The Impact of Post-Katrina Rebuilding Grants on the Resettlement Choices of New Orleans Homeowners*

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Abstract

This paper evaluates the impact of the Louisiana Road Home grant program on the post-Hurricane Katrina location choices of New Orleans homeowners. Using data from the Displaced New Orleans Residents Survey linked to administrative property assessment records, I estimate a dynamic discrete choice model of households' rebuilding, resettlement, and borrowing/savings choices. Counterfactual experiments find that the grant program significantly increased the rebuilding rate in New Orleans, particularly among households with limited credit access and large uninsured losses. I estimate that location preferences are highly heterogeneous, and that the distortion caused by expected future bailouts to New Orleans is relatively small.

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Introduction

Policymakers designing disaster relief packages face a difficult tradeoff. The desire to assist disaster victims in the short run must be weighed against the fear that subsidizing people to live in disaster-prone locations will generate moral hazard with respect to individuals' location choices. The net effect of disaster-relief expenditure on social welfare depends on the relative magnitude of any short-run welfare gains, generated by coordinating public goods provision and solving failures in insurance and lending markets, and the long-run efficiency loss generated by distorted location choices. A full empirical appraisal of the impact of disaster-relief programs on social welfare therefore must consider *both* the direct impact of disaster relief on victims' welfare and the extent to which the programs distort individuals' location decisions.

As a case study, this paper evaluates the impact of the Louisiana Road Home rebuilding grant program on the resettlement choices of New Orleans homeowners in the aftermath of Hurricane Katrina. The Road Home program provided large cash grants to individual homeowners to cover the cost of repairing damages that were not covered by homeowners' existing insurance arrangements. Less generous grant packages were provided to homeowners who chose not to rebuild. The aim of this paper is to understand how this policy affected Katrina victims' behavior and welfare in the short run and to compute an upper bound on the long-run efficiency loss that would occur if this policy's implementation caused individuals to expect a similar bailout with certainty in the future.

Because all Katrina-affected Louisiana homeowners were eligible for the Road Home program, the program's impact cannot be credibly identified with a quasi-experimental treatment/control comparison. To circumvent this obstacle, I exploit several sources of variation in choice-specific financial incentives within the program-eligible population to estimate a structural model of homeowners' post-Katrina resettlement choices. In the model, households repeatedly make choices about residential locations, home repairs, home sales, and amounts to borrow or save. The model's parameters characterize the distribution of preferences over location amenities and consumption and characterize the availability of credit for members of different demographic groups. The model is estimated using data from the population representative Displaced New Orleans Residents Survey linked to administrative property data from the Orleans Parish Assessor's Office. The model's parameters are identified by variation in the relative labor wages available in New Orleans versus away from New Orleans for workers with different pre-Katrina occupations, and variation across households in the relative generosity of the Road Home program's "rebuilding grant" and "relocation grant" options.

I use the estimated model to perform partial equilibrium policy experiments that quantify the Road Home program's short-run and long-run impacts on households' resettlement choices and welfare. To better understand the program's short-run impact on victims' welfare, I decompose the program's impact on rebuilding rates into an impact that occurred by relaxing financing constraints among households who already strongly preferred to rebuild (a welfare improvement) and an impact that occurred by inducing nearly-indifferent households to rebuild only because that choice was subsidized (a distortion). To assess the long run effects of an expectation of similar disaster-related bailouts after future disasters, I measure the effect of fully-subsidized disaster insurance on the long-run population of New Orleans, and I compute an upper bound on the deadweight loss caused by the policy-induced moral hazard.

The analysis finds that location preferences are highly heterogeneous and that large population subgroups face restricted access to credit. Policy simulations find that the Road Home program increased the fraction of homes rebuilt by Katrina's fourth anniversary by about 8% (from a base of about half), and about three quarters of this impact occurred by relaxing financing constraints for otherwise borrowing constrained households with a strong preference to rebuild. About half of the Road Home program's positive effect on households' welfare occurred by relaxing financing constraints. These patterns imply that market failures in the absence of the Road Home program were substantial, and that the intervention significantly increased aggregate short-run welfare. Policy simulations find that a guarantee of similar bailouts to New Orleans after future disasters generates a relatively small long-run distortion to location choices and a correspondingly small deadweight loss of less than 4% of the policy's expected cost.

The empirical contribution of this paper is important, because evaluations of disaster relief programs are almost entirely missing from the empirical literature in economics.[1] This is a significant gap in the literature. Disaster-relief policies have a theoretically ambiguous net impact on aggregate welfare, so the most important questions surrounding these policies are inherently empirical. Disaster-relief policies are expensive and influence large numbers of people in times of need. Additionally, disasters and disaster relief policies receive considerable attention in the popular press, suggesting that the policies are of broad general interest. The absence of disaster-relief program evaluations from the literature is probably best explained by the fact that disaster relief programs are rarely amenable to the standard program evaluation toolbox. Most disaster-relief programs target entire disaster-effected populations, so credible treatment versus control comparisons are rarely available. Also, ideal data for studying post-disaster programs are rarely available, because data collection efforts rarely achieve representative coverage of small geographic areas at particular points in time.

This paper also contributes methodologically to the literature that uses explicit behavioral mod-

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

els to study migration (ex. Kennan and Walker, 2011; Bishop, 2008; Gemici, 2007). To my knowledge, this paper estimates the first dynamic structural model of migration to explicitly include households' asset accumulation choices and to allow for the possibility of borrowing constraints. Data limitations and the computational burden of a large state space present obstacles to jointly modeling migration and borrowing/saving. This paper develops a two-stage estimation technique that circumvents this data limitation by integrating out the asset state variable in all but one period by exploiting the model-implied borrowing/saving policy. This paper also contributes to the structural migration literature by estimating a migration model using directly observable sources of variation in location-specific financial incentives.[2] Along the dimensions that are comparable to the earlier literature, this paper's findings provide an out-of-sample validation for this emerging modeling approach.

Finally, this study 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.[3] The literature on Hurricane Katrina has focused mainly on patterns of short-term population dislocation and disparities in employment, migration, and other outcomes across demographic groups in Katrina's immediate aftermath. This paper extends that literature by documenting the effects of post-Katrina disaster relief and by documenting resettlement patterns over a longer time horizon than has been previously studied.

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

I. U.S. Disaster Relief Policy and the Road Home Program

U.S. Disaster Relief Policy

Federal disaster relief policy in the United States consists of a standing apparatus for coordinating emergency relief and a precedent in recent decades of Congress providing large supplemental relief packages after severe disasters. The federal disaster relief apparatus is triggered when the President declares a county or group of counties to be a major disaster area. This declaration

[2]Earlier structural migration models have been identified using variation in a posited worker-location match component of wages, which must be inferred statistically from panel wage data.

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

permits the federal government to coordinate debris removal and repair infrastructure and also makes local residents and businesses eligible for several direct assistance programs. Homeowners and businesses become eligible for Disaster Relief Loans from the Small Business Administration (SBA), and individuals become eligible for small assistance grants from the Federal Emergency Management Administration (FEMA).

These standing programs typically fall far short of fully compensating the victims of severe disasters for their losses. FEMA assistance grants, for example, were capped at just over $10,000 when Hurricane Katrina occurred, well below the oftentimes six-figure cost of repairing or replacing flood-damaged homes. And although the SBA disaster loan program is subsidized, the program's creditworthiness standards are non-trivial for what are usually weakly-collateralized loans, and many applicants for SBA loans are rejected. Of the nearly 276,000 Gulf Coast homeowners who applied for SBA loans by the end of 2005, nearly 82% were rejected because of insufficient income or credit histories (Eaton and Nixon, 2005), a pattern consistent with this paper's model-based finding that many households with Katrina-damaged homes were borrowing constrained.

In recent decades, Congress has consistently provided additional relief in the aftermath of severe disasters by appropriating supplemental block grants to local and state governments. Localities have used these 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. The largest single post-Katrina relief program and the focus of this paper, the Louisiana Road Home program, was funded by this type of bock grant.

The Louisiana Road Home Program

Hurricane Katrina struck the U.S. Gulf Coast on August 29, 2005. In the days following the storm's initial impact, the levees that protect New Orleans gave way in several places, allowing flood waters to cover 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.

Most New Orleans homeowners with flood-damaged homes faced repair costs that significantly exceeded their insurance payouts. In many cases, shortfalls occurred because the replacement cost of homes exceeded the purchase price.[4] Other shortfalls are thought to have occurred because

[4]Most households, as a requirement to obtain a mortgage, insure up to their home's purchase price. In pre-Katrina New Orleans, housing prices were significantly less than the cost of construction. New Orleans had been losing population for a half century, and by the 2000s, New Orleans' housing stock significantly exceeded the quantity of housing that would have been demanded at construction cost. See Glaeser and Gyourko (2004) for a discussion of housing price dynamics in declining markets and Vigdor (2008) for an application of the Glaeser-Gyourko model to the pre-Katrina New Orleans housing market.

insurance companies refused valid claims in some cases where the cause of property damage was uncertain. And although New Orleans had one of the highest rates of flood insurance coverage in the country prior to Katrina, a minority of households had no insurance.

In response to the devastation in New Orleans and elsewhere on the Gulf Coast, Congress followed recent precedent and approved supplemental relief block grants to the Katrina-affected states in the months following Hurricane Katrina. The state of the Louisiana used its federal allocation to create the Louisiana Road Home program,[5] a program designed to assist pre-Katrina Louisiana homeowners by providing cash grants for rebuilding or relocating 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 was structured by the state of Louisiana to provide assistance to all affected homeowners with insurance shortfalls and also to incentivize rebuilding. Participating households selected from among three available Road Home benefits packages known as options 1, 2, and 3. Option 1 grants paid homeowners the difference between the estimated cost of repairs and the value of any insurance payments already received (up to a maximum of $150,000)[6] and required the recipient to repair and reside in the pre-Katrina home within three years and to purchase any required flood insurance. Option 2 provided the same cash grant as option 1, but required the recipient to turn their home over to a public land trust and purchase another home in Louisiana within three years. Option 3 was similar to option 2 but imposed no location or home-purchase requirement and paid a grant that was 40% smaller. Neither option 2 or 3 provided compensation for any "as-is" value of the property that was turned over to the state land trust.

This structure generated a financial incentive to rebuild, because most households could attain a higher net worth by rebuilding under option 1 than by selling privately or through Road Home option 2 or 3. Households selecting option 1 grants were in principle made "whole" regardless of the extent of home damages, because option 1 participants maintained ownership of their repaired homes and had their repair costs reimbursed. Accepting an option 2 or 3 grant entailed a significant opportunity cost, namely the foregone as-is value of the home being transferred to the state land trust. Selling privately also entailed an opportunity cost, namely the foregone Road Home compensation for any insurance shortfall. The financial incentive to rebuild was largest for house-

[5]Specifically, 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.

[6]When the Road Home program was first announced, its grant determination formula placed a cap on grant payments equal to the smaller of $150,000 and the pre-Katrina market value of the house. Citing that program provision, a group of plaintiffs sued HUD and the State of Louisiana alleging that this formula had a disparate negative impact on black households, because pre-Katrina property values were lower in black neighborhoods holding housing quality constant. In response to this suit, the Road Home program waved the cap based on pre-Katrina market values for low- and moderate-income homeowners.

holds with intermediate levels of home damage and low insurance payouts. These households had significant insurance shortfalls and homes with significant as-is value and therefore faced large opportunity costs both to selling privately and through Road Home options 2 or 3.

The Road Home program's implementation generated substantial negative press coverage. Long delays occurred at multiple stages of the application process, and most homeowners experienced lengthy delays between initiating their grant application and receiving a grant.[7] The Road Home program was announced in February of 2006, about six months after Hurricane Katrina, but the median grant payment date among New Orleans participants in the Road Home program occurred near second anniversary of Katrina. Also, many households claimed that their Road Home grants were too small to fully cover the gap between their insurance payout and the cost of repairs (Rose, Clark, and Duval-Dlop, 2008). The model considered in the remainder of this paper explicitly captures the timing of Road Home grant payments, and below I assess the robustness of the paper's findings to the possibility that grant payments were smaller than advertised.

II. Model

I turn now to the development of a dynamic discrete choice model of households' resettlement choices. This model will be used to study how households' choices might have differed under alternative disaster relief policies. 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. Households in the model face choices about where to resettle and whether/when to rebuild or sell their home. The model's parameters describe households' access to credit (for financing home repairs) and describe households' preferences over consumption and locations.

The empirical implementation of the model allows for a number of important sources of heterogeneity; including the possibility that local amenities in heavily-flooded areas were more affected by Katrina than amenities in less-flooded areas, the possibility that location preferences differed

[7] The application process for a Road Home grant was time consuming. 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. 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.

across households with different demographic traits and family backgrounds, and the possibility that credit availability differed systematically across demographic groups. The implementation also directly incorporates observable variation across households in repair costs, location-specific wages, and other relevant prices. For simplicity the notation used in this section does not explicitly denote the dependence of prices or the model's parameters on observable household and neighborhood variables.

Framework, Timing, and Preferences

I model households' resettlement choices in a dynamic discrete choice 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 $t = 0$, at which time the household is endowed with an initial state X_0 and an initial asset holding A_0.

Each period, after observing the current state (X_t, A_t) and a set of shocks $\epsilon_t(X_{t+1})$ to the preferences over the elements of X_{t+1}, households choose the next period's state (X_{t+1}, A_{t+1}). Households continue this process until retirement at age 65.[8] The location and home state then remain fixed through the terminal period T, defined to be the period when the household reaches age 80. Households may not repurchase their homes, may not live in their homes if they are still damaged or have been sold, and must hold non-negative assets at retirement.

Preferences are represented by the per-period utility function,

$$u_t = \frac{1}{\alpha}\frac{C_t^{1-\omega}}{1-\omega} + B_t(L_t) - \chi\,\mathbf{1}(L_{t+1} \neq L_t) - \kappa\,\mathbf{1}(D_{t+1} < D_t) + \eta\,\mathbf{1}(L_t = 1, 2) + \epsilon_t(X_{t+1}) \qquad (1)$$

Utility from consumption C_t is constant relative risk aversion. The term $B_t(L_t)$ captures the flow utility derived from location amenities in the household's residence location. The utility costs χ and κ capture the non-pecuniary costs of relocating (χ) and the logistical and regulatory hurdles associated with rebuilding (κ). The term $\eta \sim N(0, \sigma_\eta)$ captures persistent heterogeneity in the preference for living in New Orleans, and denotes the difference between a household's payoff to living in New Orleans from the average location payoff across households $B_t(L_t)$. The $\epsilon_t(X_{t+1})$

[8] In the empirical implementation, all households are permitted to continue adjusting states X for at least eight years after Katrina, extending the horizon over which choices are made for households near retirement when Katrina occurred.

errors capture transitory shocks to the payoffs associated with each of the available residence location and home ownership/damage state transitions, and are assumed to be i.i.d. type I extreme value.[9] The household's objective is to maximize the present value of future per-period utilities discounted by a factor β.

$$U = \sum_{t=1}^{T} \beta^{-t} \, u_t \tag{2}$$

Prices, Budget Constraint, and Expectations

Each household's consumption each period equals its income (wage earnings plus the proceeds from home sales or grant payments) minus expenses (home repair costs and rent or mortgage payments) and net asset accumulation. Each household head who worked during the year prior to Katrina receives the period-specific market wage of his or her human capital and occupation in the household's chosen labor market. Locations $L = 1$ and 2 place the household in the New Orleans labor market and location $L = 3$ places the household in a pooled "other metro South" labor market. Denote the sum of the household's workers' location-specific wages with $W_t(L_t)$. During retirement a Social Security transfer of Soc_t = \$6,000 (\$1,500 per month $\times$ 4 months) guarantees a minimum level of consumption.

Households receive housing services from their pre-Katrina homes when living in $L = 1$, and households must rent an equivalent flow of housing services at the market rate $Rent(L_t)$ when residing in $L = 2$ or 3. Households make regular mortgage payments M_t on their pre-Katrina homes until they sell the home or reach the end of the mortgage term.[10] Repairing a damaged home entails a repair cost K. Selling the home privately generates proceeds equal to the home's market value in a repaired state in post-Katrina New Orleans minus the cost of any needed repairs, $P_H - D_t \times K$. Any remaining mortgage principal, denoted $Princ_t$, must be repaid at the time of sale.

The Road Home program provides grant compensation to households whose behavior meets the program's eligibility rules and for whom participation in the program is incentive compati-

[9] The model approximates the role of unobservables using a permanent heterogeneity component η and a series of i.i.d. shocks ϵ. In reality, many unobserved factors were probably partially persistent (ex. delayed or faster-than-expected permits 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). During estimation, the role of these sorts of factors will load partially on to the model's persistent component and partially on to the i.i.d. components.

[10] Mortgages are assumed to be standard 30-year fixed-rate mortgages originated when the home was purchased. Some households had reached the 30 year term before Katrina, and therefore never face post-Katrina mortgage payments.

ble. Households who repair or sell their homes during the first two years after Katrina receive a Road Home option 1 grant G_1 in period 7, the first period after the second anniversary of Katrina. Households who repair their homes during the third, fourth, and fifth years after Katrina receive a Road Home option 1 grant at the time the repairs are made. Recall that the option 1 grant pays the difference between the repair cost and any prior insurance payouts up to a maximum of \$150,000.

$$G_{1,t} = \begin{cases} \min[\$150{,}000\ ,\ K - Ins] & \text{if } t = 7 \text{ and } D_t = 0 \text{ or } H_t = 0 \\ \min[\$150{,}000\ ,\ K - Ins] & \text{if } t \in [7, 15] \text{ and } D_{t-1} < D_t \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

Households who sell their homes during the third, fourth, and fifth years after Katrina are eligible for a Road Home option 2 grant G_2.

$$G_{2,t} = \begin{cases} \min[\$150{,}000\ ,\ K - Ins] & \text{if } t \in [7, 15] \text{ and } H_t < H_{t-1} \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

Incorporating each of these elements, and noting that households who sell their homes will participate in Road Home option 2 only if the grant amount exceeds the home's market value, the household's intertemporal budget constraint is,

$$\begin{aligned} C_t = {} & \overbrace{W_t(L_t) + Soc_t}^{\text{wage/transfer income}} + \overbrace{(\max[G_{2,t}, P_H - D_t K] - Princ_t) \times 1(H_{t+1} < H_t)}^{\text{proceeds from home sale}} + \overbrace{G_{1,t}}^{\text{R.H. grant}} \\ & - \underbrace{Rent(L_t)}_{\text{rent payment}} - \underbrace{H_t\ M_t}_{\text{mortgage payment}} - \underbrace{K \times 1(D_{t+1} < D_t)}_{\text{repair costs}} - \underbrace{(A_{t+1}/(1+r_t)\ -\ A_t)}_{\text{change in asset holding}} \end{aligned} \tag{5}$$

Finally, the budget constraint incorporates the possibility of limited credit access by allowing the effective interest rate faced when borrowing to potentially exceed the interest rate faced when saving,

$$A_{t+1} \big/ (1+r_t) = \begin{cases} A_{t+1} \big/ (1+r_S) & \text{if } A_{t+1} \geq 0 \\ A_{t+1} \big/ (1+r_B) & \text{if } A_{t+1} < 0 \end{cases} \quad ; \quad (1+r_B) \geq (1+r_S) = 1/\beta \tag{6}$$

Many papers that use dynamic discrete choice models to study investment choices explicitly impose some sort of borrowing constraint.[11] This modeling technique more closely resembles that of

[11] 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

another group 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).

Households are assumed to foresee the timing of the Road Home program's implementation and the time path of relevant prices across locations. The Road Home program was announced about six months after Katrina, and some uncertainty about the exact nature of the eventual relief program surely existed before that announcement. However, modeling that uncertainty is unlikely to substantially improve the model's performance because quick rebuilding during the first few months after Katrina was nearly impossible. The assumption that households anticipated significant wait times for Road Home grants is probably a reasonable approximation to reality, as stories of frustrating bureaucratic inefficiency involving the program's implementation appeared frequently in the press during the program's rollout.

III. Model Parameterization, Estimation, and Identification

I next turn to the parameterization and estimation of the model. Estimation proceeds sequentially. The first stage estimates a wage equation by OLS and generates predicted wages for each household in each period both in and away from New Orleans. The second stage estimates the parameters describing households' preferences and their access to credit by maximum likelihood.

Stage 1: Wage Equation

The wage paid to worker j with 2-digit pre-Katrina occupation k in labor market l at time t is,

$$\ln w_{jklt} = \ln \overline{w}_{klt} + x_{jt}'b + \mu_j \tag{7}$$

where $\overline{w}_{klt}$ is the mean local wage in the worker's 2-digit occupation and x_{jt} is a vector of human capital variables. I estimate this equation by OLS using pre-Katrina earnings data (with annual earnings divided by 3 standing in for the per period wage). I then use the estimated equation to generate predicted period/location-specific wages $\widehat{w}_{jklt}$ for each DNORS household head who worked during the year prior to Katrina. Predictions are generated for pre-2009 periods using actual location/occupation/period-specific wages $\overline{w}_{klt}$ and for all later periods using 2009 location/occupation-specific wages. Each household's wage is the sum of the household's one or two working heads' wages.

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.

Stage 2: Estimating Preferences and Credit Availability

Parameterizing Preferences and Credit Access

I next discuss the parameterization of the model's structural parameters. I normalize the payoff to living away from New Orleans $B_t(3)$ to zero. The average flow benefit to living in New Orleans $B_t(2)$ is measured relative to $B_t(3)$ and is specified as a linear function of demographic indicators. The *additional* flow benefit derived from returning to the pre-Katrina home $[B_t(1) - B_t(2)]$ is specified as a linear function of neighborhood characteristics and flooding category dummies. In addition to these long-term levels differences, I capture the possibility that living in heavily flooded neighborhoods was unappealing shortly after Katrina but became more attractive as time passed by allowing for a linear time trend in $B_t(2)$ and separate linear time trends in $[B_t(1) - B_t(2)]$ within flooding categories during the first five years after Katrina.

The utility cost to moving χ is allowed to depend on the distance and timing of a move,[12] and the utility cost to repairing one's home κ is allowed to depend on whether a home was partially damaged or destroyed. The borrowing interest rate is parameterized by the equation,

$$\ln(1+r_B) = \ln(1/\beta) + Z'\gamma_r \quad ; \qquad \gamma_r \geq 0 \tag{8}$$

where $1/\beta$ is the risk free interest rate and Z is a vector of demographic-group indicators and indicators for pre-Katrina income categories.[13] This specification normalizes the borrowing interest rate to the risk-free rate ($1/\beta$) for an omitted reference group (non-black, college-educated households with high pre-Katrina incomes) very likely to have qualified for SBA Disaster Loans and private loans. A positive value for an element of the parameter vector γ_r indicates that the corresponding group faced restricted credit access.

I jointly refer to the set of model parameters to be estimated as $\theta = [B, \chi, \kappa, \gamma_r, \alpha, \sigma_\eta]'$. The values of several remaining parameters are assigned using results and conventions from the existing literature. 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). I set the subjective discount factor to $\beta = 0.95$ annually, following Kennan and Walker (2011).

[12]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.

[13]Specifically, Z includes indicators for either household head being black, neither household head having a bachelor's degree, household income being less than \$20,000 in the year prior to Katrina, and household income between \$20,000 and \$40,000 in the year prior to Katrina.

Estimation of the Preference and Credit-Access Parameters

Estimation of the model's structural parameters proceeds by full-solution maximum likelihood. Because 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 each household's likelihood contributions. The first step utilizes the model's solution to collapse this missing asset data problem into a more tractable missing *initial asset* problem.[14] The second step computes the likelihood of each household's observed choices at a range of possible initial asset holdings and integrates each household's conditional likelihood contributions with respect to an auxiliary estimate of the conditional (on household observables) distribution of possible initial asset holdings.

To estimate the model, I assume that a sample of households $i = 1, ..., N$ each solve the above model. For each household, I define a household-specific value function $V_{it}(X, A, \eta, \epsilon)$ as a mapping from each state to the present discounted value of the household's expected future utility given an optimal choice policy and conditional on the household's exogenous variables (demographic traits, pre-Katrina home values, repair costs, insurance payments, location-specific wages, etc.). By the principle of optimality, this value function must satisfy the Bellman equation,

$$\begin{aligned} &V_{it}(X_{it}, A_{it}, \eta_i, \epsilon_{it}) = \\ &\qquad \max_{X_{it+1}, A_{it+1}} \Big\{ u_{it}(X_{it+1}, A_{it+1} | X_{it}, A_{it}, \eta_i, \epsilon_{it}) + \beta \, \overline{V}_{it+1}(X_{it+1}, A_{it+1}, \eta_i) \Big\} \\ &\overline{V}_{it+1}(X_{it+1}, A_{it+1}, \eta) = \mathrm{E}_{\epsilon} V_{it+1}(X_{it+1}, A_{it+1}, \eta_i, \epsilon_{it+1}) \end{aligned} \tag{9}$$

Because the choice specific ϵ shocks are attached to households' location and housing-state choices X_{it+1} but not borrowing/saving choices A_{it+1}, the optimal asset accumulation policy is a deterministic function A^*_{it+1} of the current state (X_{it}, A_{it}) and the chosen X_{it+1},

$$\begin{aligned} &A^*_{it+1}(X_{it+1} | X_{it}, A_{it}, \eta_i) = \\ &\qquad \arg\max_{A_{it+1}} \Big\{ u_{it}(X_{it+1}, A_{it+1} | X_{it}, A_{it}, \eta_i, \epsilon_{it}) + \beta \, \overline{V}_{it+1}(X_{it+1}, A_{it+1}, \eta_i) \Big\} \end{aligned} \tag{10}$$

[14]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.

and equation (9) may be rewritten as,

$$V_{it}(X_{it}, A_{it}, \eta_i, \epsilon_{it}) = \max_{X_{it+1}} \Big\{ u_{it}(X_{it+1}, A^*_{it+1}(X_{it+1}|X_{it}, A_{it}, \eta_i)|X_{it}, A_{it}, \eta_i, \epsilon_{it}) + \beta\, \overline{V}_{it+1}(X_{it+1}, A^*_{it+1}(X_{it+1}|X_{it}, A_{it}, \eta_i), \eta_i) \Big\} \quad (11)$$

The assumption that the ϵ shocks are drawn from the type I extreme value distribution allows for a closed form representation of the expected continuation values (McFadden, 1974; Rust, 1987),

$$\overline{V}_{it}(X_{it}, A_{it}, \eta_i) = \ln \Big[\sum_{X_{it+1}} \exp \Big[\overline{u}_{it}(X_{it+1}, A^*_{it+1}(X_{it+1}|X_{it}, A_{it}, \eta)|X_{it}, A_{it}, \eta_i) + \beta\, \overline{V}(X_{it+1}, A^*_{it+1}(X_{it+1}|X_{it}, A_{it}, \eta_i)|X_{it}, A_{it}, \eta_i)\Big]\Big] + \gamma \quad (12)$$

where $\gamma \approx 0.577$ is Euler's constant. The conditional choice probabilities take the logit expression,

$$\mathrm{P}(X_{it+1}|A_{it}, X_{it}, \eta; \theta) = \quad (13)$$

$$\frac{\exp \Big[\overline{u}_{it}(X_{it+1}, A^*_{it+1}(X_{it+1}|X_{it}, A_{it}, \eta)|X_{it}, A_{it}, \eta_i) + \beta\, \overline{V}_{it+1}(X_{it+1}, A^*_{it+1}(X_{it+1}|X_{it}, A_{it}, \eta), \eta_i)\Big]}{\sum_{X'} \exp \Big[\overline{u}_{it}(X'_{it+1}, A^*_{it+1}(X'_{it+1}|X_{it}, A_{it}, \eta)|X_{it}, A_{it}, \eta_i) + \beta\, \overline{V}_{it+1}(X'_{it+1}, A^*_{it+1}(X'_{it+1}|X_{it}, A_{it}, \eta_i), \eta_i)\Big]}$$

With these expressions it is straightforward to numerically solve the model for any particular parameterization by backward induction and construct a sample likelihood function.

Conditioning on a particular initial asset holding A_{i0} and a particular location-attachment η_i, the likelihood contribution of a household is,

$$l_i(\theta|\{X_{it}\}_{t=1}^T, A_{i0}, \eta_i; \theta) = \mathrm{P}(X_{i1}|X_{i0}, A_{i0}, \eta_i; \theta) \times \Pi_{t=1}^{11} \mathrm{P}(X_{it+1}|X_{it}, A^*_{it+1}(X_{it+1}|X_{it}, A^*_{it}), \eta; \theta) \quad (14)$$

Integrating this conditional likelihood function with respect to the distribution F of initial asset holdings and the distribution G of the unobserved heterogeneity term η_i yields the unconditional likelihood contribution,

$$l_i(\theta|\{X_{it}\}_{t=1}^T) = \int\int l_i(\theta|\{X_{it}\}_{t=1}^T, a_0, \eta_i; \theta)\, dF^i_{A_0}(a_0)\, dG_\eta(\eta; \theta) \quad (15)$$

In practice, I compute a discrete approximation of this integral. I approximate the continuous distribution F of initial asset holdings with ten support points, and I approximate the continuous distribution G of the heterogeneity term η with five support points. The approximated distribution of initial asset-holdings $\widehat{F}^i_{A_0}(a)$ assigns equal probability mass to estimates of the $5th$, $15th$, ...,

$95th$ percentiles of household-specific conditional asset distrutions,[15] and the approximated $\widehat{G}_\eta(\eta)$ assigns equal probability mass to the $10th$, $30th$, $50th$, $70th$ and $90th$ percentiles of the distribution.[16] Each household's likelihood contribution is computed as,

$$l_i(\theta|\{X_{it}\}_{t=1}^T) = \frac{1}{10}\sum_{p_a=5}^{95}\frac{1}{5}\sum_{p_\eta=10}^{90} l_i(\theta|\{X_{it}\}_{t=1}^T,\ A_{i0}{=}F_{A_0}^{i-1}(p_a),\ \eta{=}G_\eta^{i-1}(p_\eta)) \tag{16}$$

and the full-sample log-likelihood is,

$$L(\theta|\{X_t\}_{t=1}^T) = \ln\left(\Pi_{i=1}^N\, l_i(\theta \mid \{X_{it}\}_{t=1}^T)\right) \tag{17}$$

I estimate the model by maximum likelihood. An "inner loop" repeatedly computes the model's solution numerically to obtain a sample log-likelihood at candidate values of θ, and an "outer loop" searches the parameter space for the likelihood maximizing parameter vector $\widehat{\theta}$.

Identification

I next provide a sketch of the sort of observable variation that is needed to identify the model's structural parameters. The assumption that the idiosyncratic shocks ϵ are drawn from the Type-I extreme value distribution normalizes the variance of that unobserved component. As in a standard static logit model, the values of other parameters scale the importance of the model's components 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. This variation comes from the Road Home program's provisions (as discussed above) and from variation in the relative labor wage in New Orleans versus other Southern metro areas across occupations and over time. 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

[15] For each household, I model percentiles of the distribution of 2005 liquid asset holdings among households with matching observable characteristics. Appendix I describes the approach in detail, which I apply to data from the 2005 wave of the PSID.

[16] Kennan (2004) demonstrates that the best finite approximation to a continuous CDF takes this form, assigning equal weight to evenly-spaced percentiles of the continuous distribution.

choosing each location after accounting for the financial incentives to do so. For example, if the fraction of households who choose to return to their pre-Katrina homes exceeds the fraction predicted to do so based on financial incentives alone then one may infer that the flow benefit derived from the home location $B_t(1)$ is positive relative to $B_t(3) \equiv 0$. The flow benefit to residing "elsewhere in New Orleans" $B_t(2)$ is identified similarly. Observable heterogeneity in these parameters is identified by systematic differences in these patterns by household and neighborhood characteristics.

The variance of η, the term capturing persistent unobserved heterogeneity in households' flow benefit to living in New Orleans, relative to the variance of the i.i.d. ϵ shocks is identified based on 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 choose a particular location but who both make the same location choice. On average the household who received the lower financial benefit from its choice has a higher draw from the unobservables ϵ plus η. If in these 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.

Unlike many dynamic discrete choice studies that are able to identify the extent of borrowing constraints based on the extent to which current wealth influences agents' investment choices (Evans and Jovanovic, 1989; Cameron and Heckman, 2001; Keane and Wolpin, 2001), this study examines data that do not contain information on non-housing assets. The credit access parameters are nonetheless identified based on two distinct sources of variation that have been exploited previously in separate areas of the literature.

The first source of identification of the model's credit access parameters resembles an approach developed in Cameron and Taber (2004) to study borrowing constraints to college education investments. Cameron and Taber demonstrate that an effective borrowing rate is identified by the relative impact on an investment choice of a change in the direct cost of investing and a similar change in a gradually accruing opportunity cost of investing. An agent who is free to borrow will be similarly influenced by a change in the direct cost and an equivalent change in the present value of the gradually accruing opportunity cost. A borrowing constrained agent will be more strongly influenced by a change in the direct cost, because the constrained agent's marginal utility of consumption will be highest in the period in which the direct cost is paid. For displaced New Orleans homeowners, uninsured repair costs were a direct cost to returning home, and the expected labor earnings in the evacuation location relative to those in New Orleans were a gradually accruing opportunity cost to returning home.

Identification of the credit access parameters is aided by information on the timing of households' rebuilding choices relative to the timing of grant payments, and in particular the extent to which the propensity to rebuild jumped at the time that Road Home grants were dispersed. The reasoning here closely resembles that of studies in the macroeconomics literature that test the Permanent Income Hypothesis by examining consumption responses to fully anticipated income windfalls (Shea, 1995; Souleles, 1999; Stephens, 2003). Road Home grant recipients typically experienced lengthy delays before their grants were dispersed. If the rebuilding hazard of a particular demographic subgroup jumped at the time that the Road Home grants were dispersed more so than the rebuilding hazard of the omitted comparison group who was presumably unconstrained, one may infer that the particular subgroup faced restricted access to credit.[17]

The final parameters to be identified are the utility costs to moving and to rebuilding. In particular, these state transition costs must be identified separately from the flow benefits associated with the various states. To see the sort of variation needed to separately identify a transition cost, consider two generic states, x_1 and x_2. 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 to x_1 and x_2.

IV. Data

I estimate the model using a unique panel dataset that provides household-level measures of residence location, home repair status, and home ownership status at twelve evenly-spaced points in time during the first four years after Hurricane Katrina. I create the dataset by merging microdata from the Displaced New Orleans Residents Survey (DNORS) to the Orleans Parish Assessor's Office administrative property database at the street address level. The analysis also incorporates several auxiliary measures from other datasets.

The DNORS data (RAND, 2010) contribute information about households' demographic background traits, storm-related home damage, insurance coverage, and migration. The DNORS survey is not a panel study in the sense of conducting multiple interviews with each respondent, but the survey's questions illicit enough detail to construct a full retrospective panel of residence location categories. 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

[17]The Road Home program's rules explicitly allowed households who had access to loans to purchase repairs with their loan dispersements before Road Home grants were paid and use the Road Home grant to repay the rebuilding loan.

Orleans prior to Katrina. The pre-Katrina occupants of the selected dwellings were then located (sometimes back in New Orleans and sometimes elsewhere), and interviews were conducted 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 administrative property data contribute information on the timing of post-Katrina home sales and the timing of home repairs. The administrative database includes an appraised land value and an appraised improvement value (the value of structures) for each property for calendar years 2004-2009 and includes a record of all property transactions. Appendix I describes the construction of home repair status indicators based on changes over time in appraised improvement values. I merge the Assessor's data to the DNORS data by street address, and I restrict the sample to households who owned and lived in a single-family home when Katrina occurred – the segment of the population targeted by the Road Home program. I also exclude the small group of working-aged households in which neither head was employed during the year prior to Katrina, so that pre-Katrina occupation may be treated as an observable marker generating variation in post-Katrina New Orleans wages.[18] These restrictions result in a final dataset containing 560 households.

The analysis also incorporates information on wages, rents, pre-Katrina asset holdings, and block-level flood exposure from several auxiliary datasets. Appendix I and Appendix Table A1 provide details on the construction of each variable. Information on wages and rents across locations, occupations, and time comes from the 2005-2009 American Community Survey public use microdata files (Ruggles et al., 2010). Information on the conditional (on background traits) distributions of pre-Katrina liquid asset holdings of Southern urban homeowners comes from the 2005 Panel Study of Income Dynamics. Information on block-level flood exposure comes from satellite measurements compiled and disseminated by FEMA.

Table 1 describes the demographic composition of the sample. About 58% of homeowning households were black, 48% had a head with a bachelor's degree, 45% were couple-headed, and 60% earned above $40,000 in the year prior to Katrina. Table 2 summarizes the distribution of flood exposure, Katrina-related home damage, and the resources that were available to households for repairs. About three out of every four homeowning households experienced flooding, and about 70% of homes were rendered uninhabitable. Repair costs significantly exceeded insurance payouts plus liquid asset holdings for a large fraction of households across socioeconomic groups.

Table 3 describes patterns of participation in the Road Home program 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

[18] 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.

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. Only about 18% of households with an initially uninhabitable home sold the home during the first four years following Katrina, either privately or through a Road Home option 2 or 3 relocation grant. Households were more likely to sell privately than accept a Road Home relocation grant when their home was moderately damaged or the household had comprehensive insurance. Households were more likely to accept a relocation grant than sell privately when their home was destroyed or when a significant fraction of the cost of repairing the home was not covered by insurance.

Figure 1 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 2 depicts racial disparities in the resettlement of New Orleans. Panel A plots the fractions of black and nonblack households residing in New Orleans and residing in the pre-Katrina home. Black households returned to New Orleans and to their pre-Katrina homes more slowly than nonblack households, but the disparities in these location outcomes had closed by Katrina's fourth anniversary. Panels B and C present these same trends separately by home damage status. Black households with homes that were still inhabitable after Katrina returned more quickly than nonblack households with still inhabitable homes. Black households with severely damaged homes returned more slowly than nonblack households with severely damaged homes, but these patterns reversed over time and a larger fraction of black households with severely damaged homes had returned to the pre-Katrina home by the fourth anniversary of Katrina. 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), which found 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.

Figure 3 ranks two-digit occupations based on changes in the occupations' relative New Orleans wages from 2005 to 2008. Figure 4 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 sizable permanent population.

V. Parameter Estimates and Model Fit

Table 4 presents estimates of the model's structural parameters.[19] The top portion of the table presents estimates of the parameters characterizing the flow benefit from living in New Orleans $B_t(L = 1)$ and the additional benefit to the pre-Katrina home $[B_t(L = 1) - B_t(L = 2)]$ relative to resettling away from New Orleans. The estimates find that households have a strong average preference for returning to the pre-Katrina home. There are small differences in preferences for locations based on observable household and neighborhood characteristics, with blacks and residents of the poorest neighborhoods exhibiting slightly stronger than average preferences for returning. There is much more extensive *unobserved* heterogeneity in location preferences. The estimated standard deviation of η, the term capturing persistent unobserved heterogeneity in the preference for living in New Orleans, is 0.15 utils. This parameter is difficult to interpret directly, so it is useful to consider consumption equivalents for households with high and low draws of η. The flow benefit to living in the pre-Katrina home for a household belonging to the reference category is 0.15 utils (B(2)=-0.09 plus [B(1)-B(2)]=0.24), so all else equal a household with a one standard deviation below average draw of η is indifferent between living in the pre-Katrina home and living away from New Orleans. A household with η one standard deviation above average receives a flow payoff of 0.3 utils, which represents an extremely strong preference for living in the pre-Katrina home relative to living away from New Orleans. All else equal, a median income household with a one standard deviation above average draw of η would be willing to remain in the pre-Katrina home and accept a reduction in non-housing consumption of more than 90% instead of relocating away from New Orleans.

Location payoffs exhibited statistically and substantively significant time trends during the years following Katrina, presumably reflecting the effects of infrastructure being repaired and the city being repopulated. The flow benefits to residing on blocks with 50%-90% and 90%-100% of homes initially uninhabitable followed statistically significantly positive time trends during the period immediately after Katrina. Amenity levels were extremely low in these heavily-damaged areas immediately after Katrina, but the payoffs to residing in these areas increased over time. Strikingly, there is no statistically significant relationship between initial flood damage and and location payoffs in the long run.

Consistent with earlier structural migration models, I estimate large average utility costs to moving. All else equal, a median-income household would be indifferent between paying the

[19] Appendix Table A3 presents the estimated wage equation.

estimated baseline moving cost of 3.4 utils and suffering a one-period consumption reduction of more than 95%. As papers estimating structural migration models regularly point out (Kennan and Walker, 2011), the net utility cost to moving $(\chi - \epsilon_t)$ is usually close to zero (or even negative) among households who choose to move in a particular period, because people typically move at times when idiosyncratic factors (ϵ) strongly favor moving. I find that moving costs were especially high during the first period after Katrina, a finding consistent with the fact that the mandatory evacuation of the New Orleans lasted for more than a month and basic city services were unavailable in many areas even after the city officially reopened. The estimated moving cost is larger for moves to or from New Orleans than for within-city moves. The estimated utility costs to performing home repairs are on the same order as the utility costs to moving. As one would expect, the utility cost to rebuilding a destroyed home is larger than the utility cost of repairing a damaged home.

The estimated borrowing interest rate equation finds that large groups of New Orleans homeowners faced restricted access to credit for home repairs. Black households, households without a college education, and households with low pre-Katrina income faced effective borrowing interest rates well above the risk free rate. These estimated patterns are consistent with the fact that the SBA Disaster Loan program rejected a majority of applicants from the Gulf Coast in the months following Katrina (Eaton and Nixon, 2005).

Figure 5 assesses the model's in-sample fit by comparing the model's predictions (trend lines) to the empirical 95% confidence intervals (vertical lines) for three key outcomes; the percentage of homes in a livable state, the percentage of homes inhabited by the pre-Katrina owner, and the fraction of homes having been sold by the pre-Katrina owner. Separate plots for blacks and nonblacks are also provided. The model predicts the key features of the data quite well, but the model's fit is not exact in several places. The model captures the racial disparities in repair rates and location choices but under-predicts the size of the racial disparity in the probability of a pre-Katrina owner having sold their home.

VI. Policy Simulations

I next describe the results of partial equilibrium policy simulation experiments designed to examine the short-run and long-run effects of disaster-related bailouts to New Orleans. There are of course drawbacks to using partial equilibrium models to study large interventions with the potential to change local prices, but there are also important advantages to using a partial-equilibrium approach. One advantage of the partial-equilibrium approach is that it allows for greater modeling complexity in other areas. By focusing exclusively on households' choices, I am able to carefully model credit availability and the borrowing/saving choices that are crucial to understanding the Road Home program's short-run welfare effects. And although partial equilibrium policy simulations cannot characterize the magnitude of any general equilibrium feedback effects, the partial equilibrium approach is sufficient to compute an upper bound on the long-run distortion and welfare loss caused by expected future bailouts, because constant-price policy simulations will *overstate* the quantity response to a household-directed location subsidy if housing supply and labor demand are actually finitely elastic. That is because households' behavioral responses would be dampened if the subsidy's incidence actually fell partly on firms and land developers.

For each policy scenario, I compute 10,000 simulated panels for each household, initializing each panel to the household's actual location and home damage status in the first period after Katrina. I compute 1/50th of each household's simulated panels at each of the 50 support points of $A_{i0} \times \eta$ 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 $A_{i0} \times \eta$ combination conditional on the household's actual choice sequence.[20]

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

$$W_i(P) = E_{\eta, A_{i,0}|\{X_{it}\}, Z_i}\left[\frac{100 \times \Big(V(X_{i,0}, A_{i,0}, \eta|\text{Policy} = P) - V(X_{i,0}, A_{i,0}, \eta|\text{No Grants})\Big)}{V(X_{i,0}, A_{i,0}, \eta|\text{Full Reimbursement at } t{=}0) - V(X_{i,0}, A_{i,0}, \eta|\text{No Grants})}\right] \tag{18}$$

This definition normalizes each household's expected welfare to zero when no grant compensation is provided and to 100 when full reimbursement of all losses is provided at t=0. The expectation in this expression is taken with respect A_0 and η conditional on households' observed choices. I define average household welfare under a particular policy to be the average of this quantity across households. The rationale for this approach is not that full reimbursement is the correct (in some sense) policy to which others should be compared. The rationale 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

I first present the results of simulation experiments evaluating the impact of the Road Home program on households' resettlement choices. I quantify the program's impact by comparing households' choices in the actual post-Katrina policy environment (the baseline model specification) to their choices under a counterfactual scenario in which no grant program existed. I also examine

[20]The *ex post* probability that a household is characterized by a given combination of an initial asset holding and η-draw is equal to $\left(\frac{1}{50}\right) \times l(\theta|\{X_{it}\}_{t=1}^{T}, A_0, \eta)/\, l(\theta|\{X_{it}\}_{t=1}^{T})$, that is, the ex-ante weight (1/50) times the appropriate likelihood ratio.

heterogeneity in the program's impact by repeating this exercise within specific population subgroups. Table 5 presents the results of these simulations.

The simulations find that the Road Home program increased the repair rate within four years of Katrina among households with uninsured home damages by 4.0 percentage points (from 48.0% to 52.0%, an 8.2% increase) and generated a similar increase in the fraction of households residing in their pre-Katrina homes on Katrina's fourth anniversary. The program's impact was larger among households with uninsured repair costs above $75,000 (8.9 percentage point, 20.7% increase) – the group to whom the program paid the largest grants – than among households with smaller uninsured repair costs (3.0 percentage point, 6.1% increase).

The Road Home program's impact differed substantially across socioeconomic subgroups. The program's impact was slightly larger among households with pre-Katrina income below $40,000 than among those with pre-Katrina income above $40,000. Differences in the program's impacts by race were larger than differences by income. The Road Home program increased the rebuilding rate by 4.8 percentage points (9.9%) among black households and increased the rebuilding rate by 17.0 percentage points (50.2%) among black households with uninsured losses above $75,000. The Road Home program increased the rebuilding rate by just 2.2 percentage points (a 4.7% increase) among nonblack households and by just 1.1 percentage points (2.1%) among nonblacks with uninsured losses above $75,000.

Table 6 further examines the Road Home program's short-run impacts by comparing the Road Home program's impact on rebuilding rates (panel A) to the impact of several counterfactual post-Katrina interventions. This table also presents estimates of the Road Home program's short-run welfare impacts (panel B). Welfare impacts are first presented here, because the program's welfare impacts are most naturally interpreted relative to the welfare effects of related counterfactual policies. The first three rows of each panel compare the Road Home program to a hypothetical program that offers no grants but instead makes loans available at the risk-free to all households beginning on Katrina's second anniversary (mimicking the timing of the Road Home "treatment"). The next three rows compare the Road Home program to an otherwise identical program that rolled out immediately after Katrina.

The simulations find that a universal loan program generates an aggregate impact on the rebuilding rate about three fourths the size of the Road Home program's impact, and the universal loan program generates almost half of the Road Home program's positive impact on household's welfare. The loan program accounts for an even larger fraction of the Road Home program's impact among the groups estimated to have faced limited credit access. For example, among black households with uninsured losses above $75,000, the loan program's impact on the rebuilding rate is about 85% the size of the Road Home program's impact, and the loan program generates about 86% of the Road Home program's welfare improvement within among these households.

The simulations experiments find that the immediately rolled-out grant program generates a larger impact on the rebuilding rate than the more-slowly rolled out Road Home program. The difference between these two program's effects on the rebuilding rate is fairly similar across population subgroups. The more-quickly rolled out program generates significantly larger welfare gains than the Road Home program with a similar total expenditure. Because most households are substantially inframarginal with respect to their preferred locations, significant welfare improvements are achieved by quickly implementing policies that remove constraints to households' location choices.

The Deadweight Loss from Disaster-Related Subsidies

I next turn to the paper's second set of policy experiments quantifying the long run distortion associated with fully-subsidized disaster insurance to New Orleans. This policy is operationalized in the simulation experiments as a flow subsidy each period to the households currently residing in New Orleans equal to the actuarially fair premium of an insurance policy guaranteeing full compensation in the event of a future disaster. Letting τ represent the annual probability of a New Orleans resident's home being destroyed by a disaster, the size of the transfer is $\tau \times P_H$ each year.[21] I consider two scenarios, one in which a disaster is expected to occur once every 50 years (τ=2%) and another in which a disaster is expected to occur every 30 years (τ=3.33%).

The size of the deadweight loss associated with any location-specific subsidy depends on the responsiveness of households' location choices to financial incentives. Let S($W - [uc - \tau] \times P_H$) represent the long-run supply of households to New Orleans as a function of the real wage, annual labor earnings minus the potentially-subsidized user cost of housing. This supply curve is upward sloping due heterogeneity in location preferences across households.[22] The subsidy generates a rightward shift in the supply curve, which increases the equilibrium population of the city.

In order to compute an upper bound on the deadweight loss associated with this subsidy, I perform the policy simulations under the assumption that local labor demand and housing supply are infinitely elastic. Under these assumptions, the subsidy's incidence falls entirely on homeowners, and the supply elasticity of residents to the city is a sufficient statistic for the deadweight loss caused by the subsidy. If labor demand and housing supply have finite elasticities, the incidence of

[21]When implementing this policy in the simulation experiments, the annual transfer is spread evenly over the three periods that occur each year in the model.

[22]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, implying 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. In such a model, spatially targeted subsidies must generate large distortions. See Moretti (2011) and Busso, Gregory, and Kline (2013) for discussions of the efficiency consequences of local subsidies in the presence of location preference heterogeneity.

the subsidy will fall partially on firms and land developers through price changes, dampening the subsidy's distortion to households' location choices.

Under these assumptions, the deadweight loss caused by the hypothetical subsidy is approximated by the standard Harberger triangle (Harberger, 1964),

$$DWL = \left(\frac{1}{2}\right) \times [\text{Value of Housing Stock}] \times \psi \times \tau^2 \tag{19}$$

where τ is the size of the flow subsidy as a fraction of a home's value, and $\psi = d\ln \mathrm{S}/d\tau$ is the semi-elasticity of supply of residents to New Orleans with respect to τ. I estimate the semi-elasticity ψ using simulations that compare the number of households residing in New Orleans in steady state with and without the subsidy in place.

Table 7 presents the deadweight loss calculations under a range of modeling assumptions. The model-implied population semi-elasticity ψ is 0.48. The value of the New Orleans owner occupied housing stock is about $11 billion.[23] Plugging these values into equation (19) finds that the deadweight loss associated with the τ=2% subsidy (column 1) is roughly $1.1 million per year, compared to the subsidy's expected cost of roughly $220 million per year and finds that the deadweight loss associated with the τ=3.33% subsidy (column 2) is roughly $2.9 million per year, compared to the subsidy's expected cost of roughly $363 million per year. For both values of τ the flow deadweight loss is less than 1% of the program's expected cost.

These calculations implicitly assume that the elasticity of pre-Katrina New Orleans residents' location decisions provides a reasonable approximation to the elasticity of location decisions among the full population "at risk" of eventually living in New Orleans going forward. 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 might eventually consider moving to New Orleans. Indeed my simulations find that ψ=1.93 among households age 35 or less. Kennan and Walker (2011), studying the migration choices of male NSLY79 respondents beginning at age 20, find elasticities of local population with respect to local wages between 0.5 and 0.8, which, assuming that households purchase homes worth about 2.5 times annual income, imply a semi-elasticity ψ between 1.25 and 2.

Columns 3 and 4 of Table 7 compute the deadweight loss associated with the τ=2%and τ=3.33% subsidies under the more conservative assumption that 3/4 of households "at risk" for residing in New Orleans exhibit the average model-implied location elasticity and 1/4 exhibit the higher "under-35" model-implied location elasticity. This 3:1 ratio is roughly the ratio in pre-Katrina New Orleans of Louisiana-native households to households with at least one head born outside of Louisiana. These assumptions yield deadweight loss estimates of slightly less than 1% of

[23]Source: 2011 Orleans Parish Assessor's Office property appraisal data.

the policy's expected flow costs (τ=2%) and about than 1.4% of the policy's expected flow cost (τ=3.33%).

Columns 5 and 6 of Table 7 perform these deadweight loss calculations under the even more conservative assumption that all households exhibit the model-implied "under-35" location elasticity. This scenario is perhaps appropriate when considering the policy's distortion over a very long horizon, perhaps multiple generations. Even in this scenario that assumes the most elastic response, the deadweight loss associated with the flow subsidy to New Orleans is only about 3.2% of the policy's expected cost. Although disaster-related location subsidies may violate the notion of horizontal equity by transferring wealth from households in safe areas to similar households in disaster-prone areas, few enough households are marginal with respect to their preferred location that the distortion associated with these transfers appears to be relatively small.

VII. Robustness

One difficulty with a model-based approach to program evaluation is that a researcher usually cannot be completely certain what a program's treatment entailed in practice even when the program's administrative rules are known. If a program is modeled in a manner that is significantly different from the way in which the program was actually implemented, then estimates of individuals' underlying preferences based on their response to the program will be biased, and simulation-based impact estimates may not be reliable. This paper's baseline model's budget constraint specifies Road Home grants as providing full compensation for households' uninsured losses in all situations where the program's rules promise full compensation. However, press accounts during the Road Home program's implementation often included anecdotes claiming that Road Home grants fell short of fully compensating some households for their uninsured losses. To assess the robustness of this paper's findings to the possibility that Road Home grants fell short in practice, I re-estimate the model and repeat the policy simulation experiments after replacing the baseline model's budget constraint with one in which Road Home grants are 20% smaller than in the baseline model specification.[24]

Table 8 compares this paper's baseline program impact estimates to equivalent estimates computed with the re-estimated model. The top panel (panel A) of Table 8 reports the Road Home

[24] In principle, re-estimating the preference parameters under the assumption that grants were smaller could generate larger or smaller estimates of the Road Home program's impact. The modeling change reduces the magnitude of households' financial incentive to rebuild, so if estimated preferences were unaffected the program's predicted impact would be smaller. However the modeling change also reduces the the *amount of variation in financial incentives* to which observed differences in behavior across households is attributed during the structural estimation, so the estimated spatial elasticity (utility weight on consumption) must be larger after the modeling change to rationalize observed choices. The net impact of these two effects – smaller treatment but a more elastic response – could be positive or negative.

program's estimated impact on the aggregate rebuilding rate and the rebuilding rate among population subgroups. The re-estimated model that assumes a 20% shortfall in Road Home grants generates a somewhat larger estimate of the program's impact on the rebuilding rate than the baseline model (6.0 versus 4.0 percentage points). The two models generate very similar patterns of predicted Road Home impacts across population subgroups. Both specifications find that the program's impact was concentrated among households with significant uninsured losses and limited access to credit. The Road Home program's impact was larger among black households than non-black households, and the program's impact was largest among black households with uninsured losses above $75,000.

The bottom panel (panel B) of Table 8 compares the two models' predictions regarding the long-run deadweight loss caused by fully subsidized disaster insurance to New Orleans. The re-estimated model predicts somewhat larger spatial elasticities than the baseline model, both on average and among younger households. These somewhat larger elasticities cause only minor changes to the deadweight loss estimates. The high-end deadweight loss estimate of the re-estimated model remains relatively small – about 3.7% of the program's expected cost. In sum, the comparisons presented in Table 8 find that this paper's main conclusions are qualitatively robust to some uncertainty (from the researcher's perspective) regarding the generosity of Road Home grants.

VIII. Conclusion

This study performs a first of its kind impact evaluation of a large scale U.S. disaster-relief program, and the paper's impact estimates quantify several of the tradeoffs inherent to disaster relief policy. The analysis finds that the Louisiana Road Home program increased the rebuilding rate in New Orleans by Katrina's fourth anniversary by about 8.2%. About three fourths of this impact on the rebuilding rate and about half of the program's positive impact on households' welfare occurred by relaxing financing constraints for households who would have strongly preferred to rebuild even in the absence of a subsidy if the cost could be spread over time. I find that an expectation of similar bailouts after future disasters generates a relatively small long-run efficiency cost of less than 4% of the subsidy's expected cost. While these results seem favorable to the program, it should be noted that the program was far from being an optimal policy from a welfare standpoint. For instance, an otherwise identical program rolled out more quickly would have generated a larger welfare improvement with a similar total expenditure. The results do cast doubt on the view, not uncommon among economists, that moral hazard with respect to location choices is the most likely source of welfare losses from disaster-relief policies.

Of course these results should not be blindly extrapolated to all similar policies in all post-disaster settings. The findings that guaranteed post-disaster bailouts significantly increase victims' welfare at a relatively small long-run efficiency cost are driven by estimates of highly heterogeneous location preferences and extensive financing constraints. The city of New Orleans is probably not average along either of these dimensions. New Orleans is a culturally unique city with few close substitutes. New Orleans is also a relatively poor city. One would expect subsidies to cities with many close substitutes to generate larger distortions, and one would expect subsidies to more affluent cities with fewer residents facing barriers to credit to generate smaller short-run welfare gains. While this paper makes an important first step in quantifying the impacts of this class of policies, program evaluations of disaster relief policies in other contexts are certainly needed.

Another limitation of this study is its use of a partial equilibrium framework to study a large intervention. The partial-equilibrium framework was well-suited for addressing this paper's main research questions, however, a number of interesting questions cannot be studied with a partial equilibrium model. For instance, a partial equilibrium model cannot provide any evidence about the nature of equilibrium amenity spillovers, which are likely to have an important influence on post-disaster outcomes within individual neighborhoods. If a rebuilt home contributes more to a neighborhood's amenity value than a blighted home, there is an avenue outside of the partial equilibrium model though which government interventions can affect welfare. Additionally, if these amenity spillovers are a sufficiently nonlinear function of neighborhood-level rebuilding rates, then multiple rebuilding-rate equilibria can exist, and disaster-relief policy might solve or exacerbate coordination problems and influence welfare through equilibrium-selection. Understanding these sorts of related issues is one focus of my ongoing work.

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TABLE 1. HOUSEHOLD BACKGROUND CHARACTERISTICS

Trait/Characteristic	Percentage
Household Headship	
Solo male headed	17
Solo female headed	30
Couple headed	53
Race	
Either head is black	58
Neither head is black	42
Education of Most Educated Head	
H.S. dropout	8
H.S. graduate	18
Some college	25
Bachelor's degree or higher	49
Household Age †	
Under 40	22
40-49	23
50-64	30
65 or older	25
Attachment to Place	
Home purchased > 25 years before Katrina	38
Home purchased 10-25 years before Katrina	26
Home purchased 0-10 years before Katrina	37
Either household head born outside of Louisiana	23
Neither household head born outside of Louisiana	77
Pre-Katrina Annual Household Income	
< $20,000	18
$20,000 - $40,000	23
$40,000 - $80,000	34
> $80,000	26
Neighborhood Poverty	
Block group poverty rate (2000 Census), <10%	21
Block group poverty rate (2000 Census), 10% - 25%	46
Block group poverty rate (2000 Census), > 25%	33
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 households who owned single-family homes (either free-and-clear or with a mortgage) at the time of Katrina and restricts attention to households in which at least one household head was employed during the year prior to Katrina or who 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 single-family homes (either free-and-clear or with a mortgage) at the time of Katrina and restricts attention to households in which at least one household head was employed during the year prior to Katrina or who had reached retirement age. 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. Households participating in the Road Home program selected from among three benefits packages known as options 1, 2, and 3. Option 1 grants paid homeowners the difference between the estimated cost of repairs and the value of any insurance payments already received (up to a maximum of $150,000) and required the recipient to repair and reside in the pre-Katrina home within three years and to purchase any required flood insurance. Option 2 provided the same cash grant as option 1, but required the recipient to turn their home over to a public land trust and purchase another home in Louisiana within three years. Option 3 was similar to option 2 but imposed no location or home-purchase requirement and paid a grant that was 40% smaller. Source: DNORS, Assessor's Data, and Road Home participation data from the Louisiana Recovery Authority.

TABLE 4. UTILITY FUNCTION AND BORROWING RATE PARAMETERS

Parameter:	Estimate
Residence away from New Orleans: $B_t(3)$	0.00 [normalized]
Residence in New Orleans: $B_t(2)$	
Long-run level	-0.09 [0.04]
Black	0.04 [0.02]
Neither head born in Louisiana	-0.01 [0.02]
Purchased home 10-20 years before Katrina	-0.03 [0.01]
Purchased home > 20 years before Katrina	-0.02 [0.02]
Time trend during first 5 years (15 periods) after Katrina: *note: trend line = - [15 x trend]+min[t, 15] x trend*	-0.17 [0.02]
Additional benefit from pre-Katrina home: $B_t(1)-B_t(2)$	
Intercept	0.24 [0.02]
Block poverty rate (2000 Census), 10% - 25%	0.01 [0.04]
Block poverty rate (2000 Census), > 25%	0.07 [0.03]
Fraction of block homes damaged: 50-90%	
Intercept shift (long run)	-0.01 [0.02]
Time trend during first 5 years (15 periods) after Katrina: *note: trend line = - [15 x trend]+min[t, 15] x trend*	0.09 [0.03]
Fraction of block homes damaged: >90%	
Intercept shift (long run)	-0.02 [0.02]
Time trend during first 5 years (15 periods) after Katrina: *note: trend line = - [15 x trend]+min[t, 15] x trend*	0.24 [0.03]
Std. dev. of persistent heterogeneity η: σ_η	0.15 [0.03]
Moving utility cost: χ_M	
Intercept: Moves in period t=1	3.4 [0.26]
Intercept: Moves in period t>1	3.17 [0.36]
Moves to or from New Orleans	0.77 [0.38]
Move home in first period after home repair	-4.12 [0.32]
Repairing/rebuilding utility cost: χ_R	
Intercept	3.26 [0.27]
Additional utility cost to rebuilding a destroyed home	1.45 [0.38]
Log of Borrowing interest rate: $\ln(1+r_B)$	
Intercept	$\ln(1/\beta)$ [normalized]
Black	0.39 [0.12]
No bachelor's degree	0.27 [0.12]
Household income before Katrina < $20k	0.42 [0.19]
Household income before Katrina $20-40k	0.05 [0.02]
Scale of shocks relative to u(c): α	1.67 [0.42]
Observations - household-periods	6,720
Observations - households	560
Log-Likelihood	-2,695

Note: This table reports maximum likelihood estimates of the model's structural parameters (see Section III for estimation details). Assymptotic standard errors clustered at the neighborhood level are reported in brackets. Source: Author's calculations using DNORS and Assessor's data covering calender years 2005 through 2009.

TABLE 5. 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 the pre-Katrina Home		Living in New Orleans		Sold Home	
Group	No Grants	Impact of Road Home	No Grants	Impact of Road Home	No Grants	Impact of Road Home	No Grants	Impact of Road Home
All Households	48.0	***+4.0***	39.4	***+3.2***	68.5	***+1.6***	19.5	***-2.3***
Cost of repairs *not covered* by insurance								
Less than $75,000	48.9	***+3.0***	40.0	***+2.3***	69.1	***+1.1***	19.3	***-1.8***
More than $75,000	42.9	***+8.9***	36.3	***+7.5***	65.2	***+4.0***	20.0	***-4.3***
Race:								
Black	48.5	***+4.8***	40.1	***+3.9***	71.0	***+1.9***	17.9	***-2.5***
Non-black	46.7	***+2.2***	37.8	***+1.5***	62.9	***+0.7***	23.2	***-1.8***
Annual household income before Katrina								
Less than $40,000	45.9	***+4.1***	37.4	***+3.4***	69.1	***+1.5***	22.0	***-2.2***
More than $40,000	50.4	***+3.8***	41.9	***+3.0***	67.9	***+1.6***	16.5	***-2.5***
Other illustrative subgroups:								
Black households, uninsured repair costs < $75,000	50.3	***+3.2***	41.5	***+2.5***	71.5	***+1.2***	17.2	***-1.7***
Black households, uninsured repair costs > $75,000	33.8	***+17.0***	28.6	***+14.8***	66.1	***+7.8***	23.2	***-7.9***
Nonblack households, uninsured repair costs < $75,000	45.1	***+2.5***	35.9	***+1.8***	62.4	***+0.7***	25.3	***-2.1***
Nonblack households, uninsured repair costs > $75,000	51.6	***+1.1***	43.6	***+0.5***	64.3	***+0.4***	16.9	***-0.8***

Note: This table presents the results of partial equilibrium policy simulation experiments assessing the impact of the Road Home program. The first column in each pair reports the average outcome under a scenario in which no Grant Program was in place, and the second reports the Road Home program's impact. Source: Author's calculations using the estimated model.

TABLE 6. DECOMPOSITION OF THE ROAD HOME PROGRAM'S IMPACT ON HOUSEHOLDS' RESETTLEMENT CHOICES AND HOUSEHOLDS' WELFARE

	A. Percentage Living in pre-Katrina home on Katrina's 4th Anniversary				
		Blacks		Nonblacks	
Scenario	All Households	Uninsured Losses < $75k	Uninsured Losses > $75k	Uninsured Losses < $75k	Uninsured Losses > $75k
Access to Credit					
No grant program (baseline)	48.0	50.3	33.8	45.1	51.6
Impact: Loans available to all households (no grants)	***+3.0***	***+2.2***	***+14.4***	***+1.9***	***+0.4***
Impact: Actual Road Home program	**+4.0**	**+3.2**	**+17**	**+2.5**	**+1.1**
Timing of Road Home Program					
No grant program (baseline)	48.0	50.3	33.8	45.1	51.6
Impact: Actual Road Home program	**+4.0**	**+3.2**	**+17**	**+2.5**	**+1.1**
Impact: Road Home program rolled out at t=0	***+6.6***	***+5.6***	***+23.5***	***+4.8***	***+2.2***

	B. Household Welfare (0% = no grant program; 100% = full compensation at t=0)				
		Blacks		Nonblacks	
Scenario	All Households	Uninsured Losses < $75k	Uninsured Losses > $75k	Uninsured Losses < $75k	Uninsured Losses > $75k
Access to Credit					
No grant program (baseline)	0%	0%	0%	0%	0%
Impact: Loans available to all households (no grants)	+11.6%	+9.8%	+34.4%	+10.9%	+5%
Impact: Actual Road Home program	**+24.3%**	**+23.3%**	**+39.9%**	**+20.8%**	**+26.4%**
Timing of Road Home Program					
No grant program (baseline)	0%	0%	0%	0%	0%
Impact: Actual Road Home program	**+24.3%**	**+23.3%**	**+39.9%**	**+20.8%**	**+26.4%**
Impact: Road Home program rolled out at t=0	+59.5%	+59.6%	+63%	+57.9%	+60%

Note: This table presents the results of simulations comparing the Road Home program's impact on households' choices and welfare to the impact of counterfactual policies. The top panel presents impacts on repair rates, and the bottom panel presents impacts on households' welfare. For each household, welfare is normalized to zero in a scenario in which no grant program is in place, and welfare is normalized to one hundred in a scenario in which all home repairs not covered by insurance are reimbursed at t=0. Source: author's calculations using the estimated model.

TABLE 7. 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)]	0.48	0.48	0.48	0.48		
Elasticity: ψ among young households			1.93	1.93	1.93	1.93
Flow cost of subsidy ([Value of Housing Stock] • τ)	\$220 M	\$363 M	\$220 M	\$363 M	\$220 M	\$363 M
DWL ($\approx \frac{1}{2}$ • [Value of Housing Stock] • ψ • τ^2)	\$1.1 M	\$2.9 M	\$1.9 M	\$5.1 M	\$4.3 M	\$11.6 M

Note: This table calculates the deadweight loss associated with fully subsidized disaster insurance for New Orleans residents. 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.

TABLE 8. ROBUSTNESS CHECKS

A. Robustness of short-run impact estimates (4-year rebuilding rates)

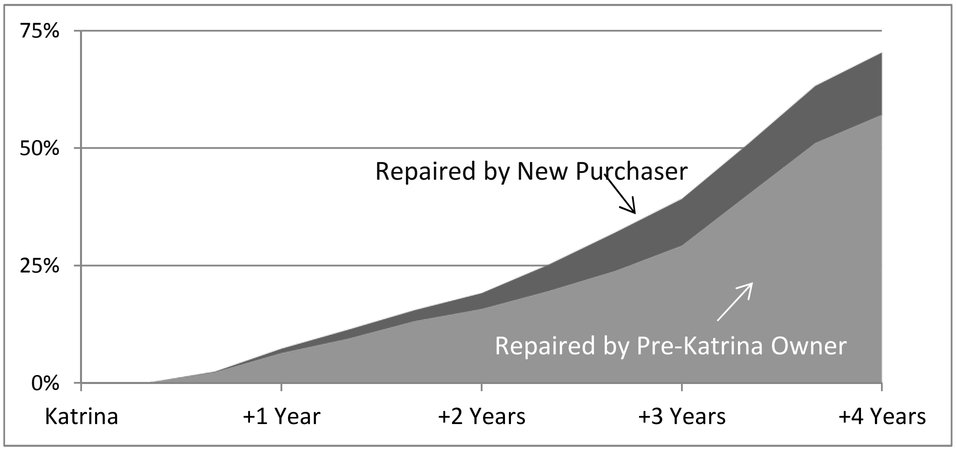
	(1)	(2)	(3)	(4)
	Baseline model		Reestimated model: Assumes a 20% Road Home shortfall	
Group	No Grants	Impact of Road Home	No Grants	Impact of Road Home
All Households	48.0	***+4***	45.6	***+6***
Race:				
Black	48.5	***+4.8***	45.0	***+7.7***
Non-black	46.7	***+2.2***	46.9	***+1.9***
Annual household income before Katrina				
Less than $40,000	45.9	***+4.1***	41.9	***+7.5***
More than $40,000	50.4	***+3.8***	49.9	***+4.2***
Cost of repairs *not covered* by insurance				
Less than $75,000	48.9	***+3***	46.3	***+5.3***
More than $75,000	42.9	***+8.9***	41.7	***+9.4***
Other illustrative subgroups:				
Black households, uninsured repair costs < $75,000	50.3	***+3.2***	46.6	***+6.4***
Black households, uninsured repair costs > $75,000	33.8	***+17***	31.7	***+18.1***
Nonblack households, uninsured repair costs < $75,000	45.1	***+2.5***	45.4	***+2.2***
Nonblack households, uninsured repair costs > $75,000	51.6	***+1.1***	51.3	***+1.1***

B. Robustness of long-run DWL estimates:

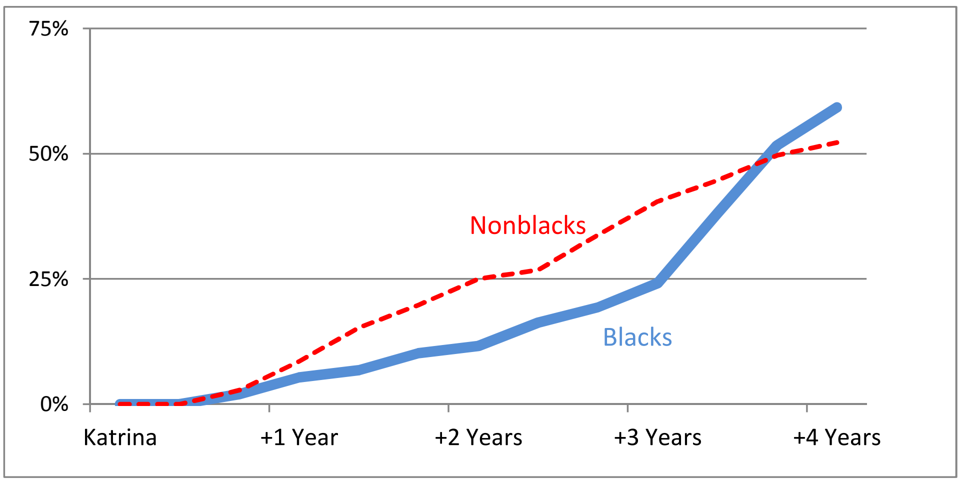
	Baseline model		Reestimated model: Assuming a 20% Road Home shortfall	
	Scenario 1	Scenario 3	Scenario 1	Scenario 3
Baseline value of housing stock	$11 B	$11 B	$11 B	$11 B
Subsidy: τ (as a % of home value)	3.30%	3.30%	3.30%	3.30%
Elasticity: ψ = dln(N.O. households / d[subsidy (τ)]	0.48		0.60	
Elasticity: ψ among young households		1.93		2.22
Flow cost of subsidy ([Value of Housing Stock] • τ)	$363 M	$363 M	$363 M	$363 M
DWL (≈ 1/2 • [Value of Housing Stock] • ψ • τ2)	$2.9 M	$11.6 M	$3.6 M	$13.3 M

Note: This table compares the results of simulation experiments using the estimated baseline model to the results of simulation experiments using the model re-estimated under the assumption that Road Home grants fell 20% short of fully compensating households for their uninsured losses. Source: author's calculations using the baseline model and the re-estimated model.

FIGURE 1. TIMING OF HOME REPAIRS



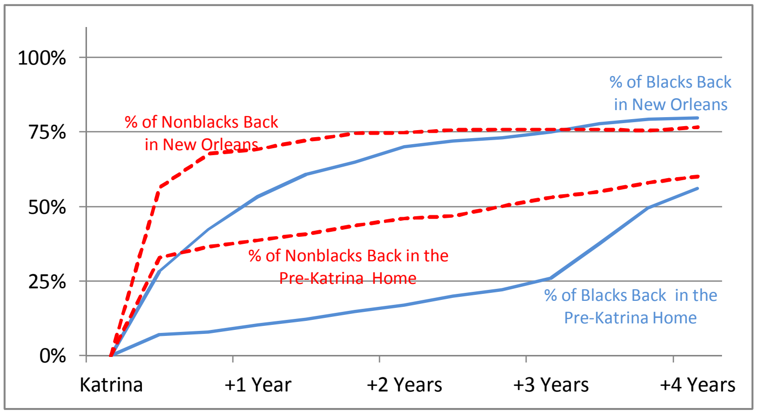
A. HOME REPAIRS BY ORIGINAL OWNER OR NEW PURCHASER



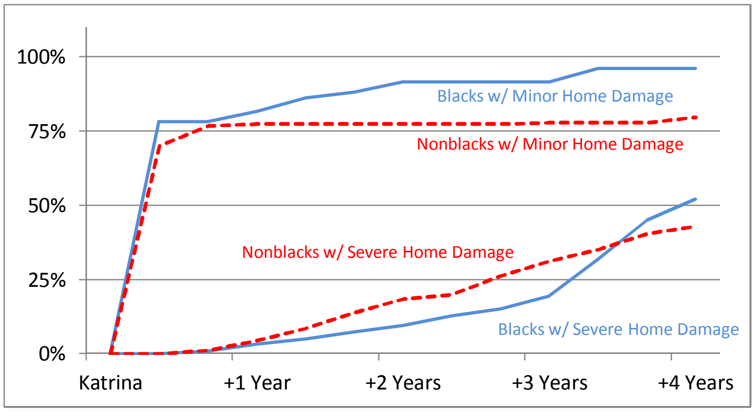
B. HOME REPAIRS BY ORIGINAL OWNER: BY RACE

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

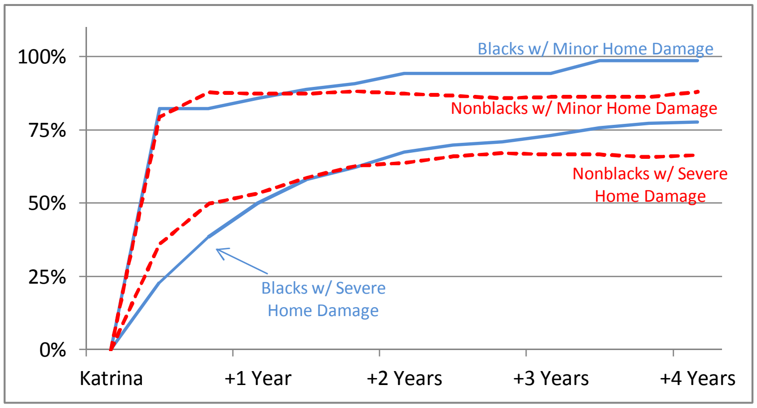
FIGURE 2. TIMING OF RETURNS TO NEW ORLEANS AND TO HOUSEHOLDS' PRE-KATRINA HOMES



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



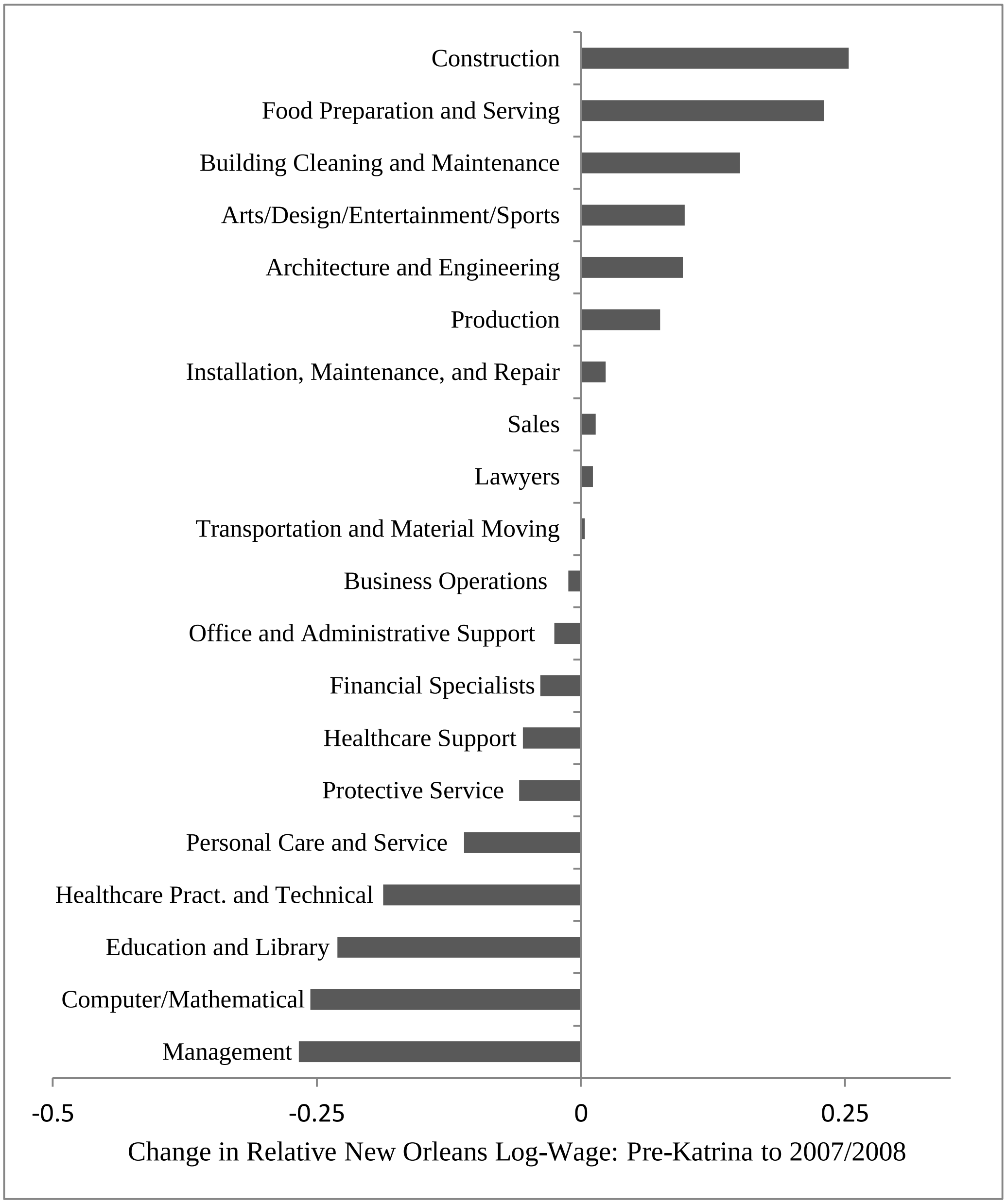
B. FRACTION ***LIVING IN PRE-KATRINA HOME*** BY RACE AND PROPERTY DAMAGE



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

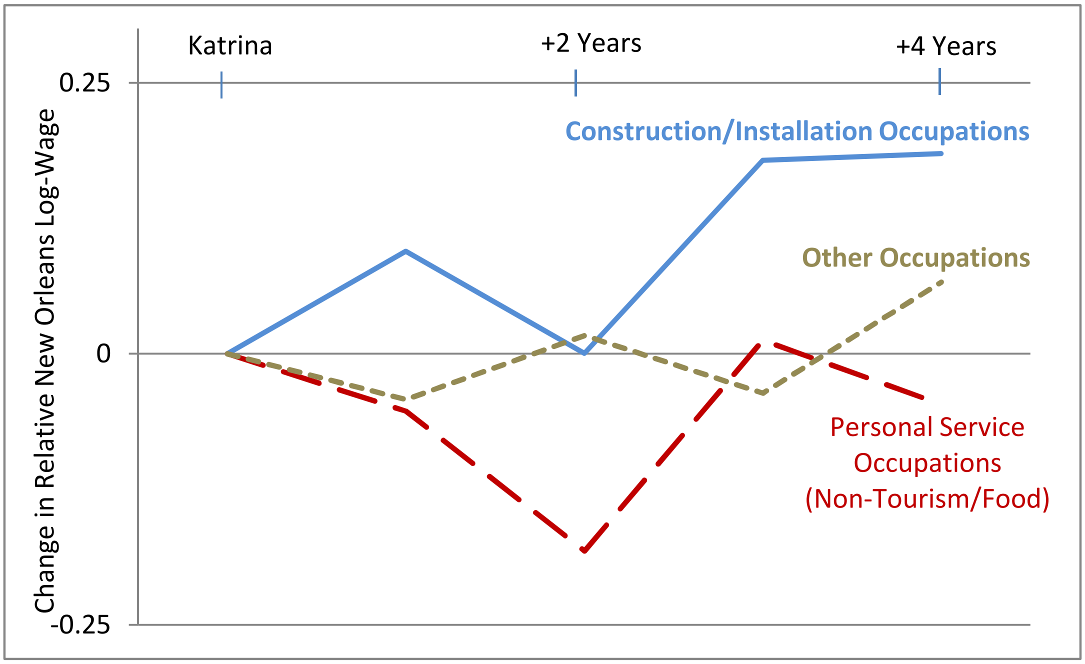
Source: DNORS and Orleans Parish Assessor's Ofiice property database.

FIGURE 3. CHANGES IN RELATIVE NEW ORLEANS WAGES FROM PRIOR TO KATRINA TO 2007/2008: BY OCCUPATION



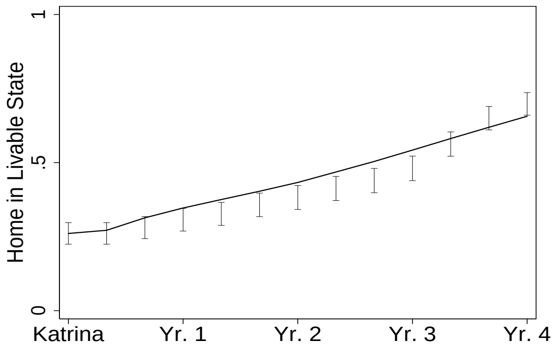
Note: The relative New Orleans log-wage is the difference between the log of mean annual earnings for workers in New Orleans minus the log of mean annual earnings for workers in other Southern metropolitan areas. This figure presents changes in the relative New Orleans log-wage from the 2005 ACS to the 2008 ACS for each two-digit occupation that was 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 4. CHANGES IN RELATIVE NEW ORLEANS WAGES
AFTER HURRICANE KATRINA BY OCCUPATION

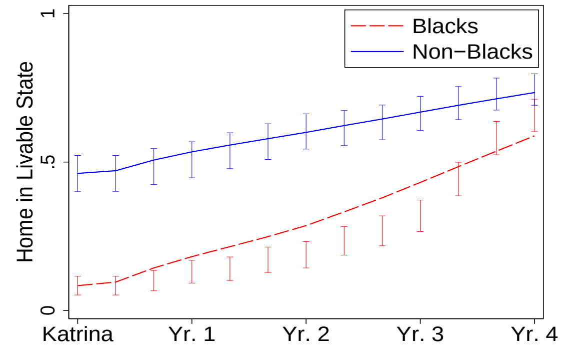


Note: The relative New Orleans log-wage is the difference between the log of mean annual earnings for workers in New Orleans minus the log of mean annual earnings for workers in other Southern metropolitan areas. This figure presents changes in the relative New Orleans log-wage from the 2005 ACS to the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

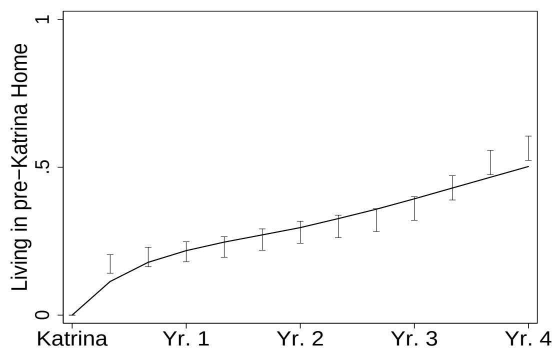
FIGURE 5. MODEL FIT



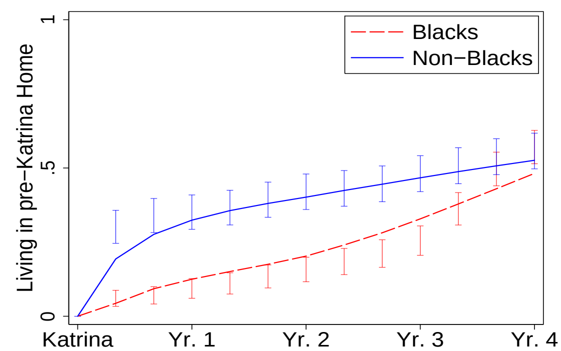
a. Home in a livable state



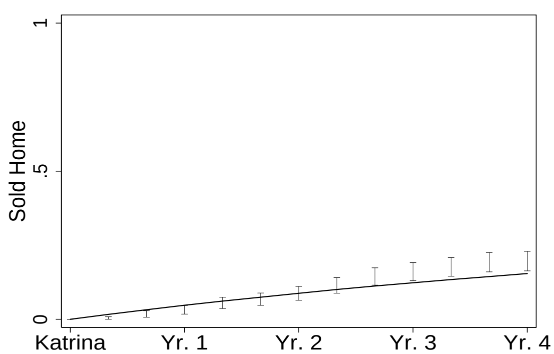
b. Home in a livable state, by race



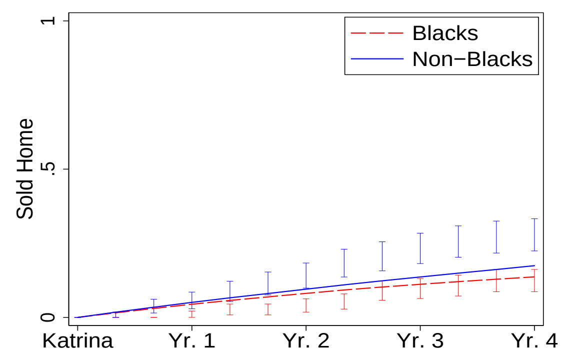
c. Living in the pre-Katrina home



d. Living in the pre-Katrina home, by race



e. Home has been sold



f. Home has been sold, by race

Note: The plotted lines depict the model's predicted trends, and the vertical bars depict empirical 95% confidence intervals. Source: Author's Calculations using the model's predictions and data from DNORS and the Orleans Parish Assessor's Ofiice property database.

Appendix I: Data

A. Housing-Related Price Variables

Appendix Table A1 describes the construction of each of the housing-related price variables used during estimation. Constructing some of these variables requires a housing price index that relates pre-Katrina New Orleans housing prices to quality-constant housing prices after Katrina in New Orleans and in other Southern metro areas. I construct this housing price index by regressing log-housing rent (from the 2005-2009 American Community Survey) on a set of housing market dummy variables and a set of building characteristics. Pre-Katrina New Orleans is the omitted housing market, so the coefficients on the included housing market dummies measure quality-constant deviations from pre-Katrina New Orleans housing prices. Appendix Table A2 presents the estimated indices. Housing prices were 35.2 log-points higher in post-Katrina New Orleans than in pre-Katrina New Orleans and 23.3 log-points higher in other Southern metros after Katrina than in pre-Katrina New Orleans.

B. Home Repair Status Imputations

I construct measures of home repair status using a three step procedure that involves; (1) creating repair status measures for each home on each Katrina anniversary using Assessor's Office records, (2) fitting a flexible hazard model using these observed repair status outcomes and an extensive list of covariates, and (3) stochastically imputing a repair status for periods that do not fall on Katrina anniversaries using based on this hazard model. The following describes these steps in more detail.

Step 1: I first classify as initially uninhabitable all homes for which property's assessed 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 (in DNORS) that its home was rendered uninhabitable by Katrina. The 2005 appraisal occurred in the first few months after Katrina in advance of the 2006 tax year and reflected Katrina-related home damage. If a home was classified as livable (not uninhabitable) immediately following Katrina, I classify the home as livable in all subsequent periods. For homes classified as uninhabitable immediately following Katrina, I classify the home as livable 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.[25]

Step 2: Among households with homes classified as initially uninhabitable, I estimate a Weibull 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 in its "current status" form by maximum likelihood using the complementary log-log specification.[26]

[25]Note: This approach would spuriously classify some homes as repaired if the Assessor's Office ever applied blanket appreciations to still-damaged properties. The Assessor's Office has told me that as a matter of policy blanket appreciations were not applied to still-damaged properties. Patterns in the data suggest that this policy was followed in practice. I find very few instances 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%.

[26]The explanatory variables 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

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 (and hence a repair period) between those two anniversaries using the estimated hazard model.

C. 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.

This approach requires estimating the conditional (conditional on household's observable characteristics) quantiles p=0.05, 0.15, ..., 0.95 of the CDF $F_{A_0}()$ of the non-housing liquid assets. I estimate this conditional liquid asset distribution using responses to the 2005 wave of the Panel Study of Income Dynamics (PSID).[27] I first use a logistic regression to estimate the probability $p(x)$ that a household has zero liquid assets conditional the household's observable traits x.[28] I next estimate the conditional quantiles of the positive asset holding distribution with a sequence of quantile regressions. For quantiles $p \leq p(x)$, I set $\widehat{F}_{A_0}^{-1}(p|x) = 0$. for each For quantiles $p > p(x)$, I set $\widehat{F}_{A_0}^{-1}(p|x)$ to the estimated $(p - p(x))/(1 - p(x))$ quantile of the distribution of assets. As an example, for a household with $p(x) = 0.2$ then $\widehat{F}_{A_0}^{-1}(p = .5|x)$ is the fitted 25th percentile of the conditional (on x) positive asset distribution.

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.

[27] Liquid assets are defined to be the sum of a household's of non-IRA stock holdings, bond holdings, and holdings in checking accounts, savings accounts, money market accounts, and CDs.

[28] The explanatory variables include; 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.

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 this rent for differences in rental prices between pre-Katrina New Orleans and post-Katrina New Orleans using regression adjusted price indeces (see Appendix I 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 this rent 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 I 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 the home was destroyed, the 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, the repair cost is imputed to be the difference between the appraised pre-Katrina improvement value and the appraised improvement value immediately after 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 (Table A2 presents the estimated indices)
Insurance payment	The insurance payment is 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 adjusting the home's appraised pre-Katrina value by a price index that reflects the difference in househing prices between pre-Katrina and post-Katrina New Orleans (see Appendix I for details on computing rental price indices)	-Pre-Katrina appraised home values come from the OPAO database -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: The dependent variable is the log of housing rent. Explanatory variables include 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 coefficients on the dummies should be interpretted as the mean difference in the log of rents between the indicated housing market and pre-Katrina New Orleans. Source: 2005-2009 American Community Survey for the New Orleans MSA and 2006-2009 American Community Survey for other Southern metro areas.

TABLE A3. 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: The dependent variable is the log of labor earnings. The sample includes all working respondents to the 2005 American Community Survey from the New Orleans metropolitan area and the pre-Katrina earnings records of all DNORS respondents who worked during the year prior to Katrina. Source: Author's calculations using ACS and DNORS.