literature that has examined patterns of post-Katrina migration and resettlement.[5] Hurricane Katrina struck the Gulf Coast of the United States on August 29, 2005 and generated, in the years following, the largest disaster-relief effort in the nation's history. The city of New Orleans received some of the storm's most concentrated and costly damage when, in the days following the storm, the city's protective levees failed and flood waters covered large areas of the city. Government disaster relief to New Orleans following Hurricane Katrina included substantial compensation packages to individual homeowners, in addition to traditional public disaster relief services such as debris removal and infrastructure repair. Program evaluation studies examining the impacts of disaster-relief programs are almost entirely missing from the empirical literature on disasters, so this study's evaluation of post-Katrina relief programs fills an important gap in that literature.

The remainder of this paper is structured as follows. Section I describes the dataset. Section II provides background information about U.S. disaster relief policy and describes the policy response to Hurricane Katrina. Section III presents the dynamic structural model to be estimated. Section IV describes the parameterization of the model for estimation and describes the estimation routine. Section V presents the structural parameter estimates and assesses the model's in-sample fit. Section VI presents the results of simulation experiments. And, Section VII concludes.

I. Data

This study analyzes a retrospective panel dataset that provides household-level measures of location, home repair status, and home ownership status at twelve evenly-spaced points during the first four years following Hurricane Katrina. The dataset draws from a population-representative survey of pre-Katrina New Orleans residents, called the Displaced New Orleans Residents Survey (DNORS), and from the Orleans Parish Assessor's Office administrative property database. The DNORS data (RAND, 2010) contribute information about demographic background traits, storm related home damage, insurance coverage, and migration. The Assessment data contribute records of post-Katrina home sales and provide information from annual property appraisals, which I use to construct measures of the timing of home repairs. I restrict attention to households that prior to Katrina owned a single-family home in New Orleans, either free-and-clear or with

[5] See Groen and Polivka (2010), Zissimopolous and Karoly (2010), Vigdor (2007 and 2008), Paxson and Rouse (2008), and Elliott and Pais (2006).

a mortgage,[6] and I exclude working-aged households in which neither head was employed during the year prior to Katrina.[7] The combined dataset contains 560 households.

DNORS was fielded by RAND and the Survey Research Center at the University of Michigan. Survey staff randomly selected dwellings from the universe of dwellings in New Orleans prior to Katrina, located the pre-Katrina occupants of selected dwellings regardless of the occupants' resettlement choices, and conducted interviews between July of 2009 and April of 2010. The resulting survey data provide a rich account of the post-Katrina experiences for a representative sample of the pre-Katrina New Orleans population.

The Orleans Parish Assessor's Office property database provides an appraised land value and an appraised improvement value (the value of structures) for each property for calendar-years 2004-2009 and provides a record of all home sales.[8] I use changes over time in each property's appraised improvement value to construct binary measures of whether repairs had yet occurred in each model period using a procedure described in Appendix I.

I obtain additional information on prices across locations from the 2005-2009 American Community Survey public use microdata files (Ruggles et al., 2010). Measures obtained from these data include occupation-by-location-specific mean wages over time and a set of rental housing price indices. Appendix II and appendix Table $A.1$ describe my method for constructing household-specific housing variables using these indices and direct measures from the two primary data sources.

Finally, I use data from the 2005 Panel Study of Income Dynamics to compute, for each DNORS household, an estimate of the distribution of liquid assets among Southern urban homeowners with similar background traits.[9] The pre-Katrina liquid asset holding is an important state variable in the dynamic model that the DNORS interviews did not collect. During the estimation routine, I condition this unobserved initial condition out of the likelihood function by computing each household's likelihood contribution at a range of values for the initial liquid asset holding and then integrating with respect to the estimated conditional asset distribution.

[6]Studying the behavior of homeowners is natural, because the vast majority of the disaster-relief programs targeted to individual households go to homeowners. Home-ownership patterns in pre-Katrina New Orleans differed somewhat from those of the U.S. as a whole. For instance, in the $2{,}000$ Decennial Census, only about 54% of New Orleans households owned their home, either with a mortgage or free-and-clear, compared to about 68% nationally. Also, New Orleans exhibited smaller disparities in home ownership rates between demographic groups than the U.S. as a whole. For example, the home-ownership rate blacks in New Orleans was about 77% that of non-blacks compared to 67% nationally.

[7]I define a household as working aged if a male head younger than 65 is present or if there is no male head and the female head is younger than 65. I apply this restriction so that pre-Katrina occupation may be treated as a source of variation in post-Katrina wages.

[8]The 2004-2009 appraisals were used to determine residents property taxes for years 2005 through 2010. Orleans Parish bills home owners in advance of the relevant tax year and, therefore, conducts the appraisals for year tax year t during the summer and fall of year $t-1$.

[9]In the PSID, I consider liquid assets to be the sum of a household's checking account balance, savings account balance, money market account balance, and the balance of non-retirement investment accounts. Appendix III describes the method for computing conditional asset distributions in more detail.

Table 1 provides descriptive statistics for this study's sample of households that owned homes in New Orleans prior to Katrina. Not surprisingly, a sample of homeowners is more affluent on average than the pre-Katrina New Orleans' population as a whole. About 60% of homeowning households earned more than \$40,000 in the year prior to Katrina, compared to about 46% of all households.[10] About 48% of homeowning households had a head with a bachelor's degree, compared to about 41% of all households. About 45% of homeowning households were couple-headed, compared to only 34% of all households.

II. U.S. Disaster Relief Policy and the Policy Response to Katrina

U.S. Disaster Relief Policy

Federal disaster policy in the United States consists of a government-run flood insurance program and an apparatus for coordinating and delivering relief in the event of a disaster. This section describes the main provisions of the programs that provide relief services directly to individuals and households.[11]

Flooding is the most common form of natural disaster, and the sole provider of flood insurance in the U.S. is the government-run National Flood Insurance Program (NFIP).[12] NFIP typically offers premiums at a discount to the actuarially fair rate for each specific location. To encourage localities to perform flood-plain maintenance and flood mitigation activities, NFIP provides discounts of between 5% and 45% to residents' premiums based on a locality's flood mitigation activities.[13] Also, NFIP offers substantial subsidies to the premiums of properties built during or before 1974 when NFIP first estimated actuarially fair premiums.[14]

The federal government's post-disaster relief apparatus is triggered when the President officially declares an area to be a major disaster area. This designation permits federal spending on ordinary clean-up activities such as removing debris and repairing infrastructure. Also, once an area has received this designation, homeowners and businesses become eligible for Disaster Relief Loans through the Small Business Administration (SBA), and property owners become eligible for small assistance grants from the Federal Emergency Management Administration (FEMA) to offset the cost of minimal repairs or safety improvements to damaged properties that were not covered by existing insurance arrangements.

[10] The summary statistics for the full population of pre-Katrina New Orleans reported in this paragraph come from the 2005 public use microdata ACS files (Ruggles et al., 2010).

[11] This section does not describe the federal government's other primary role of coordinating clean-up activities and repairing infrastructure. The federal policy for coordinating these tasks is governed by the Stafford Act of 1988, which modified the Disaster Relief Act of 1974

[12] For a comprehensive description of the program, see Federal Emergency Management Agency and Federal Insurance and Mitigation Administration (2002).

[13] This process is known as NFIP's Community Rating System.

[14] The National Flood Insurance Program refers to its set of estimated fair insurance rates as its Flood Insurance Rating Map (FIRM). Subsidies are provided to so-called pre-FIRM properties. By the time of Hurricane Katrina, the fraction of NFIP policies receiving this discount had fallen to about one in four nationally. However, for areas like New Orleans with declining populations and aging housing stocks, the fraction of properties with pre-FIRM designation remained substantially higher than the national average when Katrina struck.

In addition to these standing programs, a significant portion of government relief following major disasters is allocated on an ad hoc basis through block grants to local and state governments. Localities have used these types of grants in many ways, including; to purchase damaged homes, to provide cash grants for repairs, to provide subsidized loans for rebuilding, and to provide grants for relocating away from unsafe areas. Another variety of ad hoc disaster relief that has gained popularity in the past decade uses spatially targeted business subsidies to encourage capital investment in disaster areas and to stimulate demand for the labor of local residents.

Program evaluation studies examining the impacts of disaster-relief programs are almost entirely missing from the empirical literature on disasters, so the literature provides little evidence on the effects of these programs on resettlement choices.[15] Methodological challenges provide a likely explanation for the absence of this sort of study from the literature. Quasi-experimental research designs that are common in the program evaluation literature rely on the presence of an otherwise similar control group with which the group exposed to the program may be compared. In a given disaster area the entire affected population often receives the policy's treatment. The structural modeling approach adopted in this study allows these programs' effects to be estimated even if the programs' effects are not directly identified by a quasi-experiment.

Hurricane Katrina's Impact and the Policy Response

Hurricane Katrina struck New Orleans on August 29th, 2005. In the days following the storm's initial impact, the levees protecting the city failed and flood waters covered roughly 80% of the city (McCarthy et al., 2006). The storm and subsequent flooding left two thirds of the city's housing stock uninhabitable without extensive repairs. In addition to damaging property, Katrina displaced nearly all of New Orleans' $460{,}000$ pre-storm residents, and many spent a considerable amount of time away from the city (or never returned). Appendix Table $A.4$ provides a time line of some key events.

Table 2 describes the distribution of Katrina-related damage among homeowning households and describes the resources that were available to households for repairs. About three out of every four home owning households experienced flooding, and about 70% of homes were rendered uninhabitable.[16] Figure 1 provides kernel density estimates of repair costs for households with different pre-Katrina income levels.

A majority of households with severely damaged homes faced some repair costs that were not covered by insurance, and many households, especially those with lower income, faced substantial insurance shortfalls.

[15] One exception is a paper by Kamel and Loukaitou-Sideris (2004) that examined differences across groups in access to disaster relief following the 1994 California Northridge earthquake. The paper finds that zip codes with a lower ratio of relief spending to earthquake damage experienced larger declines in population and housing units.

[16] Appendix Table $A.3$ provides a cross-tabulation of flood exposure and home damage categories and finds that both the self-reported measure of home damage from DNORS and a measure based on changes in appraised home values from the Assessor's data are highly correlated with flood exposure. As one would expect, the two independent measures of home damage are also highly correlated with one another.

Although New Orleans had one of the highest rates of flood insurance coverage in the nation prior to Katrina, some households did not have any coverage. In some cases policies were not large enough to cover the full cost of rebuilding.[17] Finally, many have alleged that insurance companies refused some valid homeowners insurance claims, citing uncertainty about the cause of property damage.

Several government relief programs increased the resources available to households and altered households' financial incentives for rebuilding versus relocating. The remainder of this section describes these programs.

The **Louisiana Road Home program** was a large scale government[18] grant program designed to assist pre-Katrina Louisiana homeowners by providing cash grants for rebuilding that did not need to be repaid. The program was advertised as the largest single housing recovery program in US history, and during the first four years following Katrina, the Road Home program disbursed more than nine billion dollars to Louisiana homeowners.

The Road Home program addressed two policy objectives. First, the program compensated homeowners for their losses. The Road Home program made grant payments to participating homeowners irrespective of whether they chose to rebuild or to relocate. Second, the program created an incentive to rebuild by providing more generous grant packages to those who rebuilt than to those who relocated.

Participating households selected from among three available Road Home benefits packages, known as options 1, 2, and 3. Each Road Home option required participating households to meet certain obligations with regard to their rebuilding and resettlement choices.

The vast majority of New Orleans participants in the Road Home program selected option 1, the option that paid the most generous benefits. Option 1 participants agreed to repair and reside in the pre-Katrina home within three years and to purchase any required flood insurance.[19] Option 1 grants paid the estimated cost of repairs minus the value of any insurance payments already received, up to a maximum of $150,000.

Under options 2 and 3, participants received grant compensation but turned their properties over to a public land trust. Option 2 paid a grant equal to the size of the option 1 grant and required the homeowner to purchase another home in Louisiana within three years. Option 3 provided a grant that was 40% smaller than the option 2 grant but did not require the grant recipient to purchase another home or to remain in Louisiana.

[17] The reasoning of Glaeser and Gyourko (2004), discussed in the context of pre-Katrina New Orleans by Vigdor (2008), provides a rational explanation for this type of shortfall. Because housing is a durable commodity and because New Orleans' population had been steadily declining during the years prior to Katrina, many homes' market values prior to Katrina were substantially less than the home's replacement cost. As a result, even if a home was insured for its full market value, as many mortgage agreements required, insurance payments could fall short of the full cost of rebuilding.

[18] The Road Home program was funded through a U.S. Department of Housing and Urban Development Community Development Block Grant and was administered by the Louisiana Office of Community Development

[19] Rebuilding households were also required to meet a minimum set of building standards.

The Road Home program provided a financial incentive to return home by paying the most generous overall package to those who agreed to rebuild (option 1). Although the size of the grant payment itself was the same under options 1 and 2, option 2 participants lost any as-is value of their properties, because option 2 required participants to turn their properties over to the Road Home Corporation. Homeowners, of course, also had the option to sell their homes privately.

Define the Road Home program's financial incentive to rebuild to be the difference between what a household's net worth would be under Road Home option 1 and what the household's net worth would be under the more lucrative of Road Home option 2 and a private home sale. Figure 2 illustrates how this financial incentive to rebuild depended on the level of home damage and the fraction of repair costs covered by insurance. The horizontal axis plots the cost of needed repairs as a fraction of the home's value if it is repaired. The upward-sloping line plots total proceeds (grant plus insurance settlement) that the household would receive if it accepted a Road Home option 2 grant. The downward sloping lines plot the total proceeds (insurance settlement plus proceeds from the sale) that the household would receive if it sold its home privately (assuming different levels of insurance coverage). The financial incentive to rebuild is the difference between full compensation under option 1 and the upper envelope of these two lines. The financial incentive to rebuild is higher for households with less insurance coverage, and, unless insurance coverage is nearly complete, the financial incentive to rebuild is larger for households with intermediate levels of damage.

Table 3 describes Road Home program participation patterns among households with homes rendered uninhabitable by Katrina. About three quarters of households with initially uninhabitable homes participated in the Road Home program. Only about 10% of participants selected option 2 or 3. Consistent with the program's incentive structure, program participants with less comprehensive insurance and with moderate home damage were more likely to select option 1 than options 2 or 3.

About 18% of households with an initially uninhabitable home sold the home during the first four years following Katrina. As expected, more households sold their homes privately than accepted a Road Home option 2 or 3 grant if the home was moderately damaged or if the household had comprehensive insurance. More households accepted an option 2 or 3 grant if their home was destroyed or if a significant fraction of their losses were not covered by insurance.

The Road Home program was announced in February of 2006, about six months after Hurricane Katrina, and similar grant programs figured prominently in the policy debate prior to that formal announcement. The program's implementation was plagued by long delays in multiple stages of the application process. After submitting an application to the program, applicants were required to meet with a "program housing advisor" in order to provide documentation of identity, home ownership, and the home's initial value.[20]

[20] Applicants were instructed to bring personal identification, documentation for any FEMA assistance received, proof of home ownership (property tax bill, title, mortgage documents, etc.), proof of insurance, any SBA loan documents, home appraisal information, proof of income for all adult household members, and a utility bill (Road Home Program, 2006).

Those living in Louisiana attended in-person meetings at "Housing Assistance Centers" around the state. Those living out of state could conduct their meetings by telephone or at one of several Housing Assistance Centers opened in out-of-state locations with large evacuee populations, including in Houston, Dallas/Fort Worth, San Antonio, and Atlanta. Applicants then awaited a grant offer, after which the applicant formally selected one of the Road Home options, signed a corresponding "covenant," and awaited disbursement of the grant. The Road Home program's application deadline was July 31, 2007, almost two years after Katrina. The median date of grant payments for New Orleans participants occurred near the second anniversary of Katrina, and the standard deviation of grant payment dates was about four months.

Estimating a dynamic model with forward-looking agents requires making assumptions about agents' expectations. For the model that I consider in this study, agents' expectations about the Road Home program's eventual existence and about the timing of Road Home grant payments are especially important. In the model, I assume that households know immediately after Katrina that the Road Home program will eventually be available. This assumption greatly simplifies the model's solution, allowing me to ignore the manner in which households might learn about government programs. And while actual households could not have been certain about the program's eventual availability prior to its formal announcement, this particular model assumption should not significantly alter the choice problem of model households, because quick rebuilding was nearly impossible during the first few months following Katrina. Following the program's announcement, knowledge of the program was indeed widespread. Public service announcements advertised the program throughout Louisiana on television and radio and in print. The program's high participation rate itself also suggests that households were aware of the program. Without information about the timing of grant payments to individual households, I further assume that all grants became available on Katrina's second anniversary, and I assume that households foresaw that timing for payments. This assumption should provide a reasonable approximation to reality if households anticipated considerable bureaucratic inefficacy in the program's implementation.

For a household that did not have savings sufficient to cover the cost of needed repairs, the ability to borrow was crucial if the household wanted to repair its home without a long delay. For many households, the **Small Business Adminstration's (SBA) Disaster Loan Program** would be the most easily accessible lender. The SBA Disaster Loan Program is a standing program that provides loans to individual homeowners in federally declared disaster areas to cover the cost of home repairs (less any insurance payments) of up to $200,000. The terms of Disaster Loans are determined on a case-by-case basis based on an assessment of each borrower's ability to repay. Approved applicants who do not have access to other credit receive an interest rate that is no more than 4%, and approved applicants who could obtain credit elsewhere receive an interest rate that is no more than 8%. SBA's creditworthiness standards are marginally more lenient than a bank's standards, but not all applicants are approved.

The demand for SBA Disaster Loans following Hurricane Katrina was high, and by the end of 2005, about 276,000 Gulf Coast homeowners had submitted applications. However, nearly 82% of the applications were rejected due to insufficient income or a poor credit history by the applicant (New York Times, 2005). This rejection rate was higher than the rejection rates following other recent disasters, reflecting the fact that Gulf Coast homeowners on average had lower incomes and poorer credit histories than homeowners in less economically depressed regions. These figures corroborate the findings of the estimated model that many homeowners could not easily borrow to finance repairs.

The **Gulf Opportunity Zone (GO Zone)** initiative provided a package of investment subsidies and tax credits targeted to firms operating in areas impacted by the storm. This approach to disaster relief drew precedent from the use of Liberty Zones in New York City following the September 11, 2001 terrorist attacks. Spatially targeted business subsidies have been used increasingly over the past thirty years (including state Enterprise Zones and federal Empowerment Zones, Enterprise Communities, and Renewal Communities) to target transfers to areas with chronic poverty and low economic activity. The Liberty Zones and GO Zone expanded the original scope of these earlier programs by using business subsidies to cushion negative shocks caused by man-made and natural disasters.

The package of GO Zone benefits to zone businesses included both subsidies for the hiring and retention of workers and subsidies to capital investment. Specifically, the GO Zone program provided an employee retention credit or a Work Opportunity Tax Credit (WOTC) of 40% of the first $6,000 paid to a retained or newly hired employee who lived in the GO Zone on the day before Katrina struck. Existing research suggests that spatially targeted hiring subsidies positively impact local employment and wages (Busso, Gregory, and Kline, 2011). My simulation experiments consider how these subsidies might have affected households' resettlement choices through their impact on New Orleans wages.[21]

The model considered in the remainder of the paper considers the influence of these policies on households' resettlement choices. Figure 3 plots trends in home repairs and home sales during the first four years after Katrina. Few home repairs occurred in Katrina's immediate aftermath, and on Katrina's second anniversary only about one in five initially uninhabitable homes had been repaired. Substantially fewer black households than nonblack households repaired homes during the first two years after Katrina. By Katrina's fourth anniversary, about three in five households with an initially uninhabitable home had repaired the home and the racial disparity in repair rates had closed. An additional 12% of homes had been repaired by someone who purchased the home from the pre-Katrina owner.

Figure 4 plots trends in residence-location outcomes during the first four years following Katrina. Panel

[21]The GO Zone initiative also included provisions that altered the tax treatment of capital investment in ways that were favorable to businesses. These provisions altered the time frame over which businesses could deduct various spending on clean-up, demolition, and acquiring property, allowed for the use of tax exempt bonds to raise capital, and provided tax credits to offset rehabilitation expenses. The literature studying the employment impacts of programs that rely primarily on tax breaks and capital subsidies (mainly state Enterprise Zones) finds little evidence of an aggregate impact on job creation or on wages (Papke, 1993, 1994; Boarnet and Bogart, 1996; Bondonio, 2003; Bondonio and Engberg, 2000; Elvery, 2009). Bartik (1991) provides a comprehensive review of earlier evidence on the effects of place-based policies. For this reason, I restrict attention to the effects of the GO Zone's wage subsidies.

A plots the fractions of black and nonblack households residing in New Orleans and residing in the pre-Katrina home. Nonblack households returned to New Orleans and to their pre-Katrina homes much more quickly, but these disparities closed by Katrina's fourth anniversary. Panels B and C illustrate that racial disparities in the initial resettlement of New Orleans are explained in large part by differences by race in Katrina-related storm damage. Black households with homes that were still inhabitable following Katrina returned more quickly than nonblack households. Black households with severely damaged homes returned more slowly than nonblacks, but a larger fraction had returned to the pre-Katrina home by the fourth anniversary of the storm. These descriptive findings, particularly regarding initial resettlement patterns, corroborate previous research (Groen and Polivka, 2010; Zissimopolous and Karoly, 2010; Vigdor, 2008; and Paxson and Rouse, 2008) that finds that blacks returned to New Orleans more slowly than non-blacks, with differences in flood exposure accounting for some but not all of this disparity.

III. Model

To better understand how post-Katrina subsidies influenced rebuilding and resettlement patterns, I develop a dynamic discrete choice model of households' resettlement choices. The main goal of the model is understand the factors shaping the prevalence and timing of three broad resettlement outcomes; rebuild and return to the pre-Katrina home, relocate to another (potentially less flood-prone) location within New Orleans, or resettle away from the New Orleans. In the empirical implementation, I allow for the possibility that rebuilding in heavily-flooded areas is less attractive than rebuilding in less heavily-flooded areas by allowing the benefit of returning to the pre-Katrina home to depend on the fraction of nearby homes that were damaged severely by Katrina. The model's parameters describe households' access to credit (for financing home repairs) and describe households' preferences over location amenities and consumption.

A number of techniques have been adopted in the existing literature to incorporate limited credit access into dynamic discrete choice models. Some studies consider models that explicitly impose limits to credit.[22] The approach that I adopt is closer in spirit to that of studies that allow for the possibility that credit access is limited and attempt to infer from observed choices *whether or not* agents face binding borrowing constraints (Evans and Jovanovic, 1989; Cameron and Heckman, 2001; Keane and Wolpin, 2001). Studies in this vein commonly estimate their models using data in which asset accumulation choices are observed, identifying borrowing constraints from the relationship between current wealth and the choice to make an investment of a given expected return. The data that I analyze do not contain information on non-housing assets, so I adopt an alternative approach to identifying borrowing constraints that more closely resembles a strategy

[22]Many studies (i.e. Keane and Wolpin, 1997; Rust and Phelan, 1997; Keane and Wolpin , 2002a&b; Todd and Wolpin, 2006; and Kennan and Walker; 2011) have considered models in which agents consume all of their income each period. This approach provides substantial computational savings and is often a useful approximation when factors other than credit constraints are the primary interest. Other studies of environments in which borrowing is known to be constrained (i.e. Rosenzweig and Wolpin, 1993; French and Bailey, 2011) have considered models in which agents are free to save but are explicitly forbidden from holding negative net assets.

from the education literature (Cameron and Taber, 2004) and a strategy from the macro literature testing the permanent income hypothesis (Shea, 1995; Souleles, 1999; Stephens, 2003).

The estimated model allows me to assess the impact of the various post-Katrina programs on households' welfare and households' behavior and to assess the extent to which disaster-related location subsidies more generally distort households' location decisions.

Framework, Timing, and Preferences

I model the dynamic problem facing home owning households in the aftermath of Hurricane Katrina using a finite horizon, discrete time framework. Periods are indexed by $t = 0, .., T$. Each period is four months long. An asset holding $A(t)$ and a vector $X(t) = [L(t), H(t), D(t)]$ characterize the state facing the household at time t; with $L \in \{1, 2, 3\}$ denoting location (1 indicates residence in the pre-Katrina home, 2 indicates residence in another New Orleans residence, and 3 indicates residence elsewhere), $H \in \{0, 1\}$ indicating ownership of the pre-Katrina home, and $D \in \{0, 1\}$ indicating that the home damage caused by Hurricane Katrina is yet to be repaired.

Hurricane Katrina occurs at $t = 0$, and T is the period in which the household reaches age 80. At $t = 0$ the household is endowed with an initial state $X(0)$ and an initial asset holding $A(0)$. Each household owns its home at $t = 0$. Initial housing damage and initial location are exogenously determined. Each period the household observes its current state $X(t)$ and must select the subsequent period's state $X(t + 1)$. The household must hold non-negative assets at retirement, assumed to occur at age 65. The household may not re-purchase its home if it has been sold. The household may not reside in the pre-Katrina home if the home has been sold or if it is damaged.

The household chooses a consumption level $C(t)$ each period and derives constant relative risk aversion consumption utility. The household derives utility from the amenities associated with its residence location $B(L(t), t)$, and the household suffers utility costs χ^M and χ^R from moving or rebuilding. These utility costs capture the difficulty of relocating (χ^M) and the logistical and regulatory hurdles associated with rebuilding (χ^R).

Households are heterogeneous in their preference for living in New Orleans. Each household draws a random variable $\eta \sim N(0, \sigma_\eta)$ at time $t = 0$ that permanently characterizes the strength of its attachment to New Orleans relative to the average among pre-Katrina New Orleans homeowners.

Finally, each period households receive a set of i.i.d. transitory shocks $\epsilon_t\Big(X(t + 1)\Big)$ to the payoffs associated with each of the available choices. These transitory shocks capture idiosyncratic deviations of households' benefits from the various choices relative to the average benefit from those choices. Examples of factors captured by these ϵ-shocks include a delayed or faster-than-expected permit for home repairs, situations like a child's school enrollment status or a family member's health condition that influences a household's ability to move at a particular time, and especially optimistic or pessimistic expectations about the fraction of friends and family who will have returned to New Orleans at different times.[23]

Incorporating all of these factors, a household's utility each period is,

$$
\begin{aligned}
u\Big(t\Big) \;\; = \;\; & \frac{1}{\alpha}\frac{C\Big(t\Big)^{1-\omega}}{1-\omega} \; + \; B\Big(L(t),t\Big) + \epsilon_t\Big(X(t{+}1)\Big) + \eta\Big(X(t{+}1)\Big) \\
& - \chi^M \mathbf{1}\Big(L(t{+}1) \neq L(t)\Big) \\
& - \chi^R \mathbf{1}\Big(D(t{+}1) < D(t)\Big)
\end{aligned}
\tag{1}
$$

Each period t households observe the current state $\Big(X(t), A(t)\Big)$ and choice specific shocks $\epsilon_t\Big(X(t{+}1)\Big)$ and choose the next period's state $\Big(X(t+1), A(t+1)\Big)$. Households continue this process until reaching age 65, at which time the state becomes fixed and the household is retired. Households that are 57 or older when Katrina occurs continue adjusting states X throughout the first eight years following Katrina. Once the state $X(t)$ is fixed at retirement, the household derives utility during retirement until age 80 (period T). Retirement utility is the sum of amenity utility derived from the household's residence location and the consumption utility associated with a $\$4,500$ per period transfer payment plus an annuity based on the household's asset holding at retirement net of expenses (any mortgage or rent payments associated with the chosen residential location).

The household's objective is to maximize the present discounted value of future per-period utilities, denoted by U.

$$
U = \sum_{t=0}^{T} \beta^t \, u\Big(t\Big) \tag{2}
$$

where β is a subjective discount factor.

Prices and Budget Constraint

An intertemporal budget constraint requires that each household's consumption plus net asset accumulation equals its income (wage earnings plus the proceeds from home sales or grant payments) minus expenses (home repair costs and rent or mortgage payments) each period. Households are assumed to foresee the path of relevant prices over time and locations.

[23] No doubt, some of these factors are somewhat persistent over time. The model approximates the role of unobservables using only a permanent component η and a set of i.i.d. compentents ϵ. The role of factors that are partially persistent will be approximated in this framework by those factors "loading" partially on the persistent component and partially on the i.i.d. components.

Each household head that worked during the year prior to Katrina receives the market wage for his or her human capital level and occupation each period in the household's chosen labor market $W(L,t)$. Residence in locations $L = 1, 2$ places the household in the New Orleans labor market and residence in $L = 3$ places the household in a pooled "other metro South" labor market.

The household derives housing services from the pre-Katrina home if $L(t) = 1$. The household must rent an equivalent flow of housing services at the market rate $RENT(L(t))$ if $L(t) = 2$ or $L(t) = 3$. The household makes a mortgage payment $M(t)$ each period until the mortgage is paid off (30 years after the home is purchased) or until the home is sold.

The household pays a repair cost K if it chooses to repair its home. The household may not make partial repairs over multiple periods, but the household may self-finance by saving a portion of the total repair cost over several periods before purchasing repairs.

If the household sells its home at time t, it receives proceeds equal to $\Big(P^H - PRINC(t) - D(t)K\Big)$, the home's market value in post-Katrina New Orleans if it were fully repaired minus any principal remaining on the home's mortgage and the cost associated with any needed repairs.

The household's budget constraint incorporates an approximation to the Road Home program's actual eligibility rules. A household that repairs or sells its home during the first two years following Katrina is reimbursed for uninsured repair costs by a Road Home option 1 grant G_1 in period 7, the first period after the second anniversary of Katrina. If the household purchases home repairs between periods 7 and 15 (during the third, fourth, and fifth years after Katrina), the household is reimbursed by a Road Home option 1 grant G_1 at the time the repairs are made. If the household sells its home between periods 7 and 15, the household receives either a Road Home option 2 grant G_2 or the market value of the home, whichever is larger.

$$G_1(t) = \begin{cases} \min\Big[\$150{,}000\ ,\ K - INS\Big] & \text{if } t{=}7 \text{ and } D(t) = 0 \text{ or } H(t) = 0 \\ \min\Big[\$150{,}000\ ,\ K - INS\Big] & \text{if } t{\in}[7,15] \text{ and } D(t{-}1) < D(t) \\ 0 & \text{otherwise} \end{cases}$$

$$G_2(t) = \begin{cases} \min\Big[\$150{,}000\ ,\ K - INS\Big] & \text{if } t{\in}[7,15] \text{ and } H(t) < H(t{-}1) \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

(4)

The household's intertemporal budget constraint is,

$$
\begin{aligned}
C(t) \;\; = \;\; & \overbrace{W\Big(L(t),t\Big)}^{\text{wage income}} + \overbrace{\Big(\max\Big(G_2(t), P^H - D(t)K\Big) - PRINC(t)\Big)\Big(H(t) - H(t{+}1)\Big)}^{\text{proceeds from home sale}} + \overbrace{G_1(t)}^{\text{Option 1 grant}} \\
& - \underbrace{H(t)\; M(t)}_{\text{mortgage payment}} - \underbrace{RENT\Big(L(t)\Big)}_{\text{rent payment}} - \underbrace{K\Big(D(t{+}1) - D(t)\Big)}_{\text{repair costs}} - \underbrace{\Big(A(t{+}1)/(1+r) \; - \; A(t)\Big)}_{\text{change in asset holding}}
\end{aligned} \tag{5}
$$

The possibility of a borrowing constraint is incorporated by allowing the interest rate faced when borrowing to differ from (exceed) the interest rate faced when saving. That is,

$$
\begin{aligned}
A(t+1)\Big/(1+r) \;\; &= \;\; \begin{cases} A(t+1)\Big/(1+r^S) & \text{if } A(t+1) \geq 0 \\ A(t+1)\Big/(1+r^B) & \text{if } A(t+1) < 0 \end{cases} \\
r^B \;\; &\geq \;\; r^S
\end{aligned} \tag{6}
$$

Dynamic Programming Representation

Given the separability of the transient utility shocks ϵ, the solution to the household's problem may be expressed as a dynamic programming problem. Define the value function $V(X, A, \eta, \epsilon, t)$ as a mapping from each state to the expected present discounted value of the subsequent utility associated with an optimal choice policy. By the principle of optimality, this value function must satisfy the Bellman equation,

$$
\begin{aligned}
V\Big(A(t), X(t), \eta, \epsilon\Big) \;\; &= \;\; \max_{A(t+1), X(t+1)} \Bigg\{ u\Bigg(X\Big(t\Big), X\Big(t{+}1\Big), A\Big(t\Big), A\Big(t{+}1\Big), \eta, \epsilon\Big(X(t+1)\Big)\Bigg) \\
& \qquad + \; \beta\, \overline{V}\Bigg(A\Big(t+1\Big), X\Big(t{+}1\Big), \eta\Bigg) \Bigg\}
\end{aligned} \tag{7}
$$

$$
\overline{V}\Bigg(A\Big(t{+}1\Big), X\Big(t{+}1\Big), \eta\Bigg) \;\; = \;\; \text{Emax}_\epsilon V\Bigg(A\Big(t{+}1\Big), X\Big(t{+}1\Big), \eta, \epsilon\Bigg) \tag{8}
$$

Because the choice specific ϵ shocks vary with $X(t{+}1)$ but not $A(t{+}1)$, the optimal asset accumulation policy is a deterministic function A^* of the current state and the chosen state, and Equation (7) may be rewritten as,

$$
\begin{aligned}
V\Big(A(t), X(t), \eta, \epsilon\Big) \;\; &= \;\; \max_{X(t+1)} \Bigg\{ u\Bigg(X\Big(t\Big), X\Big(t{+}1\Big), A\Big(t\Big), A^*\Big(X(t), \eta, X(t{+}1), A(t), t\Big), \eta, \epsilon\Big(X(t+1)\Big)\Bigg) \\
& \qquad + \; \beta\, \overline{V}\Bigg(A^*\Big(X(t), \eta, X(t{+}1), A(t), t\Big), X\Big(t{+}1\Big), \eta\Bigg) \Bigg\}
\end{aligned} \tag{9}
$$

where $A^*\Big(X(t), \eta, X(t{+}1), A(t), t\Big)$ is given by,

$$A^*\Big(X(t),\eta,X(t{+}1),A(t),t\Big) \quad = \quad \arg\max_{A(t+1)} \Bigg\{ u\bigg(X\Big(t\Big),X\Big(t{+}1\Big),A\Big(t\Big),A\Big(t{+}1\Big),\eta,\epsilon\Big(X(t+1)\Big)\bigg) + \beta\,\overline{V}\bigg(A\Big(t+1\Big),X\Big(t{+}1\Big),\eta\bigg)\Bigg\} \tag{10}$$

This representation is convenient for estimation, because it allows for households' financial assets (which are not observed in the data) to be conditioned out of the likelihood function. In practice, I discretize the asset space, so for any current state and chosen state the definition of A^* in Equation (10) requires finding the maximal element in a finite set.

The assumption that the ϵ shocks are drawn from the type I extreme value distribution allows for a closed form representation of the expected maximal continuation value from any state (McFadden, 1975; Rust, 1987),

$$\overline{V}\Big(A(t),X(t),\eta\Big) = \ln\left\{\sum_{X(t+1)} \exp\left(\overline{u}\Big(X(t),\eta,X(t{+}1),A(t),A^*\Big(X(t),\eta,X(t{+}1),A(t),t\Big)\Big) + \overline{V}\Big(A(t{+}1),X(t{+}1),\eta\Big)\right)\right\} + \gamma \tag{11}$$

where $\gamma \approx 0.577$ is Euler's constant. Also, the conditional choice probabilities take the multinomial logit form,

$$\mathrm{P}\Big(X(t{+}1)\Big|A(t),X(t),\eta\Big) = \frac{\exp\left[\overline{u}\Big(X(t),\eta,X(t{+}1),A(t),A^*\Big(X(t),\eta,X(t{+}1),A(t),t\Big)\Big) + \overline{V}\Big(A(t{+}1),X(t{+}1),\eta\Big)\right]}{\sum_{X'(t+1)} \exp\left[\overline{u}\Big(X(t),\eta,X'(t{+}1),A(t),A^*\Big(X(t),\eta,X'(t{+}1),A(t),t\Big)\Big) + \overline{V}\Big(A(t{+}1),X'(t{+}1),\eta\Big)\right]} \tag{12}$$

Using these simplifications, it is straightforward to numerically solve the value function for any given parameterization of the model using backward induction from the time T boundary condition.

IV. Model Parameterization and Estimation

The parameters of the model to be estimated include a wage equation, a set of household preferences, and parameters describing the interest rate at which households with different demographic traits may borrow. I estimate the model sequentially. The first step estimates the wage equation. The second step takes the first step's estimates as a known input and estimates the parameters describing households' preferences and the borrowing interest rate.

Wages

Each period, each household head who was employed during the year prior to Katrina receives a wage that reflects the value of his or her skills in the worker's residence location. That wage is determined by,

$$\ln w_{jklt} = \ln \overline{w}_{klt} + x_j'\beta + \mu_j \tag{13}$$

where j indexes workers, k indexes two-digit occupations, l indexes the labor market in which the worker resides, t indexes the period, $\overline{w}_{klt}$ is a period-location-specific mean occupation wage, x_j is a vector of worker human capital variables, and μ_j is a worker fixed effect.

I estimate this equation using pre-Katrina annual earnings records from DNORS[24] and annual earnings records from the New Orleans MSA respondents to the 2005 ACS. Pre-Katrina New Orleans mean occupation wages $\overline{w}_{klt}$ come from the 2005 ACS. I obtain estimates of the worker fixed effects $\widehat{\mu}_j$ by computing the residuals from this regression for all DNORS records used to estimate equation (13).

Estimation of the structural model requires an estimate of the labor wages that each household faces in each location in each period. To construct these quantities, I compute the sum of the wages predicted by equation (13) for each household's working head or heads. I compute the location-specific mean occupation wages that enter the right-hand side of equation (13) using the ACS. In the model, each location's mean occupation wages follow their observed paths in the ACS during the first four years following Katrina and remain at their 2009 levels in each location in all later years.[25] Households with just one head who was employed during the year prior to Katrina receive that worker's wages, and couple-headed households with two working heads receive the sum of both workers' wages.

Parameterizing household's preferences and the borrowing interest rate

Two parameters describe the consumption component of utility $\frac{1}{\alpha}\left(\frac{C^{1-\omega}}{1-\omega}\right)$, the coefficient of relative risk aversion ω and a parameter α that scales the importance of consumption utility relative to that of the unobserved utility shocks ϵ.

I normalize the borrowing interest rate for a group of relatively affluent households (non-black households in which at least one household head holds a bachelor's degree and pre-Katrina with annual income

[24] I estimate the wage equation using DNORS workers living in both renter-occupied and owner-occupied dwellings.

[25] With an earlier specification of the model, I re-estimated the model under the assumption that relative New Orleans wages "decay" back to their pre-Katrina values in the out years as a sensitivity analysis. The spatial wage elasticity implied by the model increased very slightly as a result of this change, the intuition being that same variation in location choices is attributed to a smaller amount of variation in relative wages, but the change does not have any significant impact on the policy conclusions of the study. Subsequent versions of this paper will present robustness checks of this sort for the model specification presented in the paper.

exceeded $40,000) to the risk-free rate ($1/\beta$). Affluent households were likely to be eligible for the SBA Disaster Loan program or private loans. The borrowing interest rate for other households differs from the risk-free rate according to,

$$\ln(1+r^B) = \ln(1/\beta) + \gamma_1\mathbf{1}(black) + \gamma_2\mathbf{1}(nocoll) + \gamma_3\mathbf{1}(Inc < \$20k) + \gamma_4\mathbf{1}(\$20k < Inc < \$40k) \tag{14}$$

where $\mathbf{1}(black)$ indicates that a household has a black household head, $\mathbf{1}(nocoll)$ indicates that no household head has a bachelor's degree, and $\mathbf{1}(Inc < \$20k)$ and $\mathbf{1}(\$20k < Inc < \$40k)$ indicate that pre-Katrina annual household income fell in the indicated range. A positive value for any of the γ parameters indicates that on average the corresponding group faced borrowing constraints.

When estimating the location preference parameters, I normalize the payoff to living away from New Orleans $B(L = 3)$ to zero. The payoff $B(L = 2)$ and the difference $B(L = 1) - B(L = 2)$ are parameters to be estimated. I allow these parameters to depend on a small set of household and neighborhood characteristics. This parameterization captures differences in the benefits to living in neighborhoods with different levels of flood damage and captures systematic differences in attachment to place across groups.[26]

Following earlier structural migration studies (Kennan and Walker, 2011; Bishop, 2007), the utility cost to moving χ^M depends on the distance and timing of the move.[27] The utility cost to repairing one's home χ^R depends on whether the home was destroyed or the home was damaged but not destroyed.

When discussing the estimation algorithm, I jointly refer to the set of model parameters described here with $\theta = [B(L), \chi^M, \chi^R, r^B, \alpha, \sigma]'$.

I fix the values of two remaining parameters using a convention and an empirical result from the existing literature. I set the subjective discount factor to $\beta = 0.95$ annually, following earlier dynamic discrete choice studies of migration (Kennan and Walker, 2011). I set the coefficient of relative risk aversion to $\omega = 4.17$, the mean coefficient of relative risk aversion estimated by Barsky et al. (1997) using an experimental approach with Health and Retirement Study data.

[26]Specifically, I allow B($L = 2$) to follow a linear time trend during the first five years following Katrina. I allow $B(L = 1, t) - B(L = 2, t)$ to depend on the fraction of owner-occupied homes on the same block segment (the DNORS sampling unit) that were rendered uninhabitable by Katrina. I group this continuous measure into three groups; $0\% - 50\%$, $50\% - 90\%$, and $90\% - 100\%$. I allow $B(L = 1, t) - B(L = 2, t)$ to follow linear time trends during the first five years following Katrina within the two higher damage categories. This parameterization allows for the possibility that living in a neighborhood that was heavily flooded might have been especially unappealing shortly after Katrina but may become more attractive as time passes. I also allow $B(L = 1, t) - B(L = 2, t)$ to depend on the 2000 poverty rate in the household's Census block group, when the household purchased its home, and whether either head was born outside of Louisiana.

[27]Specifically, the utility cost of moving depends on an indicator for any change in location, an indicator that the move was to or from New Orleans (not within the city), and an indicator that the move occurred during the first period after a home repair. This parameterization allows for the possibilities that moving is more difficult if the destination is far away, moving home is more likely immediately following a home repair, and the moving cost is different during the first period after Katrina than in subsequent periods.

Estimation

Estimation proceeds by full-solution maximum likelihood. The full-solution method possesses greater statistical efficiency than less computationally-intensive alternatives[28] and facilitates a novel approach to addressing the particular missing data pattern that I encounter.

The data analyzed in this study do not contain information on households' non-housing assets. I use a two-step procedure to "integrate out" this missing dimension when computing households' likelihood contributions. The first step utilizes the model's solution to collapse this missing asset data problem into a more tractable missing *initial* asset data problem.[29] The second step computes the likelihood of each household's observed choices at a range of assumed initial asset holdings and integrates the conditional likelihood contributions for each household with respect the distribution of 2005 asset holdings among Southern urban homeowners with the same demographic characteristics as that household.[30]

To estimate the model, I assume that a sample of households $i = 1, ..., N$ solve the model described in the previous section. The data contain information on these households' choices $\Big\{X_i(t)\Big\}_{t=1}^{T}$, their post-Katrina circumstances, and their demographic traits, but the households' initial financial asset holdings and the households' permanent and idiosyncratic preference shocks are not unobserved.

Using equation (10) define the model's implied asset holding policy,

$$\widehat{A}_i\Big(t\Big|\Big\{X_i(\tau)\Big\}, A(0), \eta, \theta\Big) \quad = \quad \begin{cases} A_i(0) & \text{if } t = 0 \\ A^*\Big(X_i(t-1), X_i(t), A_i(t-1), t-1\Big) & \text{if } t > 0 \end{cases} \tag{15}$$

Conditional on an assumed initial asset value, the household's likelihood contribution is:

$$l_i\Big(\theta\Big|\Big\{X_i(t)\Big\}_{t=1}^{T}, A(0), \eta\Big) \quad = \quad \Pi_{t=0}^{11}\mathrm{P}\Big(X_i(t+1)\Big|X_i(t), \widehat{A}_i(t|A(0)), \eta, \theta\Big) \tag{16}$$

The household's unconditional likelihood contribution is obtained by integrating this conditional expression with respect to the distribution of initial assets $F^i_{A(0)}(a_0)$ and the distribution of the unobserved heterogeneity term $G_\eta(\eta|\theta)$:

$$l_i\Big(\theta\Big|\Big\{X_i(t)\Big\}_{t=1}^{T}\Big) \quad = \quad \int\int l_i\Big(\theta\Big|\Big\{X_i(t)\Big\}_{t=1}^{T}, \widehat{A}_i(t|a_0), \eta\Big)\, dF^i_{A(0)}(a_0)\, dG_\eta(\eta|\theta) \tag{17}$$

[28]See, for example, the Conditional Choice Probability (CCP) estimators of Hotz and Miller (1994) and Arcidiacono and Miller (2011). Aguirregabiria and Mira (2010) provide a survey of methods for estimating models of this sort.

[29]This first step requires computing the full solution to the model. For that reason, this method precludes the use of CCP estimators, which require "finite dependence" (Arcidiacono and Miller, 2011) in order to realize computational savings.

[30]These household-specific asset distributions are modeled using 2005 PSID data with a procedure described in Appendix III.

Following Kennan (2004), I approximate the continuous distribution F of initial household asset holdings and the continuous distribution G of the heterogeneity term η using discrete distributions with ten support points and five support points respectively.[31] I approximate $\widehat{F}^i_{A_0}(a)$ by assigning equal prior probability to the $5th$, $15th$, ..., $95th$ percentiles of its initial asset-holding distribution. I approximate $\widehat{G}_\eta(\eta)$ by assigning equal prior probability to the $10th$, $30th$, $50th$, $70th$ and $90th$ percentiles of the distribution. The approximation of the integral in Equation 17 is,

$$l_i\Big(\theta\Big|\Big\{X_i(t)\Big\}_{t=1}^{T}\Big) \;=\; \frac{1}{10}\sum_{p_a=5}^{95}\frac{1}{5}\sum_{p_\eta=10}^{90} l_i\Big(\theta\;\Big|\;\Big\{X_i(t)\Big\}_{t=1}^{T},\; A_i(0)=F^{i-1}_{A(0)}(p_a),\; \eta=G^{i-1}_{\eta}(p_\eta)\Big) \tag{18}$$

and the log-likelihood for the full panel dataset is:

$$Ł\Big(\theta\Big|\{X(t)\}_{t=1}^{T}\Big) \;=\; \ln\Big(\Pi_{i=1}^{N}\, l_i\Big(\theta\;\Big|\;\Big\{X_i(t)\Big\}_{t=1}^{T}\Big)\Big) \tag{19}$$

I compute the maximum likelihood estimate of θ using a nested fixed point algorithm in which an "inner loop" repeatedly computes a numerical solution to the model and obtains a sample log-likelihood at candidate values of θ, and an "outer loop" searches the parameter space for the likelihood maximizing parameter vector $\widehat{\theta}$.

I conduct inference using the asymptotic variance-covariance matrix, robust to clustering at the neighborhood level,[32]

$$\widehat{COV}_{\widehat{\theta}} = H(\widehat{\theta})^{-1}\Big(\sum_{k=1}^{K} g_k(\widehat{\theta})g_k(\widehat{\theta})'\Big)H(\widehat{\theta})^{-1} \tag{20}$$

where $H(\theta) = \partial^2 L(\theta)/\partial\theta\partial\theta'$ is the Hessian matrix and $g_k(\theta) = \sum_{\mathcal{N}(i)=k}\partial l_i(\theta)/\partial\theta$ is the sum of household scores within cluster (neighborhood) k ($\mathcal{N}(i)$ returns household i's neighborhood and j indexes neighborhoods).

[31] To approximate the distribution of initial asset holdings, I obtain an estimate of the $5th$, $15th$, ..., $95th$ percentiles of the distribution of each household's pre-Katrina asset holding conditional on the household's observed characteristics. Appendix III describes the approach in detail, which I apply to data from the 2005 wave of the PSID.

[32] I cluster by official New Orleans neighborhoods. That unit of geography is larger than Census blocks or block groups, so this approach is more conservative than clustering at these smaller units of geography at which some of the model's exogenous variables are defined.

V. Identification

The assumption that the idiosyncratic shocks ϵ are drawn from the Type-I EV distribution normalizes the variance of that unobserved component. As in a standard static logit model, the values of other parameters reflect their importance relative to the importance of unobservables.

The importance of consumption utility relative to the importance of the unobserved location-preference shocks (both permanent and transitory), is identified by variation across households in the net financial benefit of residing in New Orleans or residing in the pre-Katrina home relative to the financial benefit from staying away. Variation in the net financial benefit of residing in New Orleans or in the pre-Katrina home comes from the Road Home program's provisions (see figure 2), and from variation in the relative New Orleans wage (wages in New Orleans minus wages in other Southern metro areas) across occupations and over time (see figures 5 and 6). If households' location choices are strongly related to their location-specific financial incentives, then one may infer that consumption utility receives a large weight relative to unobserved location-preference shocks. If households with dramatically different financial incentives for returning to New Orleans return at similar rates, then one may infer that the unobserved component of location preferences receives a large weight relative to consumption utility.

The flow benefit to the various residence locations is identified by the fraction of households choosing each location after accounting for the financial incentives to do so. I normalize the flow benefit to remaining away from New Orleans $B(3)$ to zero. If the fraction of households that chose to return to their pre-Katrina home exceeds the fraction predicted to do so based on financial incentives alone then one may infer that the flow benefit to residence in the pre-Katrina home $B(1)$ is positive. The flow benefit to residing "elsewhere in New Orleans" $B(2)$ is identified similarly. The parameterization of the model allows $B(1)$ to vary with neighborhood and household characteristics. The parameters that describe how $B(1)$ differs with particular pre-determined neighborhood and household characteristics are identified by cross-sectional variation in those traits.

The scale of η, the persistent unobserved heterogeneity in the flow benefit that households derive from residence in New Orleans, relative to the scale of the ϵ shocks is identified from the degree of persistence or path-dependence in observed choices. To see this, consider two households who at time t face different financial incentives to make a particular choice but who both make the same choice. On average, the household who receives the lower benefit from that choice has a draw from the unobservables ϵ plus η that more strongly favors the particular choice. If, in this situations, the two households behave similarly going forward, then the idiosyncratic shock ϵ must have a variance that is significantly larger than that of the permanent shock η. On the other hand, if choices differ substantially going forward then the persistent shock η must have a large variance relative to that of ϵ.

The model's effective borrowing rate parameters are identified in two ways. The first source of identification resembles an approach developed by Cameron and Taber (2004) who, in the context of higher education attainment, demonstrate that an effective borrowing rate is identified by comparing how an investment choice (college attendance) varies with the direct cost of investing and with a gradually accruing opportunity cost to investing. For an agent who is free to borrow, the choice of whether to make a particular investment should be similarly influenced by a change in the direct cost of the investment and an equivalent change in (the present value of) a gradually accruing opportunity cost. For an agent who is borrowing constrained, the choice should respond more strongly to a change in the direct cost, because for a constrained agent the marginal utility of consumption will be highest in the period in which the direct cost is paid. In the case of post-Katrina rebuilding, repair costs that are not covered by insurance payments represent a direct cost that must be paid before returning to the pre-Katrina residence. The difference between expected labor earnings in the evacuation location and New Orleans represents a gradually accruing opportunity cost to returning and rebuilding.

A second source of identification involves examining the extent to which the propensity to rebuild jumps at the time that Road Home grants are dispersed.[33] This approach resembles an approach found in the macroeconomics literature on consumption that tests the Permanent Income Hypothesis by examining the consumption response to fully anticipated income windfalls (Shea, 1995; Souleles, 1999; Stephens, 2003). I impose that households in an affluent comparison group may borrow at the risk free rate, since households in that group would have been very likely to be eligible for government's subsidized SBA disaster loan program. If, following the payment of Road Home grants, the rebuilding rate of a particular group changes similarly to the rebuilding rate of this (freely borrowing) comparison group, one could infer that the group also faced low borrowing costs.

Finally, I must identify utility costs to moving and rebuilding. To see the sort of variation that allows for these sorts of "transition" costs (moving costs and repair costs both reduce the payoff to particular state transitions) to be identified separately from the states' flow benefits, consider transitions involving two states, x_1 and x_2, which each provide a flow benefit. Optimality requires that the state transition probabilities $P(X_{t+1} = x_1 | X_t = x_1)$ and $P(X_{t+1} = x_1 | X_t = x_2)$ both increase with the flow benefit of state x_1, but that the first quantity increases with the transition cost and the second quantity decreases with the transition costs. With knowledge of the distribution of unobservables, these two moments are sufficient to separately identify the transition cost and the difference between the flow payoffs in x_1 and x_2.

VI. Parameter Estimates and Model Fit

Table 4 presents estimates of the labor wage equation. In the second step of estimation, the labor wages available to households across time and space are inferred from this equation and mean year-location-

[33]Note that both approaches to identifying borrowing constraints differ from one common identification strategy in dynamic discrete choice models of various investment decisions (Evans and Jovanovic, 1989; Cameron and Heckman, 2001; Keane and Wolpin, 2001), namely examining the extent to which the choice to make an investment with a particular expected net return depends upon current wealth. In this study non-housing wealth is not directly observed

occupation specific wages computed from the ACS. Figure 5 depicts the change in relative New Orleans wages in the ACS from 2005 to 2008 for the two-digit occupation groupings that I use in this study. Figure 6 plots long-differences in relative New Orleans wages during the first four years after Katrina using a broader grouping of occupations. In post-Katrina New Orleans, comparatively high wages prevailed in occupations, like construction, concentrated in industries that produced the goods and services necessary for the region's reconstruction. Comparatively low wages prevailed in occupations, like personal service providers and healthcare technicians, that are concentrated in industries that produce goods and services whose demand is especially dependent on a sizeable permanent population.

Table 5 provides estimates of the full model's structural parameters. The estimates find that, all else equal, households have a strong preference for living in New Orleans, and specifically in their pre-Katrina homes. This estimate is driven by several features of the underlying data. By Katrina's fourth anniversary, majorities of households had returned to New Orleans, had maintained ownership of their homes, and had repaired their homes. For most households those choices were subsidized. But similar patterns occurred even among households with a negative financial return to rebuilding — namely households with a small Road Home-induced incentive to rebuild and who worked in occupations for which New Orleans offers comparatively low wages.

The flow benefits to residing on blocks with $50\% - 90\%$ or $90\% - 100\%$ of homes initially uninhabitable follow statistically significantly positive time trends. Living in these areas was an extremely undesirable option immediately following Katrina, but the benefit to residing in these areas increased over time. The estimates find no statistically significant differences in flow location benefits between block damage categories five years or more after Katrina.

The estimated borrowing rate equation finds that the effective borrowing rate is 41 log-points higher than the saving interest rate for households with a pre-Katrina income less than \$20,000 per year, 35 log points higher for households with no bachelor's degree, and 14 log-points higher for black households. These estimates suggest that large segments of New Orleans households were constrained in their rebuilding choices in Katrina's immediate aftermath by low access to credit.

Consistent with other studies that estimate structural models of migration, I find that the utility cost to moving is large relative to income. For instance, a median-income household would be indifferent between paying the estimated baseline moving cost of 2.78 utils and suffering a one-period consumption reduction of just above 90%. One might expect that returning to New Orleans soon after Katrina would be especially difficult. The mandatory evacuation of the city lasted for more than a month, and a lack of basic city services made returning difficult even after some areas of the city were officially reopened. Indeed, I find that the moving cost is especially high during the first period following Katrina. Finally, the moving cost is higher for moves to or from New Orleans than for within-city moves.

The estimated utility cost to repairing a home is on the same order as the utility cost to moving. As expected, the utility cost to repairing a destroyed home is significantly higher than the utility cost of repairing an a home that was uninhabitable but not destroyed following Katrina.

The estimated standard deviation of η, the term capturing persistent unobserved heterogeneity in the preference for living in New Orleans, is 0.65 utils. This parameter is difficult to interpret directly, so it is useful to consider the location preferences of households with η draws one standard deviation above average and one standard deviation below average. A household with $\eta = 0$ belonging to the reference category of the location flow-benefit equations receives a long-term flow benefit to residing in the pre-Katrina home of about 0.5 utils per period. A household with η one standard deviation below average has a slight preference for living away from New Orleans, all else equal, since $0.5+(-0.65)<0$. A household with η one standard deviation above average has an extremely strong preference for living in the pre-Katrina home relative to living away from New Orleans, about $0.5+0.65 = 1.1$ utils per period. Holding other location costs and amenities constant, a median income household with these location preference would be willing to remain in the pre-Katrina home and accept a reduction in non-housing consumption of over 95% instead of relocating away from New Orleans.

Table 6 assesses the model's fit. I compare the model's predicted fraction of households exhibiting four different outcomes to the empirical fraction of households exhibiting those outcome on the first four anniversaries of Katrina. I provide similar comparisons within the sample of households with initially uninhabitable homes and within three sub-samples defined by pre-Katrina household income. For each comparison, I report a cluster-corrected (clustered at the neighborhood level) chi-squared test statistic associated with the null that the predicted moment and the sample moment are equal. The model predicts the key features of the data quite well, but the model's fit is not exact in a number of places. Among the four outcomes considered, the fraction of households having sold their homes is matched least closely, and the formal chi-squared tests reject the model's fit to that outcome in several instances.

Figure 7 compares the model's predicted supply elasticity of workers with respect to local wages to the corresponding elasticity predicted by Kennan and Walker (2011). Separate spatial wage elasticities are provided for households of different ages.[34] The spatial wage elasticity for the local New Orleans population of working age is 0.22. Among households 35 or younger, a population that is more comparable with the population of young workers considered by Kennan and Walker (2011), the spatial wage elasticity is 0.96. This estimate is on the same order as Kennan and Walker's (2011) estimates of between 0.5 and 0.75.

[34]Again, household age is defined to be the age of the male household head if one is present and the age of the female head otherwise.

VII. Policy Simulations

The remainder of this paper describes the results of simulation experiments designed to examine how several aspects of disaster-relief policy influence households' behavior.

I conduct simulations of households' choices under a baseline scenario, in which households face the actual post-Katrina policy environment, and under several alternative scenarios in which particular policies are changed one at a time. For each scenario, I compute $10{,}000$ simulated panels for each household, initializing each panel using the household's actual location L and home damage status D in the first period after Katrina. I compute $1/50th$ of each household's simulated panels at each of the 50 combinations of the $A(0)$ and η used to approximate the distributions of those quantities during estimation. When computing mean outcomes from the simulated data, I weight each simulated panel by the *ex post* probability that a household falls at the particular $A(0) \times \eta$ combination conditional on the household's actual choice sequence.[35]

I also examine differences in policies' impacts on household welfare. I define the expected welfare of household i under policy P using,

$$W_i(P) = 100 \times E_{A(0),\eta}\left(\frac{V\left(X_i(t{=}0)\middle|\text{Policy} = P; A(0), \eta\right) - V\left(X_i(t{=}0)\middle|\text{No Grants}; A(0), \eta\right)}{V\left(X_i(t{=}0)\middle|\text{Full Reimbursement at } t = 0; A(0), \eta\right) - V\left(X_i(t{=}0)\middle|\text{No Grants}; A(0), \eta\right)}\right) \quad (21)$$

This definition normalizes each household's expected welfare to be zero when no grant compensation is provided and to be 100 when full reimbursement of all losses is provided at $t = 0$. The expectation in this expression is taken with respect to the *ex post* distribution of $A(0)$ and η given the household's observed choices.[36] I define average household welfare under a particular policy to be the average of this quantity across households. The rational for this approach is not that full reimbursement is the correct (in some sense) policy to which others should be compared. The rational is simply to normalize each household's welfare using two extreme states that are well-defined for each household so that any two policies may be compared in a manner that assigns equal weight to every household.

The Impact of the Road Home Grant Program

This section presents the results of simulation experiments that assess the Road Home grant program's impact on households' resettlement choices. Using the simulation methods described above, I simulate

[35]The *ex post* probability that a household is characterized by a given combination of an initial asset holding and η-draw is equal to $0.02 \times l\left(\theta\middle|\left\{X_i(t)\right\}_{t=1}^{T}, A(0), \eta\right)/l\left(\theta\middle|\left\{X_i(t)\right\}_{t=1}^{T}\right)$, that is, the ex-ante weight (1/50) times the ratio of the household's panel's likelihood conditional on an $A(0) \times \eta$ combination to the household's panel's unconditional likelihood.

[36]Again, I approximate this expression by computing the quantity inside the expectation operator at each of the 50 support points for $A(0) \times \eta$ used during estimation and taking a weighted average that assigns weights based on the *ex post* probability that a household falls at each particular $A(0) \times \eta$ combination.

households' choices under the actual post-Katrina policy environment (as approximated in the estimation routine) and I simulate households' choices under a scenario in which no grant program was provided. Table 7 presents the results of these simulations.

The simulations find that, among households with initially uninhabitable homes, the Road Home program increased the fraction of homes repaired or rebuilt by the pre-Katrina owner within four years of Katrina by 5.4 percentage points (from 49.0% to 54.4%, an 11.0% increase) and generated a similar increase in the fraction of households residing in their pre-Katrina home on Katrina's fourth anniversary.

The simulations find that the Road Home program's impact varied substantially across population subgroups. The program generated larger increases in rebuilding rates among households with pre-Katrina annual income below $20,000 per year (10.2 percentage point increase, 20.2% increase), blacks (6.4 percentage point increase, 13.0% increase), and those with few or none of their losses covered by insurance, (9.9 percentage point increase, 22.5% increase). Among households with a pre-Katrina annual income below $20,000 and with few or none of their losses covered by insurance, the Road Home program increased the rebuilding rate by 14.7 percentage points (a 34.0% increase). The program generated smaller impacts on rebuilding rates among non-blacks (3.2 percentage point increase, 6.7% increase) and those with all or most of their losses covered by insurance (0.7 percentage point increase, 1.2% increase).

Table 8 compares the Road Home program's impact on households' resettlement choices and on households' welfare to the impacts of counterfactual disaster relief policies. These comparisons provide a better understanding of the mechanisms through which the Road Home program impacted households' welfare and choices. For each comparison, the first three columns report the program's impact on the fraction of households residing in the pre-Katrina home among all households with severely damaged homes (column 1), among households with severely damaged homes and pre-Katrina income below $20,000 (column 2), and among households with severely damaged homes and pre-Katrina income above $40,000 (column 3). Columns 4, 5, and 6 report impacts on household welfare for these same three groups.

The first three-row group in Table 8 compares the impact of the Road Home program to the impact of a program that makes subsidized loans available to all households on Katrina's second anniversary (to approximately match the timing of the Road Home program's "treatment"). These simulations find that the expanded loan program generates an impact on the rate of residence in the pre-Katrina home that is about 70% the size of the Road Home program's impact. Among households with pre-Katrina annual income below $20,000, the loan program's impact is 87% the size of Road Home's impact, and among households with pre-Katrina annual income above $40,000 the loan program's impact is 55% the size of Road Home's impact. Similarly, the loan program's impact on household welfare is 40% of Road Home's impact on average, but is 69% of Road Home's impact among low-income households and just 25% of Road Homes impact among higher-income households.

This set of findings suggests that a large majority or the Road Home program's impact on resettlement behavior occurred by relaxing borrowing constraints for households who would have preferred to rebuild even in the absence of a subsidy if the associated costs could be spread over time, and the behavioral changes associated with relaxing these constraints were welfare enhancing. A smaller fraction of the program's impact occurred by inducing "marginal" households who were close to indifferent between locations to switch locations to capture the subsidy. This latter type of behavioral change has a first order effect on program costs but does not have a first order impact on household welfare in this (partial equilibrium) framework,[37] creating a deadweight loss, but these results suggest that this efficiency cost of the program was relatively small.

The second three-row group compares the Road Home program's impact to the impact of a program with the same rules as the Road Home program but that paid grants at $t = 0$. The simulations find that the fraction of households having rebuilt by Katrina's fourth anniversary is very similar under the actual Road Home program, which paid grants roughly two years after Katrina, and under a grant program that paid grants immediately after Katrina. However, the welfare effects of grant payments do depend on the timing of grant payments. The average welfare effect of the immediately rolled out program is roughly one third larger than the welfare effect of the actual Road Home program. This is because the immediately rolled out program allows households with a strong preference for living in New Orleans to do so earlier. The difference between the welfare effects of the immediately rolled out program and the later rolled out program was larger among low-income households, because that group's limited ability of to borrow makes the timing of its rebuilding decisions especially sensitive to the timing of grant payments.

The Marginal Impact of Wage Subsidies and Direct grants

The Gulf Opportunity Zone program provided $\$2,400$-per-worker wage subsidies to employers who hired or retained a worker who lived on the Gulf Coast just prior to Hurricane Katrina. In this section I present the results of simulations that compare the marginal effect of $\$2,400$ per worker boost in the present value of New Orleans labor wages (spread evenly over the first four years following Katrina) to the impact of a $\$2,400$ per worker increase in the generosity of the Road Home program's option 1 grant. This comparison examines how the timing of a location subsidy to a borrowing constrained population influences the effect of the subsidy on households' location choices. I include only working households in this comparison.

Table 9 presents the results of these simulation experiments. Both policy changes cause small changes in behavior. However, the impact of the wage subsidy is only about half of the impact of an equivalent change in the rebuilding grant. The effects of grants and wage subsidies differ because, for borrowing constrained households, the benefit of a direct grant falls entirely in the period in which repairs are purchased, when

[37] If social spill-over effects occur, that is one household choosing to rebuild increases the benefit that neighbors derive from rebuilding, then even this component of the program's impact that appears purely distortionary in partial equilibrium could have a positive impact on aggregate welfare. Measuring the strength of this sort of social interaction is a focus of future work.

the marginal utility of consumption is high. Among households with a pre-Katrina annual income less than $\$20{,}000$, the wage subsidy generates an impact that is only about 20% of the impact generated by an equivalent change in the rebuilding grant. On the other hand, among households with a pre-Katrina annual income above $\$40{,}000$, the wage subsidy generates an impact that is about 70% of the impact generated by an equivalent change in the rebuilding grant. These findings suggest that in the presence of borrowing constraints, wage subsidies are likely to have a smaller impact on households' resettlement choices than similarly sized direct grants. To the extent that borrowing constraints are concentrated in segments of the population that have few resources available for rebuilding, wage subsidies might even exacerbate disparities in rebuilding rates across groups.

One should not conclude from these results alone that subsidies to local firms are an ineffective means of providing disaster relief. To the extent that the incidence of these subsidies falls partially to firms, the subsidies may increase the number of firms finding it (weakly) profitable to operate in a disaster-affected area. Such a change may directly increase the flow benefit that a household derives from living in the area, if the presence of more firms increases the ability of households to obtain desired goods and services.

The Deadweight Loss from Disaster-Related Subsidies

Disaster-related location subsidies include up front subsidies like discounts to National Flood Insurance Program premiums and guarantees of future payments in the event of a disaster. Both types of subsidy reduce the expected cost of residing in a dangerous location. The size of the economic distortion generated by these subsidies depends on the extent to which the subsidies induce marginal households to alter their location decisions. As a final application of the model, I use the model's implied semi-elasticity of residence location with respect to housing costs to compute the deadweight loss associated with a hypothetical subsidy for living in New Orleans.

I consider the effect of a flow subsidy for living in New Orleans measured as a fraction τ of each household's home's value. For example, if $\tau = 1\%$ then a household with a $\$100{,}000$ home would receive $\$1{,}000$ per year. If the probability of a household's home being destroyed by a disaster is $\tau\%$ each year, then this subsidy provides the actuarially fair value of an insurance policy that guarantees full compensation when a disaster occurs. Therefore, I interpret the distortionary effects of this policy as an approximation of the distortionary effects of a policy that guarantees relief in the event of a disaster.

Let $S(W - \text{UCH})$ represent the long-run supply of households to New Orleans as a function of the real wage, annual labor earnings minus the user cost of housing. In the presence of moving costs and heterogeneity in location preferences across households, this supply curve slopes upward.[38] The subsidy

[38] The classic Rosen-Roback model of spatial equilibrium (Rosen, 1979; Roback, 1982) and some applications of that model in the modern local public finance literature (Albouy, 2009, for example) assume that moving is costless and that preferences are homogeneous. That assumption immediate implies that in equilibrium, all individuals are indifferent between living in any location with population greater than zero and that the supply of residents to locations is infinitely elastic with respect to the real local wage.

generates a rightward shift in the supply curve, and therefore, if the labor demand and housing supply have positive price elasticities, the subsidy increases the equilibrium population of the city. To determine an upper bound on the deadweight loss of this subsidy, I consider the case in which the long run price elasticities of labor demand and housing supply are both infinite. With infinitely elastic labor demand and housing supply, none of the subsidy's incidence falls to firms or land developers (which would dampen the subsidy's distortion of households' location choices), and the elasticity of supply of residents to the city is a sufficient statistic for the deadweight loss associated with the subsidy.

The deadweight loss of this flow subsidy to residing in New Orleans may be approximated with the standard Harberger triangle,

$$DWL = \left(\frac{1}{2}\right) \; P^{H}_{TOT} \; \psi \; \tau^{2} \tag{22}$$

where P^{H}_{TOT} is the total value of New Orleans' owner occupied housing, τ is the size of the flow subsidy expressed as a fraction of each household's home value, and $\psi = d \ln S / d\tau$ is the semi-elasticity of supply of residents to New Orleans with respect to τ.

I estimate the semi-elasticity ψ using a final set of simulations. I compare the fraction of households residing in New Orleans eight years after Hurricane Katrina (the maximum number of years for which all households are required to make location choices before some households begin to retire) under the actual post-Katrina policy regime and under a regime that pays an additional $\tau = 1\%$ subsidy to each household that owns its pre-Katrina home or rents a comparable residence in New Orleans. I estimate the semi-elasticity ψ using the percentage change in the fraction of households residing in the New Orleans from the first to the second of these scenarios.

Table 10 presents the results of these simulations and their implications for the proposed subsidy's deadweight loss. The value of the subsidy provided by guaranteed disaster relief depends on the probability that disaster relief will be needed. Computing that probability is beyond the scope of this study. I instead consider two scenarios, one in which a disaster is expected to occur once every 50 years and another in which a disaster is expected to occur every 30 years. If relief is guaranteed at no cost to the household, then the value of the subsidy under these scenarios is approximately 2% of the home's value annually ($1/50$ chance of full reimbursement) or 3.33% of the home's value annually ($1/30$ chance of full reimbursement). Using the simulation results, I estimate that $\psi = 0.45$. Using tax year 2011 property assessment records for all owner occupied homes in New Orleans, I estimate the value of the owner occupied housing stock to be roughly $\$11$billion. Plugging these values into equation 22 finds that the deadweight loss associated with the $\tau = 2\%$ subsidy is roughly $\$1$ million per year, compared to the subsidy's cost of roughly $\$220$ million

In such a model, spatially targeted subsidies must generate large distortions. See Busso, Gregory, and Kline (2011) for an expanded discussion of the efficiency consequences of local subsidies in the presence of location-preference heterogeneity.

per year and finds that the deadweight loss associated with the $\tau = 3.33\%$ subsidy is roughly \$2.7 million per year, compared to the subsidy's cost of roughly \$363 million per year.

Underlying this procedure is the assumption that the elasticity of prior New Orleans residents' location decisions provides a reasonable approximation to the elasticity of location decisions among the full population "at risk" for eventually living in New Orleans. One might expect a more elastic response from young pre-Katrina New Orleans residents who were yet to be homeowners when Katrina occurred and from residents of other areas who consider whether to move to New Orleans.

To address this concern, one could turn to the existing literature and assume that among non-pre-Katrina homeowners the long-run supply elasticity of residents to New Orleans with respect to the New Orleans wage level equals an elasticity estimated by Kennan and Walker (2011).[39] Kennan and Walker (2011) present estimates of the supply elasticity of residents to many locations by simulating the effects of permanent changes to locations wages beginning when workers are 20, and each estimate falls between 0.5 and 0.75. As another option for addressing this concern, one might assume that among non-pre-Katrina homeowners the long-run supply elasticity of residents to New Orleans with respect to the New Orleans wage level is well-approximated by the model's implied elasticity for young households. I adopt this second approach with the rationale that this approach, which assumes a somewhat larger elasticity, leads to more conservative deadweight loss estimates.

Columns 3 and 4 of Table 10 present calculations of the deadweight losses associated with the same subsidies assuming a baseline under which $3/4$ of households that reside in New Orleans exhibit the model's implied average location elasticity and $1/4$ exhibit the higher location elasticity found for young households. This $3:1$ ratio is roughly the ratio found in New Orleans prior to Katrina of Louisiana-native households to households with at least one head born outside of Louisiana. In this scenario, the deadweight loss associated with a guarantee of relief in the event of a future disaster is slightly less than 1% of the policy's expected flow costs if a disaster occurs with a probability of $1/50$ each year, and the deadweight loss associated with a guarantee of relief in the event of a future disaster is slightly more than 1% of the policy's expected flow costs if a disaster occurs with a probability of $1/30$ each year.

Columns 5 and 6 of Table 10 compute these deadweight losses under the assumption that all households exhibit the location elasticity found for young households. This scenario is perhaps appropriate when considering the policies' distortion over a very long horizon, perhaps multiple generations. However, even in this scenario that assumes the most elastic response, the deadweight loss associated with the flow subsidy to New Orleans is less than 3% of the policy's expected cost.

Substantial heterogeneity in location preferences accounts for the relatively small size of these deadweight loss figures relative to the subsidies' expected flow costs. While disaster-related location subsidies

[39] Note that Kennan and Walker report location elasticities with respect to nominal local wages, while the discussion in the previous paragraph considers location elasticities with respect to housing costs.

may comprise large difficult-to-justify transfers from residents of safe areas to residents of dangerous areas, the distortions associated with these transfers appear to be relatively small.

VIII. Conclusion

This paper develops and estimates a dynamic structural model of pre-Katrina New Orleans homeowners' post-Katrina resettlement choices and uses the model to investigate the immediate and long-term impacts of government disaster-relief policy. During the first two years following Hurricane Katrina, low-income households and black households rebuilt damaged homes at a much lower rate than higher-income households and non-black households. By the fourth anniversary of Katrina, disparities in rebuilding rates had closed substantially. The structural model finds that these patterns are best rationalized by a model in which pre-Katrina homeowners have a strong preference on average for residing in New Orleans, there is substantial heterogeneity in the strength of that location preference, and several large population subgroups face borrowing constraints.

Using the estimated model, I conduct a series of simulation experiments to assess the impact of the Road Home rebuilding grant program on households' resettlement choices and to assess the relative impacts of wage subsidies and rebuilding grants. The simulation experiments find that the Road Home program increased the fraction of households with severely damaged homes that had rebuilt within four years by about 11%. The program's impact occurred primarily within groups that otherwise lacked the savings or ability to borrow that would have been necessary to finance repairs or rebuilding if no grant program had been provided. A second set of simulation experiments comparing the impact of direct grants to the impact of wage subsidies finds that, on the margin, direct grants influence rebuilding rates by about twice the amount of similarly sized (in present value terms) wage subsidies.

I then use the model's implied elasticity of location choices with respect to financial incentives, in the context of a simple general equilibrium framework, to assess the deadweight loss associated with disaster-related location subsidies. The model finds that a guarantee of full compensation in the event of a future disaster generates a deadweight loss that is about 3% of the subsidy's expected cost under the conservative assumption that a devastating disaster will occur on average once per thirty years. While one may question the fairness of providing large transfers from safe locations to unsafe locations, these results suggest that the distortionary effects of disaster-related location subsidies are relatively small.

This paper considers a partial equilibrium model of households' resettlement choices, and as a consequence the policy experiments do not capture any general equilibrium price effects that the programs might have had, and perhaps more importantly, do not capture any social spill-over effects. A social spill-over would occur if, for instance, other things equal residing on a block on which 50% of one's neighbors had returned provided greater utility than residing on utility than residing on a block on which 40% of one's neighbors had returned. Capturing these types of effects in a dynamic model presents considerable challenges for estimation, but would lead to a more complete assessment of program impacts and will be one focus of my future work.

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TABLE 1. HOUSEHOLD BACKGROUND CHARACTERISTICS

Trait/Characteristic	Percentage
Household Headship	
Solo male headed	17.3
Solo female headed	29.6
Couple headed	53.1
Race	
Either head is black	57.6
Neither head is black	42.4
Education of Most Educated Head	
H.S. dropout	8.4
H.S. graduate	17.8
Some college	24.9
Bachelor's degree or higher	48.9
Household Age †	
Under 40	22.3
40-49	22.9
50-64	29.9
65 or older	25.0
Attachment to Place	
Home purchased > 25 years before Katrina	37.5
Home purchased 10-25 years before Katrina	25.8
Home purchased 0-10 years before Katrina	36.7
Either household head born outside of Louisiana	23.4
Neither household head born outside of Louisiana	76.6
Pre-Katrina Annual Household Income	
< $20,000	17.7
$20,000 - $40,000	22.5
$40,000 - $80,000	33.6
> $80,000	26.3
Neighborhood Poverty	
Block group poverty rate (2000 Census), <10%	21.3
Block group poverty rate (2000 Census), 10% - 25%	45.7
Block group poverty rate (2000 Census), > 25%	32.7
Observations	560

† Household age is defined to be the age of the male household head if present and the age of the female head otherwise. Note: This table reports the sample means of household background variables for the sample of pre-Katrina New Orleans households used to estimate the dynamic model. The sample includes only households that owned single-family homes (either free-and-clear or with a mortgage) at the time of Katrina. The sample also restricts attention to households in which at least one household head was employed during the year prior to Katrina or that had reached retirement age. Source: DNORS data and Assessor's data.

TABLE 2. STORM DAMAGE AND RESOURCES AVAILABLE FOR REPAIRS

	All Homeowners (N=560)					
		Pre-Katrina HH Income			Race	
	All	<$20k	$20-40k	>$40k	Blacks	Nonblacks
Flood exposure						
No flooding	26	17	16	31	11	45
0-2 feet	13	15	14	13	12	15
2-4 feet	21	31	32	16	29	11
> 4 feet	40	37	38	40	48	29
Self-reported home damage category						
Still liveable	31	26	19	36	13	53
Unliveable	48	56	57	44	60	33
Destroyed	21	18	24	21	27	14
>30% decline in appraised structure value	71	80	74	69	86	52
Imputed repair cost ($1000s)						
Repair costs	65	44	47	75	67	64

	Households with Severely Damaged Homes (N=414)					
		Pre-Katrina HH Income			Race	
	All	<$20k	$20-40k	>$40k	Blacks	Nonblacks
Imputed repair cost ($1000s)						
Repair costs	84	51	55	103	74	108
Property damage covered by insurance						
Few/none of losses covered	25	39	32	18	28	19
Some/half of losses covered	47	46	46	48	49	45
All/most of losses covered	28	15	22	34	24	37
Percentiles of Liquid Asset Distribution						
5th percentile	0	0	0	0	0	0
25th percentile	2	0	1	2	0	5
50th percentile	7	3	4	10	2	19
75th percentile	31	14	20	40	10	78
95th percentile	219	101	145	275	101	477

Note: These figures provide sample mean outcomes for pre-Katrina New Orleans households who owned their homes prior to the storm, omitting households whose household age is less than 65 and for whom neither household head is employed. Source: DNORS and Assessor's data.

TABLE 3. HOME SALES AND PARTICIPATION IN THE LOUISIANA ROAD HOME AMONG HOUSEHOLDS WITH SEVERELY DAMAGED HOMES

Group	Option 1	Option 2 or 3	Private Sale	No Sale or Grant	Total
All households with damaged homes	67	8	10	15	100
Not destroyed but unihabitable	68	5	10	17	100
Destroyed	75	14	6	5	100
Few/none of losses covered by insurance	78	12	2	9	100
Some/half of losses covered by insurance	71	9	7	13	100
All/most of losses covered by insurance	51	3	21	25	100
No flooding	0	0	18	82	100
0-2 feet	60	0	15	25	100
2-4 feet	75	5	8	12	100
> 4 feet	68	12	9	11	100
Fraction of block homes damaged: <50%	29	0	0	71	100
Fraction of block homes damaged: 50-90%	53	8	11	29	100
Fraction of block homes damaged: >90%	71	8	10	11	100
Observations					414

Note: This table describes patterns of participation in the Road Home Homeowner program within the DNORS sample analyzed in this study. A household that selected Road Home option 1 received a grant payment equal to its repair costs minus any insurance payments received and agreed to repair and reside in the home within three years of receiving the grant. A household that selected option 2 agreed to sell its home to a state land trust at a price equal to the grant that it would have been payed under option 1 and agreed to purchase another home in Louisianna within three years. A household that selected option 3 agreed to sell its home to a state land trust at a price equal to 60% of the grant that it would have been payed under option 1, but did not face any residency or home-purchase requirements.
Source: DNORS, Assessor's Data, and Road Home participation data from the Louisiana Recovery Authority.

TABLE 4. WAGE EQUATION

Dependent variable: ln(earnings)	(1)
Ln(mean occupation wage in local labor market)	1.00 [constrained]
Age	0.137*** [0.005]
Age squared	-0.001*** [0.000]
Race	
non-Black	---
Black	-0.114*** [0.028]
Gender	
Male	---
Female	-0.291*** [0.026]
Education	
High school dropout	-0.331*** [0.044]
High school graduate	---
Some college	0.045 [0.034]
Bachelor's+	0.177*** [0.034]
Intercept	-3.375*** [0.102]
Observations	5,099

Note: This table reports estimates of a regression equation explaining the difference between individual workers' earnings and the average earnings in each worker's three-digit occupation. The sample includes all working respondents to the 2005 American Community Survey from the New Orleans metropolitan area and all DNORS respondents who worked during the year prior to Katrina. The dependent variable is the log of the workers annual earnings. The regressions imposes the restriction that the coefficient on the log of the mean earnings in the worker's two-digit industry in New Orleans (as measured in the American Community Survey) equals one.
Source: Author's calculations using ACS and DNORS.

TABLE 5. UTILITY FUNCTION AND BORROWING RATE PARAMETERS

Parameter:	Estimate
Flow benefit from residence location - B(L)	
Residence away from New Orleans: B(3)	0.000 [normalized]
Residence in New Orleans: B(2)	
Long-run level	-0.068 [0.018]***
Time trend during first five years after Katrina	-0.148 [0.011]***
Additional benefit from pre-Katrina home: B(1)-B(2)	
Intercept	0.577 [0.063]***
Fraction of block homes damaged: 50-90%	
Intercept shift (long run)	-0.009 [0.096]
Time trend during first five years after Katrina	0.247 [0.036]***
Fraction of block homes damaged: >90%	
Intercept shift (long run)	0.072 [0.054]
Time trend during first five years after Katrina	0.538 [0.074]***
Black	-0.203 [0.057]***
Block poverty rate (2000 Census), 10% - 25%	-0.003 [0.093]
Block poverty rate (2000 Census), > 25%	0.050 [0.059]
Purchased home 10-20 years before Katrina	-0.066 [0.048]
Purchased home > 20 years before Katrina	-0.135 [0.055]*
Neither head born in Louisiana	0.002 [0.029]
Moving utility cost: χ^M	
Intercept: Moves in period t=1	3.515 [0.037]***
Intercept: Moves in period t>1	2.786 [0.067]***
Moves to or from New Orleans	1.240 [0.063]***
Move home in first period after home repair	-4.237 [0.098]***
Repairing/rebuilding utility cost: χ^R	
Intercept	3.582 [0.120]***
Additional utility cost to rebuilding a destroyed home	1.203 [0.019]***
Log of Borrowing interest rate: $\ln(1+r^B)$	
Intercept	$\ln(1/\beta)$ [normalized]
Black	0.141 [0.003]***
No bachelor's degree	0.357 [0.011]***
Household income before Katrina < $20k	0.414 [0.015]***
Household income before Katrina $20-40k	-0.012 [0.003]***
Scale of shocks relative to u(c): α	5.047 [1.312]
Scale of persistent unobserved heterogeneity: σ	0.647 [0.045]
Observations - household-periods	6,720
Observations - households	560
Log-Likelihood	-2,629.3

Note: This table reports nested fixed point maximum likelihood estimates of the model's structural parameters (see Section 6 for details). Assymptotic standard errors clustered at the neighborhood level are reported in brackets. Asterisks indicate statistical significance at confidence levels of (*) 5%, (**) 1%, and (***) 0.1% -- no *s are reported for the scale parameters.
Source: Author's calculations using DNORS and Assessor's data covering calender years 2005 through 2009.

TABLE 6. MODEL FIT

	All Households											
	All Households			HH Income: < $20k			HH Income: $20-40k			HH Income: > $40k		
Percentage of households	Data	Model	χ^2	Data	Model	χ^2	Data	Model	χ^2	Data	Model	χ^2
Home liveable												
1st Anniversary	30.7	32.6	0.06	22.7	22.6	0.00	21.2	25.7	0.57	36.7	38.1	0.02
2nd Anniversary	38.0	40.8	0.13	28.4	31.5	0.18	29.2	35.0	0.63	44.2	45.7	0.03
3rd Anniversary	47.7	53.4	0.78	30.7	46.5	4.26	36.5	49.0	2.97	56.7	57.1	0.00
4th Anniversary	69.6	66.3	0.56	67.0	61.7	0.81	67.2	63.8	0.25	71.3	68.5	0.34
Living in pre-Katrina home												
1st Anniversary	22.1	22.4	0.00	14.8	14.3	0.01	16.1	18.5	0.22	26.6	26.1	0.01
2nd Anniversary	29.1	29.7	0.01	21.6	21.9	0.00	23.4	26.4	0.22	33.4	33.1	0.00
3rd Anniversary	36.8	41.8	0.97	23.9	36.0	3.18	30.7	39.5	1.87	42.7	44.2	0.09
4th Anniversary	57.9	55.2	0.51	58.0	51.6	1.15	59.1	55.1	0.39	57.3	56.2	0.08
Living in New Orleans												
1st Anniversary	60.7	61.1	0.01	60.2	57.0	0.34	52.6	60.2	1.62	64.2	62.5	0.12
2nd Anniversary	71.4	71.3	0.00	71.6	68.1	0.57	67.2	71.3	1.32	73.1	72.2	0.04
3rd Anniversary	75.4	75.5	0.01	73.9	72.8	0.05	74.5	76.0	0.21	76.1	76.0	0.00
4th Anniversary	78.4	76.7	0.66	76.1	74.3	0.16	81.0	77.8	1.34	77.9	76.9	0.09
Sold pre-Katrina home												
1st Anniversary	3.2	4.8	4.12	2.3	5.8	4.68	1.5	4.5	9.02	4.2	4.7	0.18
2nd Anniversary	8.8	9.1	0.06	5.7	11.0	4.61	5.8	8.5	1.76	10.7	8.8	1.64
3rd Anniversary	16.1	12.8	4.64	11.4	15.4	1.28	13.9	11.9	0.39	18.2	12.4	11.78
4th Anniversary	19.6	15.9	4.15	19.3	19.1	0.00	15.3	14.9	0.02	21.5	15.5	7.13
Households	560			78			111			371		

	Households with an Initially Damaged Home											
	All Households			HH Income < $20k			HH Income: $20-40k			HH Income > $40k		
Percentage of households	Data	Model	χ^2	Data	Model	χ^2	Data	Model	χ^2	Data	Model	χ^2
Home liveable												
1st Anniversary	6.3	8.9	1.26	6.9	6.7	0.00	3.6	9.1	6.16	7.4	9.5	0.46
2nd Anniversary	16.2	20.0	0.88	13.7	17.4	0.64	13.4	20.5	2.23	18.3	20.5	0.21
3rd Anniversary	29.2	37.0	3.50	16.4	35.5	11.47	22.3	37.6	7.77	36.7	37.2	0.02
4th Anniversary	58.9	54.4	1.32	60.3	53.8	0.99	59.8	55.7	0.31	58.1	53.9	1.34
Living in pre-Katrina home												
1st Anniversary	3.4	5.6	2.23	5.5	4.3	0.13	2.7	6.0	2.58	3.1	5.9	2.90
2nd Anniversary	11.8	13.6	0.34	11.0	12.2	0.09	9.8	14.2	1.19	13.1	13.7	0.05
3rd Anniversary	22.0	29.2	4.70	13.7	28.8	7.62	17.9	29.7	6.14	26.6	29.0	0.71
4th Anniversary	50.0	47.1	0.59	54.8	47.5	1.25	52.7	48.4	0.34	47.2	46.3	0.05
Living in New Orleans												
1st Anniversary	51.9	53.4	0.20	58.9	52.6	0.89	45.5	54.3	2.15	52.8	53.1	0.00
2nd Anniversary	65.7	65.5	0.00	69.9	64.8	0.95	61.6	66.7	2.05	66.4	65.2	0.06
3rd Anniversary	71.3	71.0	0.00	72.6	70.5	0.17	69.6	72.3	0.53	71.6	70.5	0.07
4th Anniversary	74.9	73.0	0.82	75.3	72.6	0.28	77.7	74.6	1.00	73.4	72.4	0.07
Sold pre-Katrina home												
1st Anniversary	2.4	5.4	12.63	0.0	6.2	-	0.9	4.9	21.12	3.9	5.3	1.26
2nd Anniversary	8.7	10.2	0.95	4.1	11.7	10.85	5.4	9.4	3.42	11.8	10.1	0.89
3rd Anniversary	17.4	14.2	2.87	9.6	16.3	3.20	15.2	13.1	0.34	21.0	14.1	11.02
4th Anniversary	21.3	17.6	3.02	19.2	20.1	0.04	16.1	16.3	0.01	24.5	17.5	7.26
Households	414			66			91			257		

Note: This table compares the value of various sample moments to the model's predicted value for those moments. For each comparison, a cluster-robust chi-squared test stratistic (clustered at the neighborhood level) is reported for a test of the null that the predicted and empirical moments are equal. The critical value for the chi-squared(1) distribution with alpha=0.05 is 3.84.

TABLE 7. THE IMPACT OF THE ROAD HOME PROGRAM ON HOUSEHOLDS' RESETTLEMENT CHOICES

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Resettlement Outcomes -- Measured on Katrina's 4th Anniversary							
	Home Repaired by Original Owner		Living in pre-Katrina Home		Living in New Orleans		Sold Home	
Group	No Grant Program	Road Home Program	No Grant Program	Road Home Program	No Grant Program	Road Home Program	No Grant Program	Road Home Program
All Households	49.0	54.4	42.7	47.1	70.8	73.0	19.9	17.6
Household Income:								
< $20k	43.7	53.8	38.6	47.5	69.2	72.6	22.9	20.1
Between $20k and $40k	49.5	55.7	43.4	48.4	72.4	74.6	18.9	16.3
> $40k	50.4	53.9	43.7	46.3	70.6	72.4	19.4	17.5
Race:								
Black	49.4	55.8	43.7	48.9	73.2	75.7	17.7	15.4
Non-black	48.0	51.2	40.5	43.1	65.8	67.1	24.7	22.5
Insurance coverage:								
Few/none of losses covered	43.8	53.7	39.0	47.5	68.6	73.4	21.3	17.8
Some/half of losses covered	46.3	52.2	40.7	45.2	69.9	71.9	21.2	18.5
All/most of losses covered	58.1	58.8	49.4	49.9	74.4	74.5	16.5	16.1
Other illustrative subgroups:								
HH income < $20k and few/none of losses insured	43.1	58.1	39.3	53.0	69.5	75.9	20.6	17.0
Bachelor's degree and all/most of losses insured	56.9	58.0	47.3	48.4	72.7	72.9	17.8	17.1

Note: This table provides the results of simulation experiments designed to assess the partial equilibrium impact of the Road Home program. The first four pairs of columns (columns 1-8) report pairs of simulated outcomes, the first of each pair reporting the outcome under a scenario in which no Grant Program was in place and the second reporting the outcome under the scenario in which the Road Home program was available. The final columns (column 9) computes the Road Home program's impact households' expected welfare. Expected welfare is computed at time t=0. For each household, welfare in the scernario in which no grant program is in place is normalized to zero . For each household, expected welfare under the scenario in which all home repairs not covered by insurance are reimbursed at t=0 is defined to by one hundred. The welfare impact of the Road Home program is reported as a fraction of the welfare impact of immediate full reimbursement. Source: Author's calculations using the estimated model.

TABLE 8. DECOMPOSITION OF THE ROAD HOME PROGRAM'S IMPACT ON HOUSEHOLDS' RESETTLEMENT CHOICES AND HOUSEHOLDS' WELFARE

	Living in pre-Katrina home on Katrina's 4th anniversary			Household Welfare (0%= no-grant program, 100% = full reimbursement at t=0)		
Scenario	All Households	Pre-Katrina HH Income < $20k	Pre-Katrina HH Income > $40k	All Households	Pre-Katrina HH Income < $20k	Pre-Katrina HH Income > $40k
Access to Credit						
No grant program (baseline)	49.0	43.7	50.4	0.0%	0.0%	0.0%
Loans available to all households (no grant program)	+3.8	+8.2	+2.1	+23%	+36.1%	+13.7%
Actual Road Home program	+5.4	+10.1	+3.5	+58.2%	+63.5%	+58.6%
Timing of Road Home Program						
No grant program (baseline)	49.0	43.7	50.4	0.0%	0.0%	0.0%
Actual Road Home program	+5.4	+10.1	+3.5	+58.2%	+63.5%	+58.6%
Road Home program rolled out at t=0	+5.2	+10.5	+3.2	+79.3%	+90.3%	+76.3%

Note: This table provides the results of a set of simulations that decompose the Road Home program's impact by examining possible avenues through which the program could influence households' choices and welfare. The first set of three rows compares the impact of an expanded loan program to the impact of the Road Home program. The second set of three rows compares the impact of the Road Home program to the impact of a program with the same rules but that is rolled out at t=0. Source: author's calculations using the estimated model.

TABLE 9: THE RELATIVE IMPACT OF DIRECT GRANTS AND SIMILARLY SIZED WAGE SUBSIDIES

Group -- among population of working-aged households	Home repaired by pre-Katrina owner by Katrina's fourth Anniversary
All households with home damage not covered by insurance	
Actual policy environment	57.601
Direct grant reduced by $2,400	-0.056
Present value of New Orleans wages $2,400 lower	-0.027
Households with pre-Karina annual income < $20k	
Actual policy environment	59.017
Direct grant reduced by $2,400	-0.188
Present value of New Orleans wages $2,400 lower	-0.039
Households with pre-Karina annual income > $40k	
Actual policy environment	57.465
Direct grant reduced by $2,400	-0.043
Present value of New Orleans wages $2,400 lower	-0.032

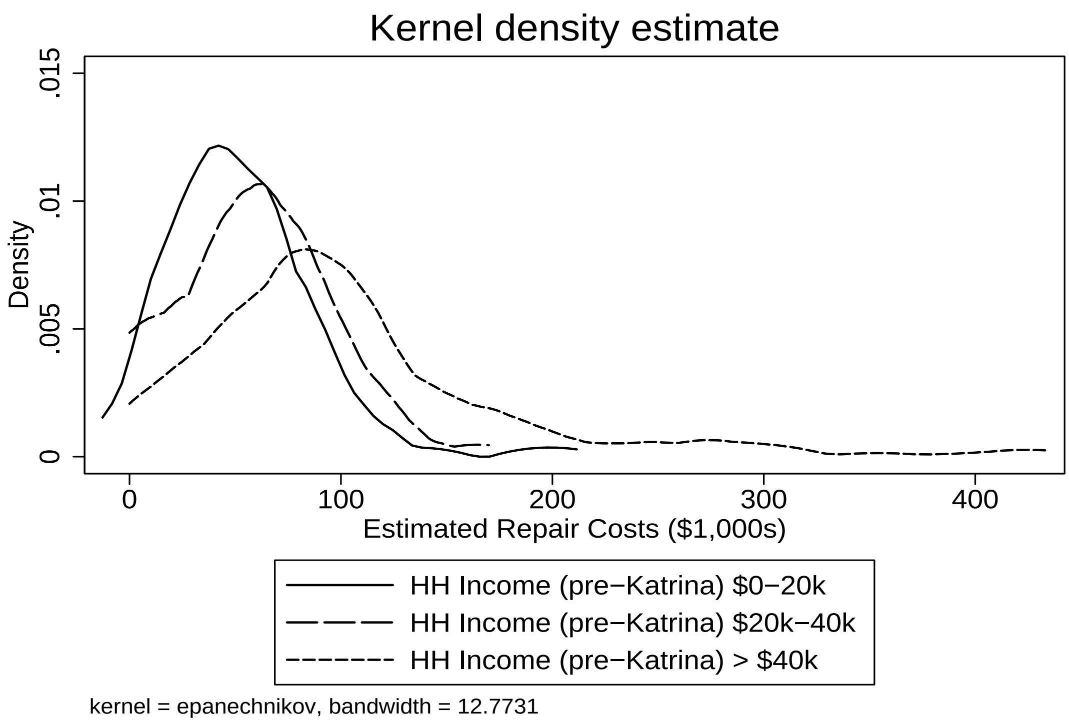
Note: This table provides the results of a set of simulation experiments that assess the relative impact of direct grants and similarly sized wage subsidies on households' resettlement choices. These experiments restrict attention to working age households (head < 65 years old). For each set of results (three-row groups), the first row provides the fraction of homes repaired by the pre-Katrina owner under a baseline simulation that imposed the actual post-Katrina policy environment. The second row provides the impact of removing $2,400 per worker from the size of each household's Road Home option 1 grants. The third row provides the impact of removing $2,400 per worker from the present value of New Orleans labor wages (spread evenly over the first four years following Katrina). Source: author's calculations using the estimated model.

TABLE 10. THE DEADWEIGHT LOSS ASSOCIATED WITH A FLOW DISASTER-INSURANCE SUBSIDY

Spatial elasticity used in DWL calculation:	Average Households' Elasticity		75% Average Elasticity 25% Young Elasticity		Young Households' Elasticity	
Per-year probability of a disaster:	1/50	1/30	1/50	1/30	1/50	1/30
Baseline value of housing stock	\$11 B	\$11 B	\$11 B	\$11 B	\$11 B	\$11 B
Subsidy: τ (as a % of home value)	2.00%	3.30%	2.00%	3.30%	2.00%	3.30%
Elasticity: ψ = dln(N.O. households / d[subsidy (τ)]	0.450	0.450	0.450	0.450		
Elasticity: ψ among young households			1.737	1.737	1.737	1.737
Flow cost of subsidy ([Value of Housing Stock] • τ)	\$220 M	\$363 M	\$220 M	\$363 M	\$220 M	\$363 M
DWL ($\approx {}^{1}/_{2}$ • [Value of Housing Stock] • ψ • τ^2)	\$1 M	\$2.7 M	\$1.7 M	\$4.6 M	\$3.8 M	\$10.4 M

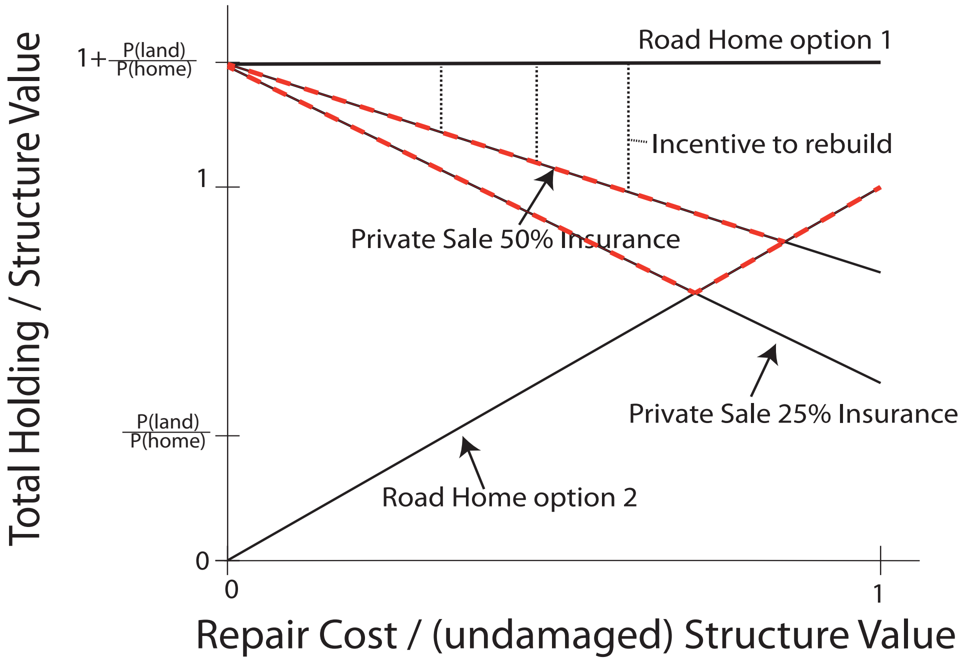
Note: This table provides the quantities necessary to compute the deadweight loss associated with a hypothetical flow subsidy to residence in New Orleans. Sources: The baseline value of the New Orleans housing stock is computed from Orleans Parish Property Assessment data. The semi-elasticity of the New Orleans homeowning population with respect to a flow subsidy to residence in New Orleans (an annual subsidy as a fraction of a household's home's value) is computed using simulations with the estimated model. The quantity labeled average households' elasticity is computed using the change in the fraction of simulated panels for all model households in which the household is living in New Orleans eight years after Katrina. The quantity labeled young households' elasticity is computed using a similar calculation among houeholds that were age 35 or less when Katrina occurred.

FIGURE 1: REPAIR COSTS AMONG HOUSEHOLDS
WITH INITIALLY UNINHABITABLE HOMES



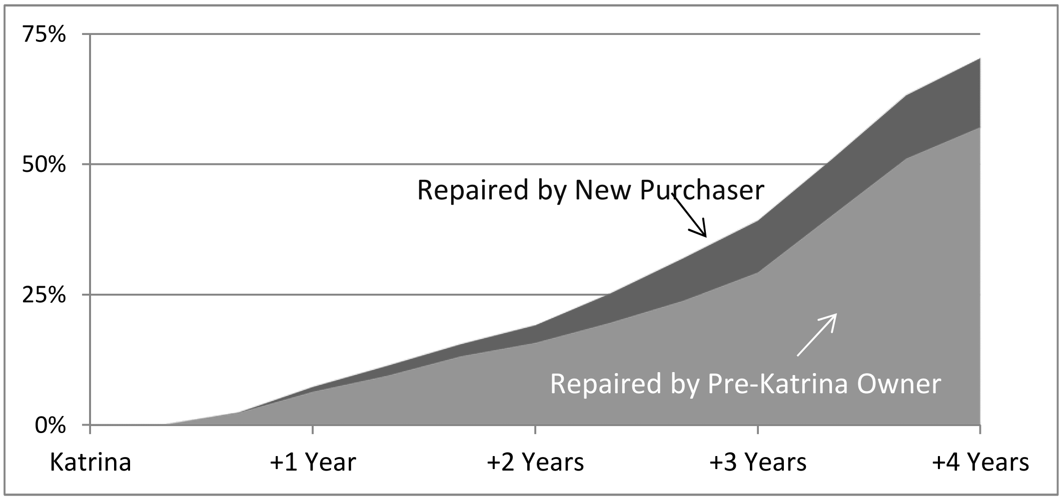
Note: This figure presents kernel density plots of repair costa for households with low, middle, and high household income during the year prior to Hurricane Katrina. Source: DNORS and Orleans Parish Assessor's Office property database.

FIGURE 2. THE FINANCIAL INCENTIVE TO REBUILD ASSOCIATED WITH THE ROAD HOME PROGRAM

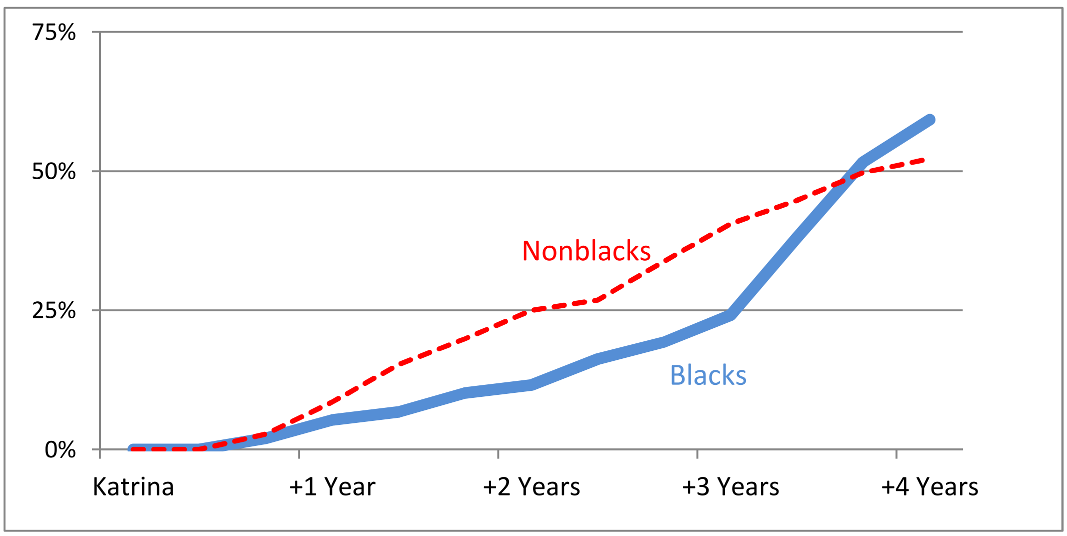


Note: If a household accepts an option 2 Road Home rebuilding grant, it holds cash approximately equal to the cost of repairs (the sum of insurance payments and the grant payment). If a household sells its home privately, it holds cash approximately equal to the as-is value of the structure following Katrina (the sale price) plus any insurance payments. This figure plots these two quantities as fractions of the home's value if it was fully repaired. The financial incentive to rebuild is the difference between the value of the home if fully repaired, which the household owns under Road Home option 1, and the upper envelope of these two quantities. The financial incentive to rebuild is highest for households with little insurance and for households with intermediate levels of home damage.

FIGURE 3: TIMING OF HOME REPAIRS



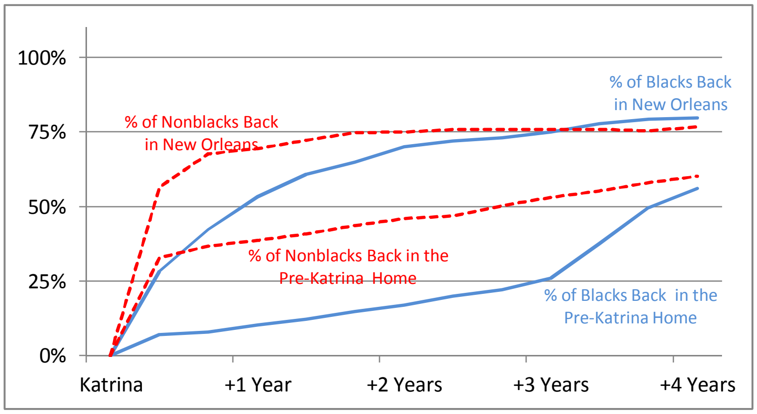
A. HOME REPAIRS BY ORIGINAL OWNER OR NEW PURCHASER



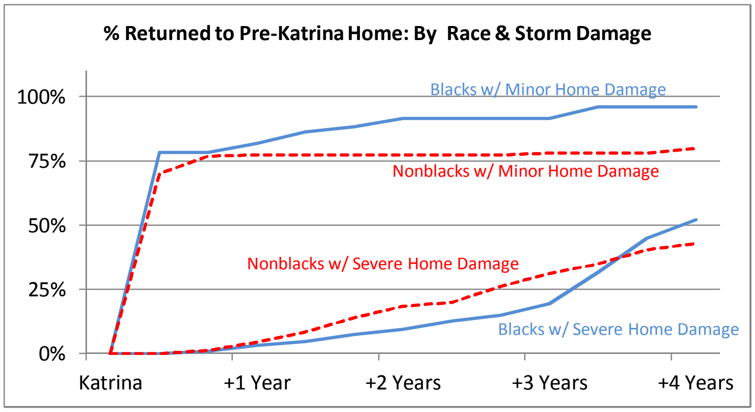
B. HOME REPAIRS BY ORIGINAL OWNER: BY RACE

Source: DNORS and Orleans Parish Assessor's Ofiice property database.

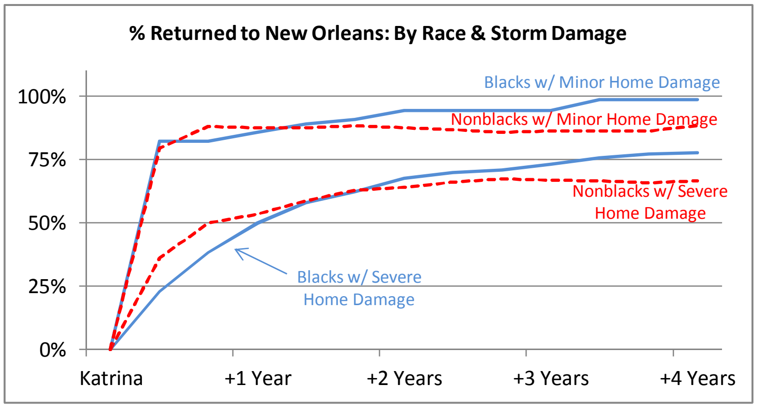
FIGURE 4: TIMING OF RETURNS TO NEW ORLEANS AND TO HOUSEHOLDS' PRE-KATRINA HOMES



A. FRACTION LIVING IN NEW ORLEANS AND FRACTION LIVING IN THE PRE-KATRINA HOME BY RACE



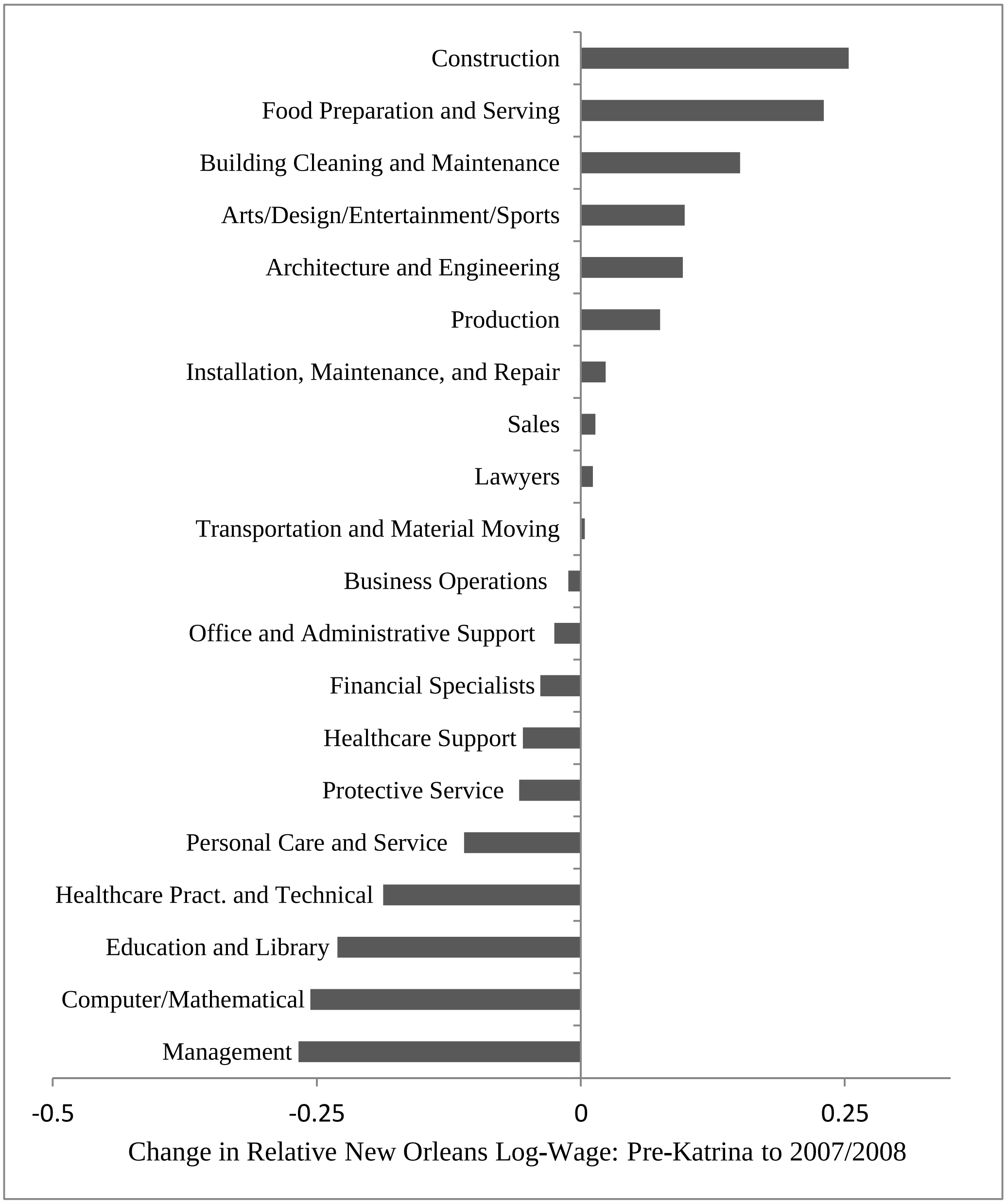
B. FRACTION LIVING IN PRE-KATRINA HOME BY RACE AND PROPERTY DAMAGE



C. FRACTION LIVING IN NEW ORLEANS BY RACE AND PROPERTY DAMAGE

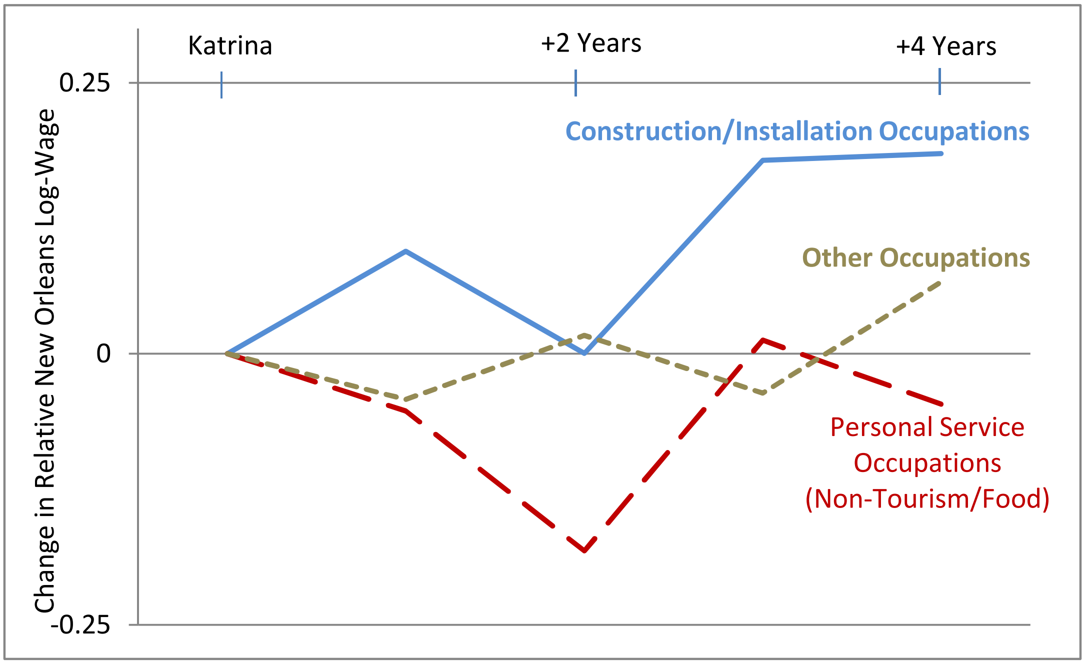
Source: DNORS and Orleans Parish Assessor's Ofiice property database.

FIGURE 5: CHANGES IN RELATIVE NEW ORLEANS WAGES FROM PRIOR TO KATRINA TO 2007/2008: BY OCCUPATION



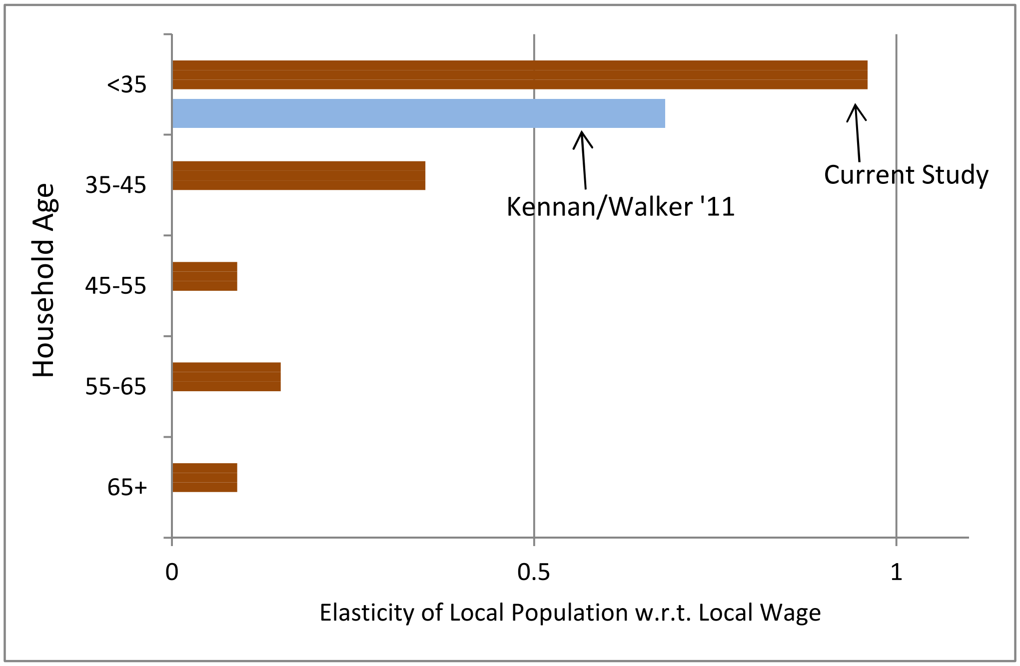
Note: The "relative New Orleans log-wage" is the difference between the log of mean annual earnings for workers in the occupation in New Orleans minus the log of mean annual earnings for workers in the occupation in other Southern metropolitan areas. This figure presents changes in the relative New Orleans log-wage from the 2005 ACS to the 2008 ACS for each two-digit occupation that comprised at least 1% of the workforce in pre-Katrina New Orleans. The ACS annual earnings questions asks about earnings during the 12 months prior to the ACS interview, so 2005 responses describe earnings during a period amost entirely before Katrina, and 2008 responses describe earnings that occurred roughly half in 2007 and half in 2008. Source: American Community Survey, 2005 and 2008.

FIGURE 6: CHANGES IN RELATIVE NEW ORLEANS WAGES
AFTER HURRICANE KATRINA BY OCCUPATION



Note: The "relative New Orleans log-wage" is the difference between the log of mean annual earnings for workers in the occupation in New Orleans minus the log of mean annual earnings for workers in the occupation in other Southern metropolitan areas. This figure presents changes in the relative New Orleans log-wage from the 2005 ACS to the relative New Orleans log-wage in later years for three broad occupation classifications. Source: American Community Survey, 2005-2009.

TABLE 7. SPATIAL WAGE ELASTICITIES IMPLIED BY THE ESTIMATED MODEL



Note: This figure plot's the elasticity of local population with respect to the local wage. Separate elasticities are provided depending on households' ages at the time of the permanent wage change. The dark bars plot the elasticities implied by the model estimated in this study. The light bar plots the elasticity estimated by Kennan and Walker (2011) using a sample comprised exclusively of younger workers. Source: Author's calculations using the estimated model and Kennan and Walker (2011).

TABLE A1. CONSTRUCTING HOUSING-RELATED PRICE VARIABLES

Variable	Method Used to Create Variable	Data source
Monthly mortgage payment for pre-Katrina home	Standard 30-year mortgage formula: inputs include the home's purchase date, purchase price, and an assumed 20% down payment	-Assessor's data
Monthly rent for a different New Orleans residence	Step 1: impute the home's rental value in pre-Katrina New Orleans 0.0785 x (appraised pre-Katrina value) / 12. Step 2: adjust that for differences in rental prices between pre-Katrina New Orleans and post-Katrina New Orleans using regression adjusted price indeces (see Appendix II for details on computing rental price indices)	-Pre-Katrina appraised home values come from Assessor's data -Housing price indices are computed using information on rental prices and building characteristics from the American Community Survey
Monthly rent for a residence in another Southern metro	Step 1: impute the home's rental value in pre-Katrina New Orleans 0.0785 x (appraised pre-Katrina value) / 12. Step 2: adjust that for differences in rental prices between pre-Katrina New Orleans and the post-Katrina market in other Southern metro areas using regression adjusted price indeces (see Appendix II for details on computing rental price indices)	-Pre-Katrina appraised home values come from Assessor's data -Housing price indices are computed using information on rental prices and building characteristics from the American Community Survey
Cost of repairing home damage	-If home was destroyed, repair cost is imputed to be the appraised pre-Katrina improvement value multiplied by a price index that reflects the difference in housing prices between pre-Katrina and post-Katrina New Orleans (this assumes that post-Katrina housing prices more accurately reflect building costs than pre-Katrina prices (Vigdor, 2008)) -If the home was unihabitable but not destroyed, repair cost is imputed to be the difference between the appraised pre-Katrina improvement value and the appraised improvement value immediately following Katrina multiplied by a price index that reflects the difference in housing prices between pre-Katrina and post-Katrina New Orleans	-Appraised home values come from Assessor's data -Housing price indices are computed using information on rental prices and building characteristics from the American Community Survey
Insurance payment	Imputed by scaling the household's repair costs by a fraction based on the household's categorical response to the DNORS question asking what fraction of losses were covered by insurance (all or almost all, 1.0; most, 0.75; about half, 0.5; some 0.25; very few, none, or had no insurance, 0.0)	-DNORS
Sale price of pre-Katrina home if it is repaired	Imputed by multiplying the home's appraised pre-Katrina value using regression adjusted price indeces (see Appendix II for details on computing rental price indices)	-Pre-Katrina appraised home values come from Assessor's data -Housing price indices are computed using information on rental prices and building characteristics from the American Community Survey

TABLE A2. HOUSING PRICE INDEX REGRESSIONS

	(1)		(2)	
Housing Market Indicators				
Pre-Katrina New Orleans	---		---	
Post-Katrina New Orleans	0.383***	[0.015]	**0.352*** **	**[0.015]**
Elsewhere in Metro South	0.333***	[0.014]	**0.233*** **	**[0.013]**
Constant	6.142***	[0.013]	6.142***	[0.013]
Controls for building characteristics: centered around 2005 New Orleans means (X i-X bar)	No		Yes	
Observations	706,073		706,073	

Note: These regressions were computed using all renting households that lived in the New Orleans MSA in 2005-2009 or in another Southern metro from 2006-2009. The estimates were computed by regressing the log of rent on a constant, an indicator that an observation came from post-Katrina New Orleans, an indicator that an observation came from another southern metro, and (in the second column) a set of building characteristic variables centered around their mean values in the 2005 New Orleans sample. The housing market dummies should be interpretted as the mean difference in the log of rents between the indicated housing market and pre-Katrina New Orleans. Source: American Community Survey.

TABLE A3. DISTRIBUTION OF STORM DAMAGE BY FLOOD EXPOSURE

	Self-reported home damage				Appraised structure value declined >30%		
Flooding	Still Inhabitable	Uninhabitable but not Destroyed	Destroyed	Total	Still Inhabitable	Uninhabitable	Total
None	92	8	0	100	84	16	100
0-2 feet	31	60	9	100	24	76	100
2-4 feet	11	69	19	100	4	96	100
> 4 feet	1	59	39	100	0	100	100
Observations				560			560

Note: this table describes the relationship between the depth of flooding on a household's block and the damage to the household's home. Source: flood depth comes from maps produced by FEMA. Self reported home damage comes from DNORS interviews. The property appraisal based measure classifies a property as uninhabitable if its appraised improvement value declined by more than 30% from the last appraisal prior to Katrina to the first appraisal after Katrina (conducted during the Fall of 2005).

TABLE A4: POST-KATRINA POLICY TIMELINE

Date	Event
August 27, 2005	• New Orleans Mayor Ray Nagin announces a state of emergency and suggests a voluntary evacuation of the city.
August 28, 2005	• Mayor Nagin announces a mandatory evacuation of New Orleans, and the Louisiana Superdome is opened as a refuge for those unable to leave the city.
August 29, 2005	• Hurricane Katrina makes landfall on the Gulf coast.
August 29, 2005	• President George W. Bush declares much of the Gulf coast (including New Orleans) to be a major disaster area. This designation allows residents who suffer storm-related damages to seek assistance through standing federal disaster relief programs, such as FEMA's Disaster Assistance Grants and SBA's Disaster Assistance loans.
September 6, 2005	• Mayor Nagin orders a forced evacuation of New Orleans, and National Guard troops enter the city to enforce the order. The city's population of pre-storm residents falls to nearly zero, from the pre-storm level of about 460,000.
September 28, 2005	• Residents of least damaged areas of the city are first permitted to return, but, with few city services yet restored, very few return this early.
December 17, 2005	• Congress passes the Gulf Opportunity Zone initiative into law.
February 20, 2006	• Louisiana officially announces the Road Home rebuilding grant program .
March 2, 2007 (week of)	• The first Road Home rebuilding grant is paid to a New Orleans homeowner.
July 31, 2007	• The deadline for submitting Road Home grant applications occurs.
December 7, 2007 (week of)	• About 32,000 Road Home grants have been paid to New Orleans homeowners, about 75% of the total number of grants eventually dispersed.

Appendix I: Imputing Home Repair Status

I construct measures of home repair status using a three step procedure. The procedure is to:

1. Use annual appraised improvement values to infer repair status on $1st$, $2nd$, $3rd$, and $4th$ anniversaries of Katrina.
2. Estimate a Weibull hazard model of the time until home repair for households with initially uninhabitable homes, following the approach of Grummer-Strawn (1993) for fitting such a model to "current-status" data.
3. Use the fitted model and the measures of repair status on anniversaries of Katrina to stochastically impute a repair status for the periods that do not fall on anniversaries of Katrina.

Step 1: I classify a home as initially uninhabitable if the property's improvement value in the Orleans Parish Assessor's Office property database declined by more than 30% between the 2004 appraisal and the 2005 appraisal or the household self-reported its home having been rendered uninhabitable by Katrina. The 2005 appraisal occurred in the months after Katrina in advance of the 2006 tax year and reflects Katrina-related home damage.

If a home is classified as liveable (not uninhabitable) immediately following Katrina, classify the home as liveable in all subsequent periods. For homes classified as uninhabitable immediately following Katrina, classify the home as liveable on the $1st$, $2nd$, $3rd$, and $4th$ anniversaries of Katrina if, during the 2006, 2007, 2008, and 2009 appraisals respectively, the appraised improvement value exceeds the 2005 appraised improvement value.

One might fear that blanket appreciations applied by the Assessor's Office would cause some still-damaged homes to be classified by this procedure as liveable following a small increase in the appraised value. There are two reasons to think that blanket appreciations are unlikely to confound this classification rule. First, in communications with the Assessor's Office, I was informed that blanket appreciations were not applied to still-damaged properties. Second, I find very few instances in the data in which a home classified by this procedure as "still damaged" in year t experiences a positive change in assessed improvement value that does not exceed 25%.

Step 2: Among households with homes classified as initially uninhabitable, I estimate a Wiebull accelerated failure time model of the time until home repair. Because I have data on repair status at particular points in time instead of duration data (time until home repair), I follow Grummer-Strawn (1993) and estimate the model by maximum likelihood in its "current status" form using the complementary log-log regression,

$$\ln\Big(-\ln\Big(S(t_i)\Big)\Big) = \alpha + p\ln t_i + Z_i'\beta \tag{23}$$

where $S(.)$ is the survivor function, t_i is a time at which repair status is observed, and Z_i is a vector of household and neighborhood characteristics.[40]

Step 3: For each household observed with its home still damaged at anniversary an t and its home repaired by anniversary $t+1$, I stochastically impute a repair date between those two anniversaries using the estimated hazard

[40] The explanatory variables embedded in the vector Z_i in this model include; an indicator that a home was destroyed by Katrina, an indicator that a household is black, an indicator that a household is above age 65, an indicator that a household is solo-female headed, an indicator that a household is solo-male headed, an indicator that a household's more educated head is a high school dropout, an indicator that a household's more educated head is a high school graduate, an indicator that a household's more educated head attended college but did not attain a bachelor's degree, an indicator that at least one head was born outside of Louisiana, an indicator that the household purchased its home before 1980, an indicator that the household purchased its home between 1980 and 1995, an indicator that the household's block received 2 to 4 feet of flooding, an indicator that the household's block received greater than 4 feet of flooding, an indicator that $50\% - 90\%$ of the owner-occupied homes on a household's block segment were rendered uninhabitable by Katrina, an indicator that $90\% - 100\%$ of the owner-occupied homes on a household's block segment were rendered uninhabitable by Katrina, an indicator that the household's income during the year before Katrina was less than \$20,000, and an indicator that the household's income during the year before Katrina was between \$20,000 and \$40,000.

model. Periods in this paper's structural model each span four months, so between any two anniversary periods there are two non-anniversary periods. If an imputed repair date falls during the first four months following the earlier anniversary, the home is classified as repaired at both intermediate periods. If an imputed repair date falls during the fifth through eighth months following the earlier anniversary, the home is classified as not repaired at the first intermediate period and repaired at the second intermediate period. If an imputed repair date falls during the first last months leading up to the later anniversary, the home is classified as not repaired at both intermediate periods.

Appendix II: Computing Housing-Related Price Variables

Table $A1$ describes how I construct each housing-related price that I use in the analysis.

Constructing several of these variables requires a set of rental-price indices that relate the cost of rental housing in pre-Katrina New Orleans to the cost of rental housing in post-Katrina New Orleans and the cost of rental housing in the pooled group of other Southern metro areas. I compute these rental-price indices using a regression to adjust rents across markets for observable differences in the housing characteristics.

$$\ln \text{rent}_i = \gamma_0 + Z_i'\gamma + \gamma_{\text{post-K-N.O.}} + \gamma_{post-K-South} + e_i \tag{24}$$

I use ACS data on rents and building characteristics for three distinct housing markets; the market in pre-Katrina New Orleans, the market in post-Katrina New Orleans from 2006 to 2009, and the market in a pooled sample of "other Southern metro" areas from 2006 to 2009. I regress the log of rent on a set of building characteristics and housing market fixed effects. The housing-market fixed effects describe the difference between the log-rental-price level in the indicated market and the log-rental-price level in pre-Katrina New Orleans.

Appendix Table $A2$ presents estimates of these rental-price indices. After adjusting for building characteristics, I find that rental price levels in post-Katrina New Orleans exceeded rents in pre-Katrina New Orleans by 35 log points, and rental price levels in other Southern metros during the post-Katrina period exceeded rents in pre-Katrina New Orleans by 23 log points.

Appendix III: Imputed Asset Distributions

I approximate the distribution of possible asset holdings for each sample household using the discrete approximation method suggested by Kennan (2004). Kennan shows that the best n-point finite approximation to a continuous distribution assigns equal weight to each of the percentiles $(2i-1)/(2n)$ for $i = 1, ..., n$. I approximate the distribution of pre-Katrina asset holdings for each household using 10 support points that assigns equal probability to the household holding the $5th$, $15th$, ..., and $95th$ percentiles of the distribution of liquid assets among households sharing the given household's observable characteristics.

For each sample household, I must therefore estimate $F^{-1}_{A(0)}(p)$ for $p = 0.05, 0.15, ..., 0.95$ and where $F_{A(0)}()$ is the CDF of the distribution of liquid non-housing assets conditional on the household's observable characteristics. To accomplish this, I model the conditional distribution of liquid assets using responses to the 2005 wave of the Panel Study of Income Dynamics (PSID).

I define each PSID household's liquid asset holding to be the sum of the household's of non-IRA stock holdings, bond holdings, and holdings in checking accounts, savings accounts, money market accounts, and CDs. I then estimate a model of each quantile of the liquid asset distribution conditional on observable household characteristics using a two step procedure. First, I model the probability that a household has zero liquid assets using a logistic regression of an indicator for zero assets on a large set of household covariates.[41] Denote with $p(x)$ the predicted probability of having zero assets conditional on a particular combination of these covariates x. I set $\widehat{F}^{-1}_{A(0)}(p|x) = 0$ for each $p < p(x)$.

Second, I estimate the remaining values of $\widehat{F}^{-1}_{A(0)}(p|x)$ using a sequence of quantile regressions of the log of liquid assets on the same set of covariates among households that hold positive assets. For a given value of the covariate vector x, I estimate $\widehat{F}^{-1}_{A(0)}(p|x)$ to be the estimated $\left(\frac{p - p(x)}{1 - p(x)}\right)^{th}$ quantile of the distribution of assets among those with positive assets. For example, if $p(x) = .25$ then $\widehat{F}^{-1}_{A(0)}(p = .5|x)$ is the fitted 33 $1/3$ percentile, conditional on x, of the distribution of assets among those positive assets.

[41] The list of covariates used in this model includes; indicators for solo-female headed household, solo-male headed household, the more educated household head being a high school dropout, the more educated household head having attended college but not received a bachelor's degree, the more educated household head having a bachelor's degree, a household head being black, the household residing in an urban area, the household residing in the south, an interaction of southern and urban, indicators for each of the four highest housing value quintiles, the age of the male head if present and the female head's age otherwise, and the square of the age of the male head if present and the square of the female head's age otherwise. When linking these estimates back to DNORS households, all DNORS households are classified as Southern and urban. The other inputs depend on the household's survey responses.