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-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 moral hazard in location choices induced by expected future relief generates small deadweight costs as a fraction of disaster relief expenditures.

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Introduction

In recent decades, government responses to severe natural disasters in the United States have regularly included transfers to individual property owners with uninsured losses. This *de facto* social insurance policy involves a classic insurance versus moral hazard tradeoff. Post-disaster transfers cushion large negative wealth shocks and allow otherwise borrowing constrained households with strong location ties to finance post-disaster reconstruction. However, the anticipation of post-disaster transfers presumably distorts equilibrium residence location choices toward relatively disaster-prone locations if, as presently occurs, relief packages are financed out of general revenue. The relative magnitude of these benefits and efficiency costs is an empirical question. A full empirical appraisal of the impact of disaster-relief programs on social welfare needs to 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 (RH) on the resettlement choices of New Orleans homeowners in the aftermath of Hurricane Katrina. RH provided large cash grants to individual homeowners to cover the cost of repairing damages that were not covered by the homeowners' existing insurance arrangements. Less generous grant packages were provided to homeowners who chose not to rebuild. The first contribution of this paper is an estimate of RH's impact on Katrina victims' medium-run rebuilding and resettlement choices, and a decomposition of that impact into a component coming from "marginal" households responding RH's financial incentives and a component occurring because RH relaxed financing constraints for otherwise households who would have strictly preferred to rebuild without RH if if they had access to credit. The second contribution is an estimate of households' annual willingness to pay for a guarantee of similar transfers in the event of future disasters in New Orleans. For comparison, I provide a back-of-the-envelope calculation of the annual deadweight loss caused by the actuarially unfair (with respect to a location's disaster risk) financing of disaster relief.

To facilitate the program evaluation and welfare analysis, I develop and estimate a dynamic discrete choice model of households' post-Katrina choices regarding home repairs, residence locations, and amounts to borrow or save. The model's parameters characterize the availability of credit for members of different demographic groups and the distribution of preferences over location amenities and consumption. In the model, each household in the aftermath of Katrina makes period-by-period choices about where to live, whether to repair its pre-Katrina home or sell its pre-Katrina home, and an amount to borrow or save. I exploit several sources of variation in choice-specific financial incentives to estimate the model – one based on specific aspects of the RH grant formula and the other on differences across occupations in post-Katrina wage changes in

New Orleans.

The estimated model finds that household location preferences are sufficiently heterogeneous that most households are strongly *inframarginal* with respect to their preferred rebuilding and resettlement choices. I estimate that several large population subgroups systematically lacked access to rebuilding loans, suggesting that some households who would have had a strict preference to rebuild if the costs could be smoothed over time would not have rebuilt in the absence of post-disaster government transfers. The prevalence of credit constraints in the estimated model is consistent with the high rate at which the federal government's subsidized disaster loan program denied applications in the months following Katrina.

Computing an estimate of RH's impact on households' rebuilding choices requires an estimate of the rebuilding choices households would have made if no grants had been provided. Toward that end, I use the estimated model to perform a series of counterfactual policy experiments including simulations of households' choices under a regime where all post-disaster transfers are withheld. I find that RH increased the fraction of initially uninhabitable homes rebuilt within four years of Katrina by four percentage points (from a base of 48%). While RH's structure did explicitly encouraged rebuilding, I find most of the program's impact occurred by relaxing financing constraints for households with strong location attachments but for whom borrowing constraints would have been binding in the absence of grant transfers. The program's impact was most heavily concentrated among households with large uninsured losses and who belonged to the subgroups with the largest barriers to credit. For example, the program increased the rebuilding rate among black households with greater than $75,000 in uninsured damages by 17 percentage points (from a base of 34%).

Finally, I perform a welfare analysis to quantify the moral hazard versus insurance tradeoff associated with the *de facto* social insurance policy of regular post-disaster transfers. In the current political equilibrium, post-disaster transfers are financed out of general revenue and thus provide a net subsidy to locations with above average disaster risk. This policy generates deadweight costs if some households choose to live in a relatively disaster-prone locations only because they are shielded from the full expected cost of that choice. Policy simulations suggest that the flow deadweight loss from this actuarially unfair financing scheme is no more than about 4% of expected expenditures. For comparison, I compute New Orleans homeowners' annual willingness to pay for guarantees of disaster relief packages more generous and less generous than RH in the event of future disasters in New Orleans. I find that households' willingness to pay for a guarantee that RH will be available after future disasters is *more than an order of magnitude larger* than the efficiency loss from the policies' actuarially unfair financing. This result suggests that large reductions to the generosity of disaster relief packages cannot be justified by fears of this form of policy-induced moral hazard alone.

These empirical results are significant contributions. 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. However, evaluations of disaster relief programs are almost entirely missing from the empirical literature in economics.[1] 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 models 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.[2] 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.[3] 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.[4] 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 docu-

[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.

[2] Thom (2010) and Rendon and Cuecuecha (2007) develop models of international migration that allow for asset accumulation, but both directly assume that individuals are unable to borrow.

[3] 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.

[4] See Gregory and Sastry (2014), Groen and Polivka (2010), Zissimopolous and Karoly (2010), Vigdor (2007 and 2008), Paxson and Rouse (2008), and Elliott and Pais (2006).

menting 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

A. 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 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. 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 block grant.

B. 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.[5] Other shortfalls were alleged to have occurred because 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 Louisiana used its federal allocation to create the Louisiana Road Home program (RH),[6] 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 RH disbursed more than nine billion dollars to Louisiana homeowners.

A participating household could accept its RH grant as a rebuilding grant or as a relocation grant. Subject to an upper limit of $150,000, both grant types provided compensation equal to the "value of home damages" minus the value of any insurance payouts already received. There were several important differences between rebuilding and relocation grants. While both provided the same cash payout,[7] relocation grant recipients were required to turn their properties over to a

[5]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.

[6]Specifically, RH 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.

[7]The cash grants for relocating and for rebuilding were the same except for one particular circumstance. All RH grants were initially capped at the pre-Katrina value of a household's home. For households classified as "low

state land trust. For households with partial home damages, this stipulation introduced a sizable opportunity cost to relocating. On the other hand, rebuilding grant recipients were only required to sign covenant agreements to use their grants for rebuilding and to not sell their homes for at least three years.

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 RH 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 RH compensation for any insurance shortfall. The financial incentive to rebuild was largest for households 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 RH options 2 or 3.

RH'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.[8] RH was announced in February of 2006, about six months after Hurricane Katrina, but the median grant payment date among New Orleans participants in RH occurred near the second anniversary of Katrina. Also, many households claimed that their RH 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 RH grant payments, and below I assess the robustness of the paper's findings to the possibility that grant payments were smaller than advertised.

Grant recipients often experienced lengthy delays between initiating their grant applications and receiving a grant. RH was announced in February, 2006, but the median grant payment date

or moderate income," this cap was waved for rebuilding grants (in response to the argument that the provision had disparate impacts by race, because identical homes had different market values in predominantly black versus white neighborhoods) but not for relocation grants.

[8]The application process for a RH 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 RH options, signed a corresponding "covenant," and awaited disbursement of the grant.

occurred after Katrina's second anniversary in 2007. The model explicitly captures the timing of the program's rollout. Despite the program's slow rollout, RH had disbursed nearly ten billion dollars to Louisiana homeowners by Katrina's fifth anniversary.

II. Model

I turn now to a 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.

II.1 Primitives

There are many home-owning households indexed $i=1,...,I$. Time passes in discrete four-month-long periods indexed $t=0,...,T_i,...,T_i+T_R$. Katrina occurs at $t=0$ damaging many households' homes, retirement occurs (for household i) in period T_i, and T_R periods are spent in retirement. Households differ in their housing-related costs, labor market opportunities, levels of attachment to New Orleans, and accesses to credit.

Households make choices each period about where to live, whether to repair or sell their home, and how much to borrow or save. Let $\ell_{it} \in \{1,2,3\}$ denote i's residence location; $\ell_{it}=1$ is i's pre-Katrina home, $\ell_{it}=2$ is elsewhere in New Orleans, and $\ell_{it}=3$ is "away from New Orleans." Let $h_{it} \in \{-1,0,1\}$ denote i's home-ownership state; $h_{it}=0$ indicates that i owns its home but in a damaged state; $h_{it}=1$ indicates that i owns its home in a repaired state; and $h_{it}=-1$ indicates that i has sold its home. Households make choices $d_{it}=[\ell_{it},h_{it}]$ each period until retirement, and choose how much to borrow or save every period. Let a_{it} denote i's financial asset holding at the end of period t.

II.1.1 Monetary Incentives

Housing-Related Costs: Several housing-related costs and prices affect a household's incentive to rebuild: 1) i's remaining mortgage balance when Katrina occurred ($M_i \geq 0$); 2) the market value of i's home if sold privately in a repaired state p_i; 3) the cost of repairing/restoring the house from it's damaged state $(k_i \leq p_i)$; 4) the value of any (non-RH) insurance payments received $(ins_i \leq k_i)$; and 5) possible grant reimbursements through RH.

If household i has yet to rebuild entering period t, the household may repair its home by paying a one-time repair cost k_i at the beginning of the period. Households who rebuild are reimbursed for uninsured damages by a RH (option 1) grant $G_{1i} = \min(\$150{,}000, k_i{-}ins_i)$. Reflecting RH's slow rollout, the cost of repairs that occur before Katrina's second anniversary ($t\!=\!6$) are reimbursed in the first period after Katrina's second anniversary ($t\!=\!7$). Repairs that occur after Katrina's second anniversary are reimbursed at the start of period the repairs occur. RH grants become unavailable after Katrina's fifth anniversary.

For each period that a household resides away from its pre-Katrina home, the household rents accommodations comparable to its pre-Katrina home at a cost of $rent_i = \delta \times \mu_j \times p_i$, where δ is the user cost of housing and μ_j is a market-specific housing price index.[9] If a household still owns its home entering period t, it may sell its home either privately or through RH (option 2). The proceeds from a private sale are p_i if the home is in a repaired state and $p_i - k_i$ if the home is in a damaged state, and the proceeds from selling through RH (option 2) are $G_{2,i}$.

Labor Market Opportunities: Household i faces different wages in New Orleans $\{w^1_{it}\}_t$, and outside of New Orleans $\{w^0_{it}\}_t$. The two vectors of wages differ across households depending on the household heads' pre-Katrina occupations. As discussed further in Section III, households with different occupation mixes experienced significantly different wage shocks in New Orleans relative to region-wide trends in the aftermath of Katrina, which is one important source of identifying variation. Households are assumed to have full information about the time path of wages and the timing of RH's rollout.[10]

II.1.2 Household Preferences

Households derive utility from consumption and location amenities and suffer utility costs if they move or do home repairs. Additionally, each period households receive a set of shocks ϵ_{it} to the payoffs from available choices. These shocks are distributed i.i.d Type I extreme value, with one shock $\epsilon_{it}(d_{it})$ associated with each element $d_{it} = [\ell_{it}, h_{it}]$ of a household's choice set. The period

[9] See the appendix for details on the construction of this price index.

[10] Households were presumably not certain about the details of RH prior to the grant program's announcement (about six months after Katrina) or, following the announcement, when the grants would be disbursed. Modeling uncertainty about RH's details during Katrina's immediate aftermath would be unlikely to affect the model's predictions in a meaningful way, because rebuilding during the first few months after Katrina was nearly impossible. The assumption that households anticipated the significant wait times associated with RH 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.

utility function is,

$$\tilde{u}_{it}(d_{it}|x_{it}) = u_{it}(d_{it}|x_{it}) + \epsilon(d_{it}) \tag{1}$$

$$u_{it}(d_{it}|x_{it}) = \underbrace{\alpha \times \frac{c_t^{1-\omega}}{1-\omega}}_{\text{Consumption Utility}} + \underbrace{b_{\ell(i,t),t} + \eta_i \mathbf{1}(\ell_{it} \in \{1,2\})}_{\text{Amenity Utility}} - \underbrace{\chi_{it}\, \mathbf{1}(\ell_{it} \neq \ell_{it-1})}_{\text{Disutility from Moving}} - \underbrace{\kappa_{it}\, \mathbf{1}(h_{it} > h_{it-1})}_{\text{Disutility from Rebuilding}}$$

The first term gives utility from consumption (c_{it}). The parameter ω is the coefficient of relative risk aversion, and α weights the importance of consumption utility relative to other factors. The terms χ_{it} and κ_{it} are utility costs, above and beyond the financial costs, from moving and doing home repairs respectively. Payoffs from location amenities include a component $b_{\ell(i,t),t}$ that depends on observable household and location characteristics and an idiosyncratic component $\eta_i \sim N(0, \sigma_\eta^2)$ characterizing i's attachment to New Orleans.

The flow payoffs that households receive from location amenities and the utility costs to moving or doing home repairs are allowed to vary across households and over time. The observable component of location amenities is given by,

$$b_{\ell(i,t)t} = \begin{cases} 0 & \text{if } \ell(i,t) \ = \ 3 \text{ (normalization)} \\ z_i'\gamma_1 + \gamma_2 \min(t,15) & \text{if } \ell(i,t) \ = \ 2 \\ \underbrace{z_i'\gamma_1 + \gamma_2 \min(t,15)}_{\text{Payoff to New Orleans}} + \underbrace{z_{\ell(i0)}'\gamma_3 + z_{\ell(i0)}'\gamma_4 \times \min(t,15)}_{\text{Additional Payoff to pre-Katrina Home}} & \text{if } \ell(i,t) \ = \ 1 \end{cases}$$

The first line is a normalization, setting the payoff to residing away from New Orleans to zero. The second line gives the value of living in New Orleans but not in the pre-Katrina home. The specification allows the possibility that households with different backgrounds receive different flow payoffs from residing in New Orleans (γ_1),[11] and that the payoff to residing in New Orleans follows a time trend during the first five years after Katrina (γ_2). The third line gives the payoff to living in the pre-Katrina home. The specification allows the possibility that households from different "types" of neighborhoods received systematically different payoffs to returning to their pre-Katrina home *above and beyond the payoff to returning to New Orleans generally*, both in Katrina's immediate aftermath (γ_3) and over the longer term (γ_4).[12]

[11]In the empirical implementation, the variables included in $z_i'\gamma_1$ are; an intercept, an indicator one that household head is black, an indicator that neither household head was born in Louisiana, an indicator that the household has owned its home for more than 20 years, and an indicator that the household has owned its home for between 10 and 20 years.

[12]In the empirical implementation, the variables included in $z_{\ell(i0)}'\gamma_3$ are; an intercept, an indicator that the pre-Katrina Census block's poverty rate was 10-25%, an indicator that the pre-Katrina Census block's poverty rate was $> 25\%$, an indicator that between 50% and 90% of the block's homes were severely damaged, and an indicator that

The utility cost to repairing one's home is given by,

$$\kappa_{it} \;=\; \kappa_1 \;+\; \kappa_2 1(\text{HomeDestroyed}_i)$$

where the second term allows this utility cost to be different for households whose homes were destroyed by Katrina than for households whose homes required repairs but were not destroyed. The utility cost to moving is given by,

$$\chi_{it} \;=\; \underbrace{\chi_1 \times 1(t=1)}_{\text{Move immediately after Katrina}} \;+\; \underbrace{\chi_2 \times 1(t>1)}_{\text{Later move}} \;+\; \underbrace{\chi_3 1(\ell_{it}=3 \text{ or } \ell_{it-1}=3)}_{\text{Move to or from New Orleans}} \;+\; \underbrace{\chi_4 1(h_{it} > h_{it-1})}_{\text{Move same period as home repairs}}$$

The first term is the utility cost to moving in Katrina's immediate aftermath. The second term is the cost to moving after period 1. The third term allows the possibility that moves to and from New Orleans involve larger utility costs than within-city moves. The last term is an indicator that the household moved immediately after repairing its home, which is essentially an interaction term that allows the utility cost to rebuilding and moving home in the same period to be different than the sum of the two utility costs.

II.1.3 Intertemporal Budget Constraint/Credit Availability

The household intertemporal budget constraint is given by,

$$\begin{aligned}
c_{it} \;=\; & \;\; 1\big(\ell_{it} \in \{1,2\}\big) \times w^1_{it} \;+\; 1\big(\ell_{it}=3\big) \times w^0_i && \Big\}\text{ labor earnings} \\
& - \; 1\big(\ell_{it} \in \{2,3\}\big) \times \text{rent}_{\ell(i,t)} - 1\big(h_{it} \geq 0\big) \times mortgage_{it} && \Big\}\text{ flow housing costs} \\
& - \; 1\big(h_{it} > h_{i,t-1}\big) \times k_i && \\
& + \; 1\big(h_{i7}=1 \;\text{ and }\; t=7\big) \times G_{1i} && \Bigg\}\text{ repair costs/reimbursements} \\
& + \; 1\big(h_{it} > h_{it-1} \;\text{ and }\; t>7\big) \times G_{1i} && \\
& + \; 1\big(h_{it} < h_{it-1}\big) \times \max\Big\{G_{2i}\,,\; p_i - 1\big(h_{it}=0\big) \times k_i\Big\} && \Big\}\text{ home sale proceeds} \\
& + \; 1\big(t > T_i\big) \times SS_t && \Big\}\text{ Social Security annuity} \\
& + \; a_{it-1} \times R_{t-1} \;-\; a_{it} && \Big\}\text{ change in asset holding.}
\end{aligned}$$

$>90\%$ of the block's homes were severely damaged. To capture different rates of infrastructure repair in parts of New Orleans with different rates of damage, the term $z_i'\gamma_4$ includes an indicator that between 50% and 90% of the block's homes were severely damaged, and an indicator that $>90\%$ of the block's homes were severely damaged.

The first line captures labor income, which may differ depending on whether or not the household is living in the New Orleans labor market, where $1(\cdot)$ is the indicator function. The second line captures flow housing costs, which involve a rent payment if the household is living away from it's pre-Katrina home and a mortgage payment if the household still owns its home.[13] The next line captures the one-time repair cost the household incurs if it repairs its home $(h_{it} > h_{it-1})$. The next two lines capture the reimbursement of these costs by RH, reflecting the fact that RH grants were typically paid out more than two years after Katrina. The next line captures the proceeds a household receives if it sells its home $(h_{it} < h_{it-1})$, the larger of the RH option 2 grant the private market price $\max\{G_{2i}\ ;\ p_i - 1(h_{it}=0) \times k_i\}$.[14] The second to last line captures a Social Security retirement annuity the household receives during retirement. Finally, a household may change its asset holding at interest rate R_t.

Central to understanding RH's effects on rebuilding and on welfare is whether or not households had the ability to borrow to finance rebuilding. In settings where a researcher knows *ex ante* that households are unable to borrow, researchers sometimes impose directly that households in a model cannot borrow.[15] Instead, I study a framework that allows the possibility of borrowing constraints, so that households' credit availability can be estimated from observed choices. As in Cameron and Taber (2004), I model a borrowing constraint as an effective interest rate when borrowing that is higher than the interest when saving.[16] The interest rate faced by household i is given by,

$$R_t = \begin{cases} \dfrac{1}{\beta} & \text{if } a_t \geq 0 \\ \\ \dfrac{1}{\beta} \times \exp(z_i'\rho) & \text{if } a_t < 0 \end{cases} \tag{2}$$

where $\rho \geq 0$ is a set of parameters to be estimated. If ρ is a vector of zeros, all households are free to borrow. If particular elements of ρ are sufficiently large, households with the associated values of z_i are not able to borrow to finance investments.[17]

[13] Households are assumed to own their home free and clear 30 years the home's purchase. From that point forward, $mortgage_{it}=0$.

[14] The market value of i's home if sold privately *before* being repaired is assumed to be $p_i - k_i$.

[15] See, for example, Rosenzweig and Wolpin (1993) and French and Bailey (2011).

[16] Other studies that seek to infer the extent of credit constraints in the context of empirical choice models include Evans and Jovanovic (1989), Cameron and Heckman (2001), and Keane and Wolpin (2001).

[17] In the empirical implementation, the elements of z_i included in the borrowing interest rate equation $(z_i'\rho)$ are; an indicator one that household head is black, an indicator that neither household head has a bachelor's degree, and indicator that pre-Katrina household income was below \$20,000, and an indicator that pre-Katrina household income was between \$20,000 and \$40,000.

Household Problem

The household's decision problem is naturally expressed recursively as a dynamic programming problem. Let $x_{it} = [\ell_{it-1}, h_{it-1}, a_{it-1}, \eta_i, z_i]$ denote a vector of state variables that includes; i's location (ℓ_{it-1}), home status (h_{it-1}) and asset holding (a_{it-1}) at the end of the previous period, i's permanent idiosyncratic preference for New Orleans (η_i), and permanent background variables (z_i).

By the principle of optimality, the expected discounted lifetime utility following from a given state x_{it} may be expressed with the Bellman equation,

$$V_t(x_{it}) = \max_{d_{it}} \Big\{ \max_{a_{it+1}} \tilde{u}_t\Big(d_{it}, a_{it}\Big|x_{it}\Big) + \ \beta\, \overline{V}_{t+1}\Big(\Gamma\Big(x_{it}, d_{it}, a_{it}\Big)\Big) \Big\} \tag{3}$$

$$\text{where,} \quad \overline{V}_{t+1}(x_{it+1}) = \mathrm{E}_\epsilon V_{t+1}(x_{it+1})$$

$$\text{and,} \quad \Gamma\Big(\underbrace{[\ell_{it-1}, h_{it-1}, a_{it-1}, \eta_i, z_i]}_{x_{it}}, \underbrace{[\ell_{it}, h_{it}]}_{d_{it}}, a_{it}\Big) = [\ell_{it}, h_{it}, a_{it}, \eta_i, z_i]$$

The household considers both the current period payoff to its choice as well as the expected continuation value that is associated. The law of motion $\Gamma(.)$ simply states that the location, housing state, and asset holding chosen in one period (ℓ_{it}, h_{it}, a_{it}) are state variables in the next period.

The value function can be solved with backwards induction, starting from the household's retirement age. 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 in earlier periods (McFadden, 1974; Rust, 1987),

$$\overline{V}_{it}(x_{it}) = \ln\Big[\sum_{d_{it}} \exp\Big[u_t\Big(d_{it}, a^*_{t+1}(d_{it}|x_{it})\Big|x_{it}\Big) + \ \beta\, \overline{V}_{t+1}\Big(\Gamma\Big(x_{it}, d_{it}, a^*_{t+1}(d_{it}|x_{it})\Big)\Big)\Big]\Big] + \gamma \tag{4}$$

where $\gamma \approx 0.577$ is Euler's constant, and $a^*_t(d_{it}|x_{it})$ is the optimal asset/savings decision conditional on the household's discrete choice d_{it}. Note that because the choice specific ϵ shocks are specific to the household's discrete choice, the optimal asset accumulation policy is deterministic,

$$a^*_t(d_{it}|x_{it}) = \arg\max_{a_{it}} u_t\Big(d_{it}, a_{it}\Big|x_{it}\Big) + \ \beta\, \overline{V}_{t+1}\Big(\Gamma\Big(x_{it}, d_{it}, a_{it}\Big)\Big) \tag{5}$$

This feature of the model is also convenient for the estimation of the model given the structure of available data. While auxiliary data is available on the distribution of households' non-housing assets *at the time Katrina occurred*, panel data is not available on households' asset holding in the years after Katrina. Nonetheless, it is possible to construct the likelihood of the observed discrete choices d_{it} for a given model parameterization θ. After calculating the optimal asset accumulation rule $a_t^*(.)$ given θ in a first stage, the probability of a particular discrete choice takes the logit form,

$$\mathrm{P}(d_{it}|x_{it};\theta) = \frac{\exp\left[u_t\Big(d_{it}, a_t^*(d_{it}|x_{it})\Big|x_{it};\theta\Big) + \beta\,\overline{V}_{t+1}\Big(\Gamma\Big(x_{it}, d_{it}, a_t^*(d_{it}|x_{it})\Big);\theta\Big)\right]}{\sum_{d'_{it}} \exp\left[u_t\Big(d'_{it}, a_t^*(d_{it}|x_{it})\Big|x_{it};\theta\Big) + \beta\,\overline{V}_{t+1}\Big(\Gamma\Big(x_{it}, d'_{it}, a_t^*(d'_{it}|x_{it})\Big);\theta\Big)\right]} \tag{6}$$

As explained further in Section IV, these expressions can be used to reduce the problem that panel asset data is missing entirely into a problem that *pre-Katrina-assets*-data is missing, a problem which can be solved by integrating a conditional (on pre-Katrina assets) likelihood function with respect to the distribution of pre-Katrina assets conditional on households' observable characteristics.

III. Data

Measuring the long-term resettlement choices of the victims of severe natural disasters is not feasible with many standard data sources. In large cross-sectional survey datasets (e.g. the Census) fielded years after a disaster, it is generally not possible to identify who in the sample lived in a disaster-effected neighborhood at the time the disaster occurred. In long-term panel studies like the PSID or NLSY, sample sizes are usually far too small to draw any meaningful conclusions about a subpopulation from any small geographic area. I address this measurement challenge by combining information from an ambitious survey effort that, four years after Katrina, located and interviewed a population-representative sample of households *who lived in New Orleans right before Hurricane Katrina*, and annual measures from the Orleans Parish Assessor's Office on the state of those same households' New Orleans homes.

The Displaced New Orleans Residents Survey (DNORS) was fielded by RAND and the Survey Research Center at the University of Michigan. Survey staff randomly selected dwellings from the universe of dwellings in New Orleans prior to Katrina. 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. I draw information from the DNORS data (RAND, 2010) on households' demographic background traits z_i, insurance coverage ins_i and other variables entering the household's budget constraint, and post-Katrina location histories ℓ_{it} for $t = 1, ..., 12$ – i.e. during the first four years after Katrina.

The Orleans Parish Assessor's Office administrative property database (OPAO data) contains annual appraisals of the land value and improvement value (the value of structures) for every home in New Orleans and a record of every New Orleans home sale. I merge these OPAO records to the DNORS survey data by street address.[18] Then using the information from the OPAO data, I construct measures of the timing of all home sales and home repairs by DNORS respondents.[19] I use these measures to compute the home state variable h_{it} (indicating whether each home has been sold $h_{it} = -1$, was still owned but in a damaged state $h_{it} = 0$, or was still owned in a repaired state $h_{it} = 1$), again for $t = 1, ..., 12$.

I restrict the merged DNORS and OPAO data to the segment of the population targeted by the Road Home program, households who owned and lived in a single-family homes when Katrina occurred. 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.[20] 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 RH. Only about 10% of participants selected option 2 or 3. Consistent with the program's incentive structure, program participants with less comprehensive

[18] During the merge, I use DNORS respondents' pre-Katrina addresses.

[19] Appendix I provides details on this procedure.

[20] 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.

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 RH option 2 or 3 relocation grant. Households were more likely to sell privately than accept a RH 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 plots the annual hazard of a still-damaged home being repaired by the original owner during the first, second, third, and fourth years. Black households, households without a bachelors degree, and household with annual pre-Katrina income below $40,000 all exhibited significantly lower repair hazards in the first and second years after Katrina and a larger spike in the repair hazard after Katrina's third anniversary than non-black, college-educated households with pre-Katrina annual income above $40,000. These patterns are consistent with this paper's estimates that groups with lower socio-economic status faced binding borrowing constraints that prevented them from purchasing home repairs before the disbursal of RH grants during the third year after Katrina.

Figure 3 ranks two-digit occupations based on changes in the occupations' relative New Orleans wages from 2005 to 2008. 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. Figure 4 shows that workers in pre-Katrina occupations that experienced high relative wages in New Orleans after Katrina tended to return at higher rates. The y-axis in each panel plots deviations from the average likelihood of residing in New Orleans on the second and fourth anniversaries of Katrina by pre-Katrina occupation affiliation after controlling for a broad set of labor supply (to New Orleans) shifters.[21] The x-axis plots the composition-adjusted log-wage pre-

[21] Specifically, the graphs plot the coefficients on occupation dummies from linear probability models for residing in New Orleans. The control variables in these regressions are an indicator that a worker is black, an indicator that

mium in post-Katrina New Orleans, relative to other Southern Metro areas, for each occupation. A 10 percentage point higher prevailing relative wage in a worker's pre-Katrina occupation was associated with a 3.6 percentage point higher likelihood of residing in New Orleans on the second anniversary of Katrina and a 2.8 percentage point higher likelihood of residing in New Orleans on Katrina's fourth anniversary.

IV. Estimation

I next turn to the parameterization and estimation of the model. A number of the model variables are estimated outside of the model directly from data; including the wage offers in New Orleans $\{w^1_{it}\}_t$ and away from New Orleans $\{w^0_{it}\}_t$, and the private home sale offer price p_i. Appendix I describes these procedures in detail. The remaining parameters are estimated by maximum likelihood within the model.

IV.1 Parameters Estimated Within the Model

I estimate the parameters $\theta = [\alpha, \gamma, \kappa, \chi, \sigma^2_\eta, \rho]$ by maximum likelihood. Recall that the parameter α weights consumption utility relative to other factors, γ characterizes the impact of observable location traits on flow location-amenity payoffs, κ and χ characterize the disutility of doing home repairs and moving, σ^2 is the variance of unobserved heterogeneity in households' attachment to New Orleans, and ρ characterizes the effective interest rate at which households can borrow. I do not attempt to estimate the discount rate or the coefficient of risk aversion, and instead calibrate $\beta = 0.95$ annually (Kennan and Walker 2011) and $\omega = 4.17$ (Barsky et al. 1997).

Evaluating the likelihood function requires integrating over two state variables that are not observed in the data. The unobservable component of households' location preferences η_i is not measured by definition. A larger obstacle to estimation is that the DNORS and OPAO data on households' resettlement choices do not contain information on households' asset holdings a_{it}. I circumvent this obstacle by combining information from an auxiliary data source on the *distribution* of households' asset holdings at the time Hurricane Katrina occurred and the structural model's prediction on households' optimal discrete-choice-specific asset accumulation choices (Equation 5).

Conditioning on a particular initial asset holding a_0 and a particular location-attachment η, the

the worker was born in Louisiana, indicators for the worker's home purchase year categories, the 2000 poverty rate in the worker's pre-Katrina Census tract, the fraction of the pre-Katrina block's homes severely damaged by Katrina, a bachelor's degree indicator, the log of the worker's household's pre-Katrina annual income, and the log of storm-related property damages if positive.

likelihood of a single household's panel of discrete choices is,

$$l_i\Big(\theta\Big|\{d_{it}\}_{t=1}^T, a_0, \eta; \theta\Big) = \mathrm{P}\Big(d_{i1}\Big|x_{i1} = [\ell_{i0}, h_{i0}, a_0, \eta, z_i]; \theta\Big)\times \quad (7)$$
$$\Pi_{t=2}^{12}\mathrm{P}\Big(d_{it}\Big|x_{it} = \Gamma\Big(x_{it-1}, d_{it-1}, a^*_{t-1}(d_{it-1}|x_{it-1})\Big); \theta\Big)$$

where the terms $P(d_{it}|x_{it};\theta)$ are from Equation (6), the asset accumulation rules $a^*_t(.|.)$ comes from Equation (5). Integrating this conditional likelihood function with respect to the distribution of initial asset holdings $F(a_0)$ and the distribution of the unobserved heterogeneity term $G(\eta_i)$ yields the unconditional likelihood contribution,

$$l_i\Big(\theta\Big|\{d_{it}\}_{t=1}^T\Big) = \int\int l_i\Big(\theta\Big|\{d_{it}\}_{t=1}^T, a_0, \eta; \theta\Big)\, dF_{a_0}(a_0|z_i)\, dG_\eta(\eta; \theta) \quad (8)$$

In practice, I compute a discrete approximation of this integral,

$$l_i\Big(\theta\Big|\{d_{it}\}_{t=1}^T\Big) \approx \frac{1}{10}\sum_{F_a=5}^{95}\frac{1}{5}\sum_{G_\eta=10}^{90} l_i\Big(\theta\Big|\{d_{it}\}_{t=1}^T, F_{a_0}^{-1}(F_a|z_i), G_\eta^{-1}(G_\eta)\Big) \quad (9)$$

The ten support points used to approximate $F(.|z_i)$ are the the 5th, 15th, ..., 95th percentiles of the distribution of pre-Katrina assets conditional on z_i. See Appendix I for a description of the method used to estimate the conditional distribution $F(.|z_i)$ of asset holdings using data from the PSID, matching on observable household characteristics. The five support points used to approximate $G(.)$ are the 10th, 30th, 50th, 70th and 90th percentiles of $N(0,\sigma_\eta^2)$.[22]

The MLE estimate of θ is the paramater vector that maximizes the full-sample log-likelihood,

$$L\Big(\theta\Big|\{\{d_{it}\}_{i=1}^T\}_{i=1}^I\Big) = \sum_{i=1}^I \ln\Big(\, l_i\Big(\theta\;\Big|\;\{d_{it}\}_{t=1}^T\Big)\Big) \quad (10)$$

I compute this estimate using an algorithm that iterates between an "inner loop" that computes the model's solution numerically for any given θ to obtain the optimal asset rule and conditional choice probabilities with Equations (5) and (6), and an "outer loop" that searches the parameter space for the likelihood maximizing parameter vector $\widehat{\theta}$.

[22] 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.

IV.2. 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 RH's provisions (as discussed earlier) 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 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 $b_{\ell=1,t}$ is positive relative to $b_{\ell=3,t} \equiv 0$. The flow benefit to residing "elsewhere in New Orleans" $b_{\ell=2,t}$ 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 RH grants were disbursed. 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). RH grant recipients typically experienced lengthy delays before their grants were disbursed. If the rebuilding hazard of a particular demographic subgroup jumped at the time that RH grants were disbursed 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.[23]

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

[23]RH's rules explicitly allowed households who had access to loans to purchase repairs with their loan disbursement before RH grants were paid and use the RH grant to repay the rebuilding loan.

sufficient to separately identify the transition cost and the difference between the flow payoffs to x_1 and x_2.

V. Parameter Estimates and Model Fit

Table 4 presents estimates of the model's structural parameters.[24] The top portion of the table presents estimates of the parameters characterizing the flow benefit from living in New Orleans $b_{\ell=2,t}$ relative to living away from New Orleans $b_{\ell=3,t} \equiv 0$, and the additional benefit to the pre-Katrina home $[b_{\ell=1,t} - b_{\ell=2,t}]$. The estimates find that all else equal 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. The extent of preference heterogeneity within groups is significantly larger than the average difference in preferences between demographic groups. The estimated standard deviation of η, the term capturing persistent unobserved heterogeneity in the preference for living in New Orleans, is roughly four times the average difference in preferences between blacks and non-blacks and more than twice the difference between neighborhoods with high versus low poverty rates in the 2000 decennial Census. This pattern implies that a significant fraction of households are inframarginal with respect to their preferred location, and is consistent with reduced form results showing that households facing significantly different financial incentives returned at similar rates.[25]

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 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 estimated baseline moving cost of 3.4 utils and suffering a greater than 90% one-period reduction

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

[25] Fu and Gregory (2016), using data on the full universe of New Orleans homeowners linked to administrative data from the Road Home program, exploit a discontinuity in the RH grant formula for defining homes as repairable or destroyed to identify causal spillover effects from one household rebuilding on the likelihood that same-block neighbors rebuild. Their first stage finds rebuilding elasticities that are comparably small to those found in this paper.

in non-housing consumption. As noted by Kennan and Walker (2011), who estimate a related dynamic migration model, the net utility cost to moving $(\chi - \epsilon_t)$ is typically close to zero (or even negative) among households who choose to move in a particular period, because people 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. The estimated borrowing interest rates for black households, households without a college education, and households with low pre-Katrina income are so far above the risk free rate that they are nearly equivalent to the complete unavailability of rebuilding loans to these households. These estimates are consistent with the fact that the federally-subsidized SBA Disaster Loan program, with lending standards more lenient than private banks', rejected a large majority of applicants from the Gulf Coast in the aftermath of Katrina (Eaton and Nixon, 2005).

Figure 5 assesses the model's in-sample fit 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. 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. Counterfactual Policy Experiments

I next describe the results of partial equilibrium policy simulation experiments designed to examine the short-run and long-run effects of guaranteed transfers to New Orleans homeowners when disasters occur. There are drawbacks to using partial equilibrium models to study large interventions with the potential to change local prices. There are also important advantages to using a partial equilibrium approach, in particular the fact that the framework 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 accurately predicting resettlement choices in counterfactual scenarios without rebuilding grants. Also, the partial equilibrium approach is sufficient to compute an upper bound on the equilibrium and welfare loss associated with the distortionary financing of disaster relief expenditures. That is because constant-price policy simulations will *overstate* the quantity (population) response to location-specific subsidies if housing supply and labor demand are actually finitely elastic, since households' behavioral responses would be dampened if the subsidy's incidence falls 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 aggregating across simulations, I then weight each simulated panel by $w_i(a_{i0}, \eta) = \left(\frac{1}{50}\right) \times l(\theta|\{d_{it}\}_{t=1}^{T}, a_0, \eta) / \, l(\theta|\{d_{it}\}_{t=1}^{T})$, the *ex post* probability of each particular particular $a_{i0} \times \eta$ combination given the household's actual choice sequence. I first characterize RH's impact on households' rebuilding choices. I then perform a welfare analysis comparing the insurance benefits from disaster relief to the excess burden of the programs' spatially biased financing.

VI.1. The Impact of the Road Home Grant Program

I first present the results of simulation experiments evaluating the impact of RH 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 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 RH 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).

RH's impact differed substantially across socioeconomic subgroups. The program's impact was slightly larger among households with pre-Katrina income below \$40,000 (4.1 percentage point increase) than among those with pre-Katrina income above \$40,000 (3.8 percentage point increase). Differences in the program's impacts by race were larger than differences by income. RH 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. RH 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 compares RH's impact on rebuilding rates to the impact of two alternative disaster relief policies. The first counterfactual policy regime involves providing **Universal Disaster Loans** in place of RH grants. Specifically, the policy involves the following provisions:

- No RH grants are paid out.
- The credit market is unchanged from the actual post-Katrina credit market for the first two years after Katrina.
- Beginning on Katrina's second anniversary (to mimic the timing of RH's "treatment") eligibility for the SBA disaster loans program is expanded to all households. Specifically, I set each household's borrowing interest rates to the household's estimated borrowing rate during the first two years after Katrina and set all borrowing rates to the risk free rate $1+r_B = 1/\beta$ after Katrina's second anniversary.

The simulation experiments find that this universal loan program generates an impact on the overall rebuilding rate about three fourths the size of RH's impact. This result suggests that the main mechanism driving RH's impact was the relaxing of financing constraints for households who preferred to rebuild, even without RH's net subsidy for rebuilding, if the rebuilding costs could be smoothed over time. 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: among black households with uninsured losses above $75,000, the loan program's impact on the rebuilding rate is about 85% the size of RH's impact. This finding suggests that a large component of the welfare benefit from post-disaster transfers occurs by allowing households with strong location preferences to finance their preferred resettlement choices.

The second counterfactual policy regime is a **Quickly Rolled-out Road Home** program. Specifically, the policy involves the following provisions:

- RH option 1 rebuilding grants and RH option 2 relocation grants are available immediately after Katrina.
- All other RH provisions are unchanged (i.e. option 1 grant recipients must use the grant to rebuild and must reside in the rebuilt home for at least three years).

Many stories of hardship associated with the slow process of rebuilding in New Orleans appeared in the press during the first two years after Katrina. The simulation experiments finds that this immediately rolled-out grant program generates a larger and more immediate impact and a larger impact on rebuilding rates (6.6 percentage points versus 4.0 percentage points) than the actual

Road Home program, which allowed nearly two years to pass before the payment of most grants. I quantify the welfare consequences of this accelerated rebuilding below.

VI.2. The Insurance Value of Guaranteed Ex-Post Bailouts

The historical record suggests that flooding risks are uninsurable in purely private markets. The high spatial correlation of claims makes it difficult for even large companies to remain liquid in the event of a severe flood. Private markets for flood insurance emerged in both the 1890s and 1920s, but nearly all companies insuring against flood damage exited that market after a severe flood of the Mississippi River in 1927, and nearly all private homeowners insurance policies have excluded flood coverage since the 1927 Mississippi River flood.[26] In the later half of the 20th century, the federal government has stepped in, providing both explicit flood insurance through a National Flood Insurance Program (NFIP) and implicit insurance through regular transfers to partially offset uninsured damages after severe disasters.

In standard models of the optimal provision of social insurance, the first best solution – when there is no moral hazard problem arising from asymmetric information – is to provide full insurance, financed with taxes that are actuarially fair to each individual given the individual's private risk-mitigation choices. For example, the optimal replacement rate for unemployment insurance is 100% if it was possible to levy taxes conditioned on individuals' job search intensities (Bailey 1978, Chetty 2006). The primary factor influencing a particular household's risk of experiencing a natural disaster is the household's residence location choice. Viewed as a social insurance policy, the first best solution to optimally structuring disaster relief would thus resemble mandatory publicly provided insurance coverage. The program would provide full compensation for losses when disasters strike, and would be financed by a system of taxes that reflect the disaster risk at each household's residence location.

In practice, disaster relief packages, though generous in recent decades, do not provide full compensation to all victims. And in the current political equilibrium, *ad hoc* disaster relief expenditures are financed out of general revenue and thus provide a net subsidy to locations with above average disaster risk. In a final exercise based on the New Orleans disaster relief case study studied in this paper, I use the estimated model to calculate the welfare effects of providing more or less generous disaster relief packages in the event of disasters in New Orleans, and I quantify the efficiency loss associated with the present actuarially unfair financing of disaster relief to New Orleans.

I calculate the welfare effects of committing to each of several alternative disaster relief packages by aggregating individual households' equivalent variations, or willingness to pay to avert

[26] See Moss (2002) for a detailed history of private and public provision of flood insurance in the United States.

particular policy changes. Letting p denote the annual probability of a disaster occurring, the equivalent variation EV_i is defined implicitly for each household and each combination of the unobserved states, initial assets A_{i0} and permanent location preference η, by the equality,

$$\begin{aligned} p \quad & \overline{V}_0(x_{i0}, a_{i0} - \mathbf{EV}_i(a_{i0}, \eta), z_i, \eta | d_{i0} = 1, \textbf{Policy=\textit{``transfers''}}) \; + \\ (1-p)\, & \overline{V}_0(x_{i0}, A_{i0} - \mathbf{EV}_i(a_{i0}, \eta), z_i, \eta | d_{i0} = 0, \textbf{Policy=\textit{``transfers''}}) \\ & \qquad = \quad p \quad \overline{V}_0(x_{i0}, a_{i0}, z_i, \eta | d_{i0} = 1, \textbf{Policy=\textit{``no transfers''}}) \; + \\ & \qquad\quad (1-p)\, \overline{V}_0(x_{i0}, a_{i0}, z_i, \eta | d_{i0} = 0, \textbf{Policy=\textit{``no transfers''}}) \end{aligned}$$

The left hand side gives the expected value of discounted future utility in a policy regime where RH is implemented in the event of a disaster ($d_{i0} = 1$). The right hand side gives the expected value of discounted future utility in a policy regime where no grants are provided in the event of a disaster. I set the annual disaster hazard to $p = 1/30$.[27] I compute aggregate willingness to pay by summing these measures for all of the households in my sample with Katrina damaged homes and then scaling up the result to provide a population-level estimate,[28]

$$EV = \underbrace{\left(\frac{\text{Grants to DNORS sample}}{\text{Tot. Grants to NOLA}} \right)}_{\text{Scale up from DNORS to full population}} \times \sum_{i \in Damaged} \underbrace{\left(\sum_{p_a=5}^{95} \sum_{p_\eta=10}^{90} w_i(a_{i0}, \eta)\, \mathbf{EV}_i(a_{i0} = F_{a_0}^{i-1}, \eta = G_\eta^{i-1}) \right)}_{\text{Household i's predicted willingness to pay}}$$

Panel A of Table 7 presents the results of these calculations. The first row shows that the New Orleans population's aggregate willingness to pay annually for a guarantee of RH in the event of future disasters in New Orleans is \$338.1M per year, while the policy's expected cost is \$142M per year ($\frac{1}{30} \times$\$4.26B).[29] Thus, as an expenditure policy in isolation, a guarantee that RH grants will be paid in the event of a disaster yields an expected surplus of \$196.1M per year. There are two channels that can account for this surplus; (i) insurance of households' consumption streams against a wealth shock, and (ii) allowing otherwise borrowing constrained households with a strong location attachment to finance rebuilding.

The second row of Panel A isolates the pure consumption-insurance component of this surplus. Specifically, I compute households' willingness to pay annually for a guarantee of RH grants in the event of future disasters in New Orleans, if the candidate alternative policy provides universal disaster loans. Under this candidate alternative policy, all households – even those previously

[27] Assuming a lower disaster hazard yields similar qualitative results, but generates a value for the distortion caused by actuarially unfair financing of disaster policy that is even smaller as a fraction of willingness to pay for a guarantee of relief in the event of a disaster.

[28] Again, the weights $w_i(a_{i0}, \eta)$ provide the *ex post* probability of each particular particular $a_{i0} \times \eta$ combination given a household's observed choices.

[29] RH grants paid to New Orleans homeowners totaled \$4.26B, roughly half of total statewide cost of the program

credit-constrained – are allowed to borrow at the risk-free rate beginning on Katrina's second anniversary (mimicking the timing of RH's rollout). The New Orleans population's aggregate willingness to pay annually for a guarantee of RH in the event of future disasters in New Orleans in this case is \$224.6M (annual surplus of \$224.6M-\$142.0M=\$82.6M). This pattern implies that just under half of the surplus associated with a guarantee of post-disaster transfers is attributable to the insurance of consumption, and just above half of the surplus occurs by ensuring that households with strong location attachments and who are otherwise financing-constrained can rebuild/resettle in their preferred location.

The third row of Panel A reports households willingness to pay for a guarantee that RH will be rolled out more quickly after future disasters. The New Orleans population's aggregate willingness to pay annually for a guarantee of an immediate rollout of these disaster grants after future disasters is \$358.5M, on the same order as households' willingness to pay for the actual RH program. Because many households strictly prefer to rebuild but faced binding credit constraints, an immediately rolled-out version of the program generates significantly larger welfare improvements than the actual RH program. Administrators from the RH program cited worries about fraud as one important explanation for the deliberate pace of grant payments. While it is possible that the program's slow rollout prevented fraudulent grant payments, the slow rollout also imposed significant costs on non-fraudulent grant recipients.

VI.3. The Efficiency Loss from Guaranteed Ex-Post Bailouts

Although guaranteed post-disaster expenditures appear, in isolation, to be significantly welfare improving, committing to less generous relief policies may still be optimal if the manner in which these expenditures are financed generates sufficiently large distortions. This section provides a back-of-the-envelope calculation of the efficiency loss from these distortions based on the estimated model to understand how elastic location choices are with respect to financial incentives.

The non-distortionary, optimal policy to finance guaranteed post-disaster transfers would be one that imposes on each household the location-specific expected cost of any future transfers – that is, if p is the per-period hazard of a devastating disaster, an *ad valorem* property sur-tax $\tau^* = p$ each period on the home's replacement cost. In practice, *ad hoc* disaster relief expenditures in the U.S. are typically financed from general revenue (i.e. $\tau = 0$). This policy generates an excess burden relative to the optimal $\tau^* = p$ policy, because households who marginally prefer to live away from New Orleans under the optimal policy and who marginally prefer to live in New Orleans with the effective subsidy in place have a first order effect on the expected level of future disaster-relief spending but receive no first order increase in utility from changing locations. Letting $\psi = d\ln(\text{NOLA Pop.})/d\tau$ denote the compensated semi-elasticity of the supply of residents to New Orleans with respect to τ, the (flow) excess burden associated with this deviation from optimal financing can be quantified using the standard Harberger triangle approximation (Harberger, 1964),[30]

$$EB = \left(\frac{1}{2}\right) \times [\text{Tax Base}] \times \psi \times |\tau - \tau^*|^2 \tag{11}$$

or equivalently,

$$EB = \Delta\text{Revenue} \times \left(\frac{1}{2}\right) \times \psi \times |\tau - \tau^*| \tag{12}$$

Panel B of Table 7 presents estimates of the excess burden from spatially-biased financing of disaster relief computed in this manner. The total cost of RH grants to New Orleans homeowners after Hurricane Katrina was \$4.26B, so, maintaining the assumption that $p = 1/30$, the annual revenue required to fund a guarantee of RH relief in the event of future disasters is $\frac{1}{30}\times$ \$4.26B = \$142M. The deviation from optimal policy is $|\tau - \tau^*| = |0 - p| = \frac{1}{30}$. Using the estimated model to simulate the near steady-state location distribution of the pre-Katrina population of New Orleans 10 years after Katrina with and without a property surtax in place, I compute a population semi-elasticity ψ of 0.43. Plugging these values into equation (12) yields a flow excess burden loss of about \$1 million per year, a figure that is more than an order of magnitude smaller than the expected welfare improvement caused by a guarantee of post-disaster transfers. This result suggests that even if it is not politically feasible to finance disaster relief with actuarially fair property taxes, the efficiency loss caused by disaster policy distorting *ex ante* location choices is a weak rationale for committing to less generous post-disaster expenditures.

Performing this excess burden calculation using the location semi-elasticity ψ of all New Orleans homeowners during the first decade after Katrina is likely to understate the long-run distortion associated with the spatially biased financing, because location choices are not equally elastic over the life-cycle. It is well-known that location choices are more elastic among young people due to weaker location ties and a longer horizon over which the benefits of migration can accrue (Greenwood, 1997). Indeed my simulations find that ψ=1.69 among households age 35 or less. Similarly, 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 average home values are 2.5 times annual income, imply a semi-elasticity ψ between 1.25 and 2. To compute a more conservative estimate of the flow excess burden likely to occur over the long run, I repeat the excess burden calculation using the high-end estimate $\psi = 2$,

[30]This "shape" of the Harberger triangle follows from the assumption that labor demand and housing supply are perfectly elastic. If labor demand and/or housing supply are finitely elastic, this formula yields an upper bound on the excess burden.

yield an estimate of \$4.7M per year. While larger than the baseline excess burden estimate, this number is still more than an order of magnitude smaller than the welfare improvement caused by a guarantee of post-disaster transfers, and the qualitative conclusion stands. This back-of-the-envelope calculation suggests that the efficiency loss caused by disaster policy distorting *ex ante* location choices is a weak rationale for committing to less generous post-disaster expenditures.

VIII. Conclusion

This paper performs a first of its kind impact evaluation of a large scale U.S. disaster-relief program. I find that the Louisiana Road Home grant program increased the aggregate rebuilding rate in New Orleans by Katrina's fourth anniversary by about four percentage points (from a base of about half), while generating significantly larger rebuilding rate impacts among subgroups with large uninsured losses and who faced restricted access to rebuilding loans (for example, a seventeen percentage point impact among black households with >\$75,000 in uninsured damages). The main mechanism driving RH's impact was the relaxing of financing constraints for households who preferred to rebuild, even without the RH program's net subsidy for rebuilding, if the rebuilding costs could be spread out over time.

A welfare analysis finds that the actuarially unfair financing of disaster relief – drawing funds from general revenue instead of from taxes that reflect locations' disaster risks – generates a deadweight loss of no more than four percent of expected annual expenditures on disaster relief. This efficiency loss is at least an order of magnitude smaller than my estimate of households' willingness to pay for a guarantee of transfers similar to RH grants in the event of future disasters. While these results seem favorable to the program, it should be noted that RH was far from an optimal policy from a welfare standpoint. For instance, an otherwise identical program rolled out more quickly would have generated a substantially larger welfare improvement at a similar total cost. The results do cast doubt on the view that moral hazard with respect to location choices is the most likely source of welfare losses from disaster-relief policies.

Important extensions to this paper will perform similar evaluations of other disaster relief programs. The finding 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.

Another important extension to this paper will study the general equilibrium effects of disaster relief policies. The partial equilibrium framework used in this paper is 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
Census block group: year-2000 poverty rate	
<10%	21
10% - 25%	46
> 25%	33
Observations	560

Note: This table shows the distribution of household background characteristics in the main estimation sample. The sample consists of households who owned single-family homes in New Orleans (either free-and-clear or with a mortgage) when Hurricane Katrina struck. Most variables are from the Displaced New Orleans Residents Survey (DNORS), a RAND survey conducted about four years after Katrina with a sample representative of the pre-Katrina New Orleans population (irrespective of households' post-Katrina resettlement locations). Home purchase information is from the linked Orleans Parish Assessor's Office property records of the DNORS respondents. The poverty rate categories are based on the 2000 decennial Census poverty rates of households' pre-Katrina (2005) Census blocks. † Household age is defined to be the age of the male household head if present and the age of the female head otherwise.

TABLE 2. STORM DAMAGES AND FINANCIAL RESOURCES AVAILABLE FOR REPAIRS

	All Homeowners (N=560)					
		Pre-Katrina HH Income			Race	
	All	<$20k	$20-40k	>$40k	Black	Nonblack
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 livable	31	26	19	36	13	53
Unlivable	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	Black	Nonblack
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: This table describes the distribution in the main estimation sample of Katrina-related flood damage and the distribution of financial resources available to households for rebuilding. The sample consists of households who owned single-family homes in New Orleans (either free-and-clear or with a mortgage) at the time of Katrina. The sample frame and reports of home damage and insurance coverage come from the Displaced New Orleans Residents Survey (DNORS), a RAND survey conducted about four years after Katrina with a sample representative of the pre-Katrina New Orleans population (irrespective of households' post-Katrina resettlement locations). Flood depth measures are from satellite images, compiled and disseminated by the Federal Emergency Management Agency (FEMA), linked at the Census block level to DNORS respondents' home locations. Changes in appraised property values are from the linked Orleans Parish Assessor's Office property records of DNORS respondents. Repair costs are computed based on changes in appraised property values pre-to-post Katrina combined with DNORS information on property damage (see the appendix for details). Conditional liquid asset distributions are imputed at the DNORS household level using asset data from the 2005 PSID, and adjusting in a flexible manner for region, homeownership status, urban status, and a detailed set of household characteristics (see the appendix for details).

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 uninhabitable	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 shows take-up rates in the Louisiana Road Home grant program among New Orleans homeowners whose homes were severely damaged by Hurricane Katrina. The program participation data are from the administrative records of the Louisiana Road Home program linked to this study's estimation sample of respondents to the Displaced New Orleans Residents Survey (DNORS), a RAND survey conducted about four years after Katrina with a sample representative of the pre-Katrina New Orleans population (irrespective of post-Katrina resettlement locations). Home sales information comes from the linked Orleans Parish Assessor's Office property records of DNORS respondents. The Road Home program offered three benefits packages known as option 1 (a grant for rebuilding), option 2 (a grant for purchasing another home in Louisiana), and option 3 (a grant for relocating with no location or home-purchase requirements). Option 1 "rebuilding grants" provided cash equal to the estimated value of uninsured property damages (capped at $150,000) and required the recipient to repair and reside in the pre-Katrina home for three years. Option 2 "relocation grants" provided the same cash payment as option 1 (the estimated value of damages less any prior insurance payouts) but required recipients to turn their property over to a public land trust (with no additional compensation for the property's as-is value) and to purchase another home in Louisiana within three years. Option 3 "relocation grants" a provided 40% smaller payment than option 2 but imposed no location or home-purchase requirement. About 3/4 of New Orleans homeowners with severely damaged homes accepted a Road Home grant. Consistent with the program's incentive structure (discussed in more detail in the text), households were more likely to sell their home privately than accept a "relocation grant" when damages were relatively minor, in which case the home maintained a significant as-is value, or when damages were mostly insured, in which case the relocation grant offer was small.

TABLE 4. UTILITY FUNCTION AND BORROWING RATE PARAMETERS

Location Amenity Valuations	
Living away from New Orleans: $b_{\ell=3,t}$	0.00 [normalized]
Living in New Orleans: $b_{\ell=(1,2),t}$	
1(Black)	0.04 [0.02]
1(Neither head born in Louisiana)	-0.01 [0.02]
1(Owned home 10-20 years)	-0.03 [0.01]
1(Owned home > 20 years)	-0.02 [0.02]
Intercept	2.46 [0.04]
min(t, 15)	-0.17 [0.02]
Living in the pre-Katrina Home: $(b_{\ell=1,t} - b_{\ell=2,t})$	
Intercept	0.24 [0.02]
1(Block poverty 10% - 25%)	0.01 [0.04]
1(Block poverty > 25%)	0.07 [0.03]
1(50-90% damage)	-1.35 [0.02]
1(50-90% damage) x min[t, 15]	0.09 [0.03]
1(>90% damage)	-3.62 [0.02]
1(>90% damage) x min[t, 15]	0.24 [0.03]
Std. dev. of persistent heterogeneity η: σ_η	0.15 [0.03]
Moving (utility) cost: χ	
1(t = 1)	3.40 [0.26]
1(t > 1)	3.17 [0.36]
1(Move is to/from New Orleans)	0.77 [0.38]
1(First period after home repairs)	-4.12 [0.32]
Repairing/rebuilding (utility) cost: κ	
Intercept	3.26 [0.27]
1(Home was destroyed by Katrina)	1.45 [0.38]
(Log of) Borrowing interest rate: $\ln(R_B)$	
Intercept	$\ln(1/\beta)$ [normalized]
1(Black)	0.39 [0.12]
1(No bachelor's degree)	0.27 [0.12]
1(Pre-Katrina income < $20k)	0.42 [0.19]
1(Pre-Katrina income $20-40k)	0.05 [0.02]
Consumption utility weight: α	0.60 [0.15]
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). Asymptotic standard errors clustered at the neighborhood level are reported in brackets. Source: Author's calculations using data from the Displaced New Orleans Residents Survey (DNORS), a RAND survey conducted about four years after Katrina with a sample representative of the pre-Katrina New Orleans population (irrespective of households' post-Katrina resettlement locations), linked with administrative records from the Orleans Parish Assessor's Office property database.

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***
Smaller 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 Louisiana Road Home grant program. The first column in each pair of columns reports the average outcome under a counterfactual scenario in which no grants were provided, and the second reports the Road Home program's impact on the outcome relative to the no-grants counterfactual. Source: Author's calculations using the estimated model.

TABLE 6. THE IMPACT OF COUNTERFACTUAL DISASTER RELIEF POLICIES ON POST-KATRINA REBUILDING RATES

	(1)	(2)	(3)	(3)
	[Baseline]	Impact of various polies (relative to baseline) on rebuilding rates		
Population subgroup	4th anniv. rebuilding rate without rebuilding grants	Universal rebuilding loans	Road Home program	*Quickly rolled-out* Road Home program
All households	48.0	***+3.0***	**+4.0**	***+6.6***
Black Households:				
Uninsured losses < $75k	50.3	***+2.2***	**+3.2**	***+5.6***
Uninsured losses > $75k	33.8	***+14.4***	**+17**	***+23.5***
Nonblack households:				
Uninsured losses < $75k	45.1	***+1.9***	**+2.5**	***+4.8***
Uninsured losses > $75k	51.6	***+0.4***	**+1.1**	***+2.2***

Note: This table shows the results of simulation experiments computing the impacts of several counterfactual policy interventions on the rebuilding rates of New Orleans homeowners with initially-damaged homes as of Hurricane Katrina's fourth anniversary. Column 1 shows simulated rebuilding rates in a counterfactual scenario in which no grants were provided, holding the post-Katrina credit market -- i.e. the availability (or not) of post-Katrina rebuilding loans for different population subgroups -- the same as actually occurred after Katrina. Column 2 shows simulated impacts relative to the no-grants baseline, of making rebuilding loans available at the risk-free interest rate to all households beginning on Katrina's second anniversary (mimicking the timing of the Road Home program's rollout), again holding the post-Katrina credit market the same as it actually occurred during the first two years after Katrina. Columns 3 shows the impacts relative to the no-grants baseline of the actual Road Home program. Colum 4 shows the impacts relative to the no-grants baseline of an identical grant program rolled out immediately after Hurricane Katrina. Column Source: author's calculations using the estimated model.

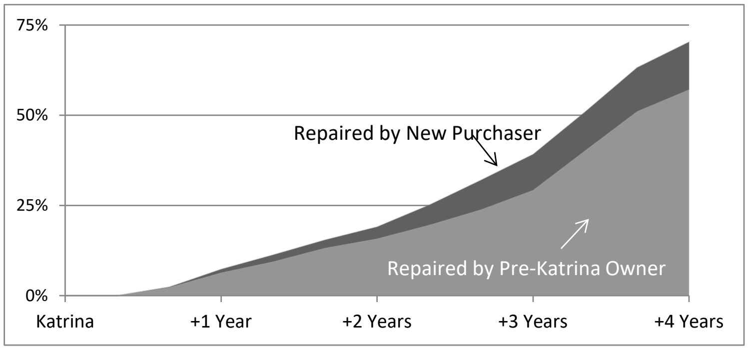
TABLE 7. WELFARE ANALYSIS

Baseline -- policy response when a disaster occurs	Candidate -- policy response when a disaster occurs	A. Welfare loss from removing post-disaster transfers and loans		
		Reduction in Avg. Expenditure Per Year	Equivalent Variation Per Year	Welfare Reduction Per Year
Road Home Program	No post-disaster transfers, actual post-Katrina credit market	\$142.0M	\$338.1M	\$196.1M
Road Home Program	No post-disaster transfers, universal disaster loans	\$142.0M	\$224.6M	\$82.6M
Road Home program rolled out immediately	Road Home Program (actual timing)	\$0	\$358.5M	\$358.5M

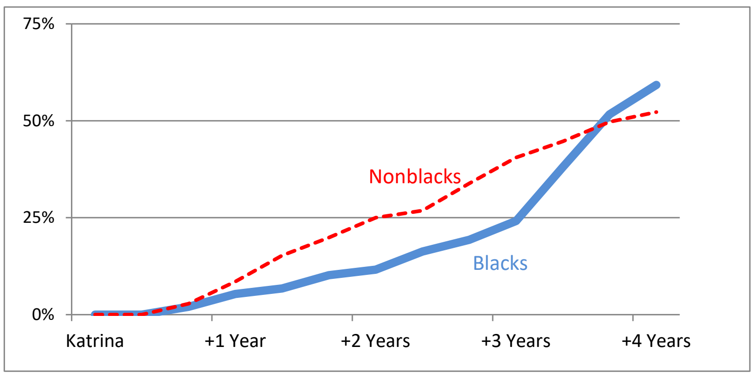
Baseline Policy	Candidate Policy	B. Welfare loss from actuarially unfair financing	
		Reduction in Revenue Per Year	DWL Per Year
3.3% NOLA property surtax	0% NOLA property surtax	\$142.0M	\$1.0M
3.3% NOLA property surtax	0% NOLA property surtax, elastic response (ψ=2)	\$142.0M	\$4.7M

Note: Panel A reports New Orleans homeowners' aggregate willingness to pay (computed by aggregating household-level equivalent variations -- see the text for details of the calculations), under several baseline disaster expenditure policies to avoid changes to different candidate alternative disaster expenditure policies. Panel B reports estimates of the excess burden associated with deviating from the optimal, actuarially fair (with respect to location disaster risk) tax policy to fund these expenditures. See the text for a detailed explanation of these calculations and detailed descriptions of the various baseline and candidate policies. Source: Author's calculations using the estimated model.

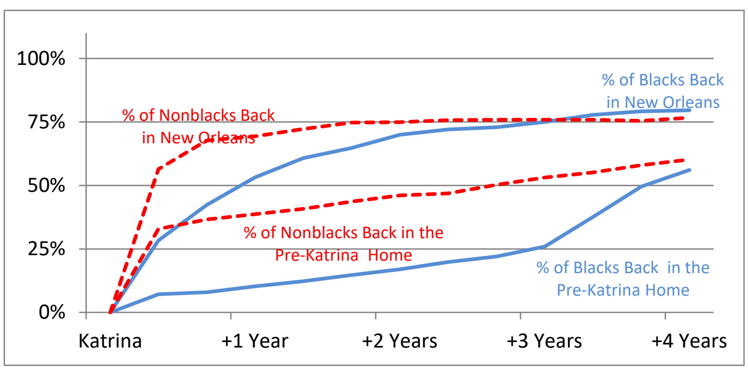
FIGURE 1. TIMING OF HOME REPAIRS AND MOVES BACK TO NEW ORLEANS



A. HOME REPAIRS BY ORIGINAL OWNER AND NEW PURCHASER



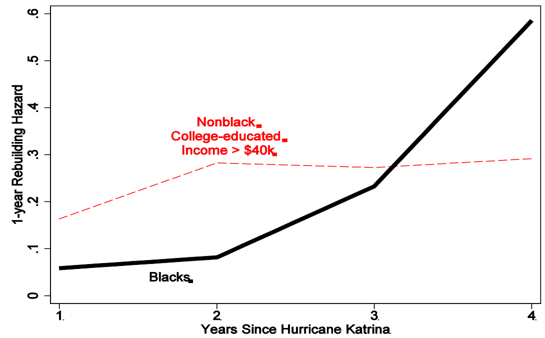
B. HOME REPAIRED BY ORIGINAL OWNER BY RACE



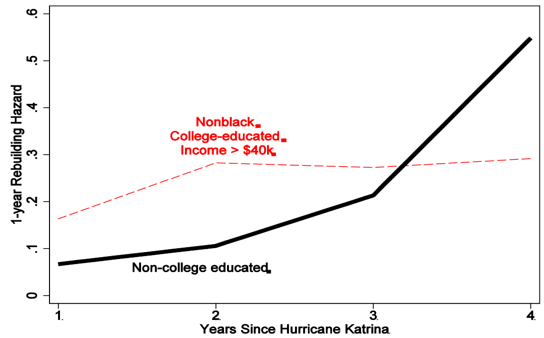
C. FRACTION LIVING IN NEW ORLEANS AND FRACTION LIVING IN THE PRE-KATRINA HOME BY RACE

Note: These figures show post-Katrina trends in the repair rates of New Orleans homes that were owner occupied prior to Katrina (Panels A and B) and trends in the fraction of pre-Katrina New Orleans homeowners residing in New Orleans and in their pre-Katrina homes (Panel C). The sample consists of households who owned single-family homes in New Orleans (either free-and-clear or with a mortgage) when Hurricane Katrina struck. Households' background characteristsics (race) and residence location histories are from the Displaced New Orleans Residents Survey (DNORS), a RAND survey conducted about four years after Katrina with a sample representative of the pre-Katrina New Orleans population (irrespective of households' post-Katrina resettlement locations). Information on the timing of home repairs and home sales is from the linked Orleans Parish Assessor's Office property records of the DNORS respondents.

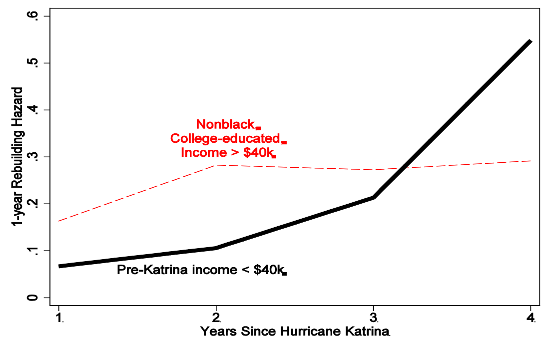
FIGURE 2. ANNUAL REPAIR HAZARDS BY DEMOGRAPHIC GROUP



A. ANNUAL REPAIR HAZARD OF BLACK HOUSEHOLDS



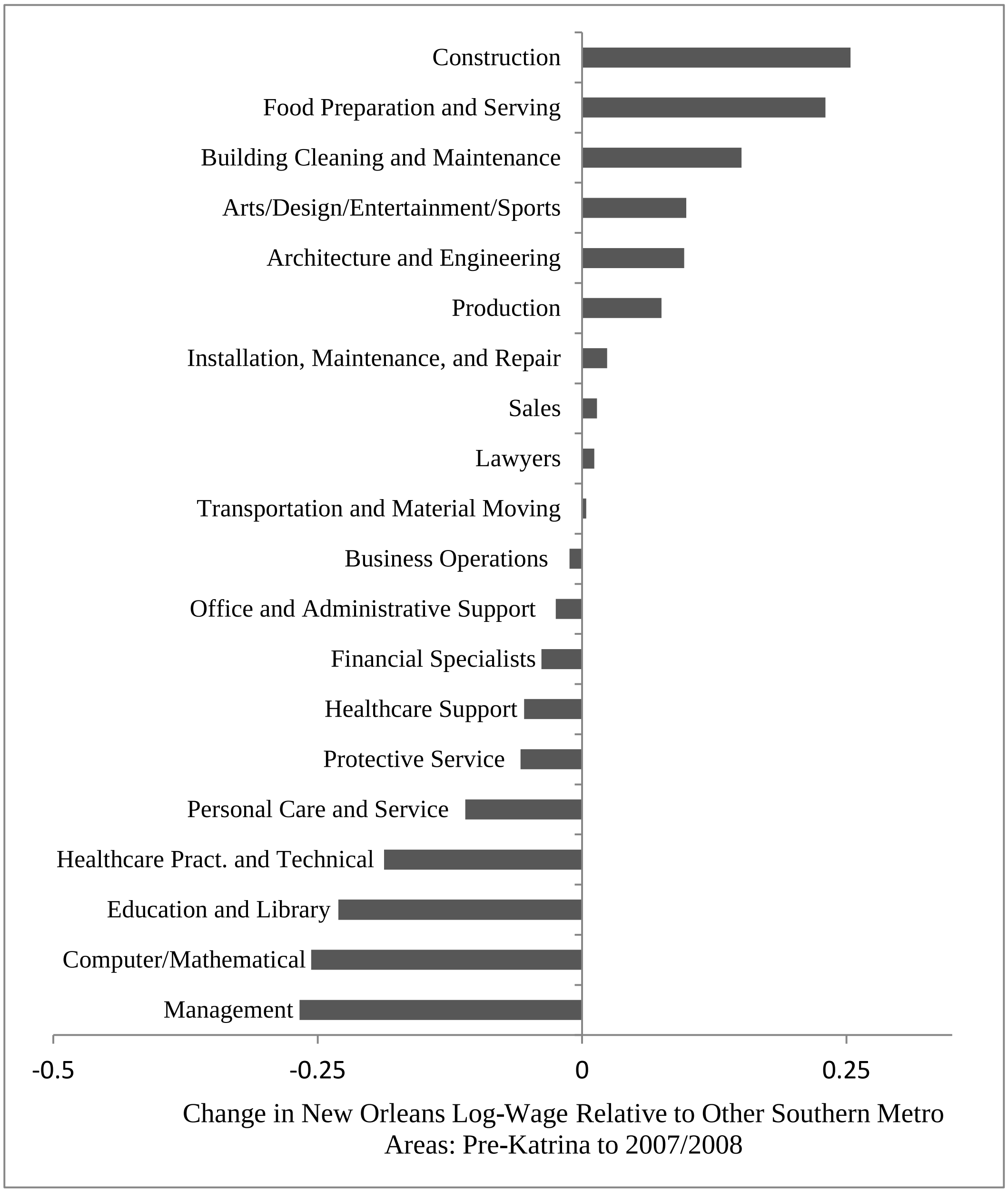
B. ANNUAL REPAIR HAZARD OF HOUSEHOLDS
WITH NO BACHELORS DEGREE



C. ANNUAL REPAIR HAZARD OF
LOW INCOME HOUSEHOLDS

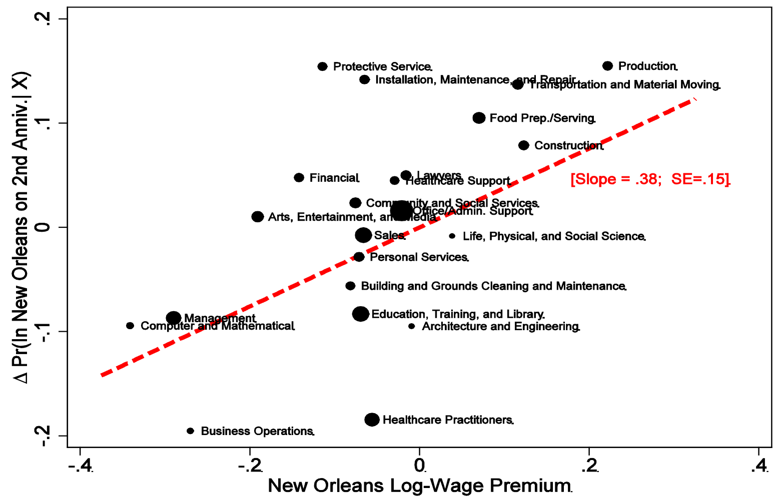
Note: This figure plots the yearly hazard that households with Katrina damaged homes who had not yet repaired their homes by Katrina anniversary "y-1" had repaired their homes by anniversary y. Specifically, the figures compare the repair hazards of black households (panel A), households without college degrees (panel B), and households with pre-Katrina annual income < $40,000 (panel C) to the repair hazards of a more affluent comparison group (non-black, college-educated households with pre-Katrina annual income > $40,000) hypothesized to have had access to federally subsidized rebuilding loans. The Small Business Administration (SBA) coordinates a subsidized disaster loans program after all federally declared disasters. While the SBA disaster loan program uses lending standards that are more lenient than private banks', SBA disaster loans applications still have non-trivial income and credit history requirements for what often amount to weakly collateralized loans. In the months following Hurricane Katrina the SBA disaster loan program rejected a *majority* of loan applicants. The Louisiana Road Home *grant* program did not disburse the bulk of its rebuilding grants to New Orleans homeowners until early in the third year after Hurricane Katrina. The large spikes in rebuilding hazards among lower-S.E.S. groups near the payment of Road Home grants but not among higher S.E.S. groups is suggestive evidence that these lower-S.E.S. groups faced systematic financing constraints.

FIGURE 3. PRE-KATRINA TO 2007/2008 CHANGES IN OCCUPATION-SPECIFC LOG-WAGE PREMIUMS FOR NEW ORLEANS RELATIVE TO OTHER SOUTHERN METRO AREAS

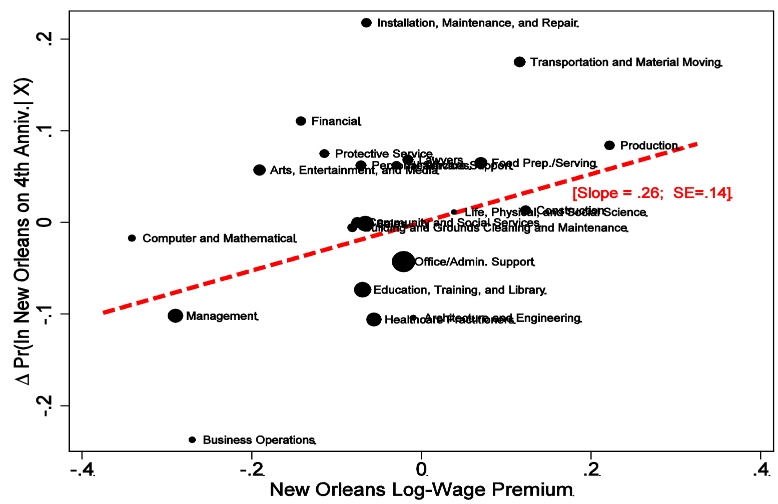


Note: This figure shows changes from 2005 to 2007/2008 in occupation-specific New Orleans log-wage premiums (specifically, changes in composition-adjusted log-annual earnings in New Orleans relative to composition adjusted log-annual earnings in other Southern metropolitan areas). Data are from the 2005 and 2008 American Community Surveys (ACS). ACS respondents report earnings during the 12 months prior to their ACS interview, so 2005 responses describe earnings during a period almost entirely before Katrina, and 2008 responses describe earnings occurring roughly half in 2007 and half in 2008. The figure shows all two-digit occupations with at least 1% of the pre-Katrina New Orleans workforce.

FIGURE 4. NEW ORLEANS WAGE PREMIUMS AND
ADJUSTED RETURN RATES BY OCCUPATION



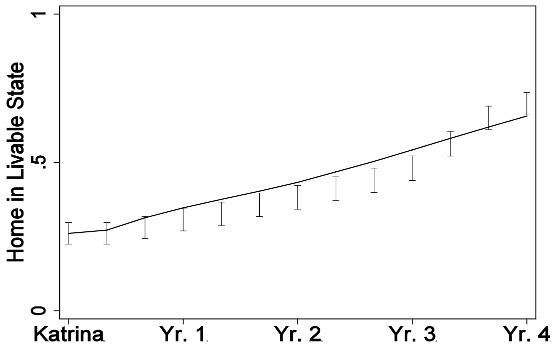
A. PROBABILITY OF LIVING IN NEW ORLEANS
ON KATRINA'S 2ND ANNIVERSARY



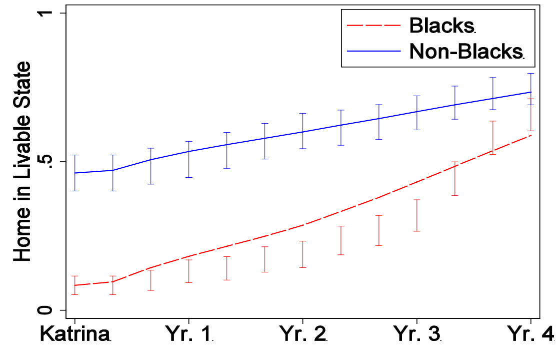
B. PROBABILITY OF LIVING IN NEW ORLEANS
ON KATRINA'S 4TH ANNIVERSARY

Note: This figure plots regression adjusted occupation "impacts" on the probability of workers residing in New Orleans on the second and forth anniversaries of Katrina (y-axis) against the prevailing composition-adjusted log-annual earnings premium in New Orleans relative to other Southern metropolitan areas in the worker's pre-Katrina occupation (x-axis). Composition adjusted log-wages are computed with data from the American Community Survey (ACS). Occupation-specific "impacts" on return rates are computed among household heads from this study's main estimation sample: respondents to the Displaced New Orleans Residents Survey (DNORS) who owned homes in New Orleans prior to Katrina. "Impacts" on return rates are the estimated coefficients on worker pre-Katrina occupation dummies from linear probability models for residing in New Orleans after controlling for a host of labor supply (to New Orleans) shifters, including; worker's race, worker's education, whether the worker was born in Louisiana, home purchase-year categories, the 2000 poverty rate in the worker's pre-Katrina Census tract, the fraction of the pre-Katrina block's homes severely damaged by Katrina, the log of the worker's household's pre-Katrina annual income, and the log of storm-related property damages if positive.

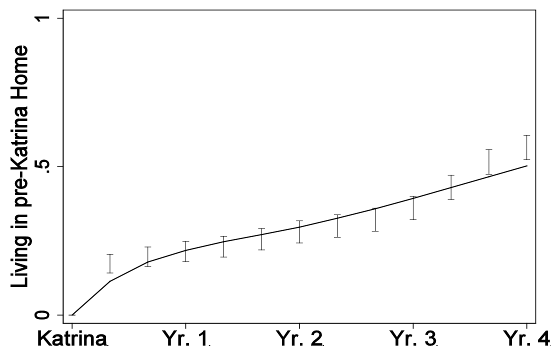
FIGURE 5. MODEL FIT



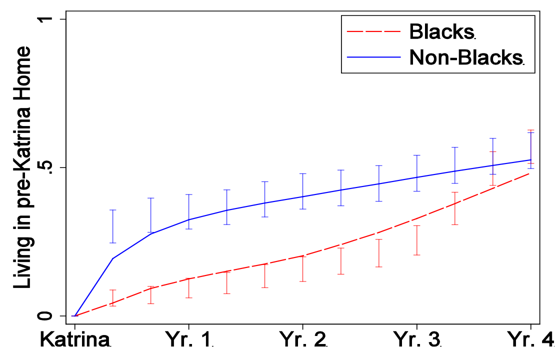
a. Home in a livable state



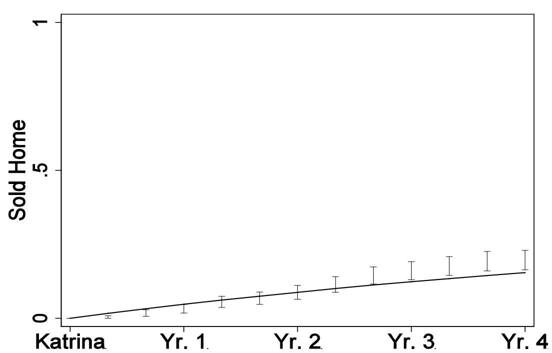
b. Home in a livable state, by race



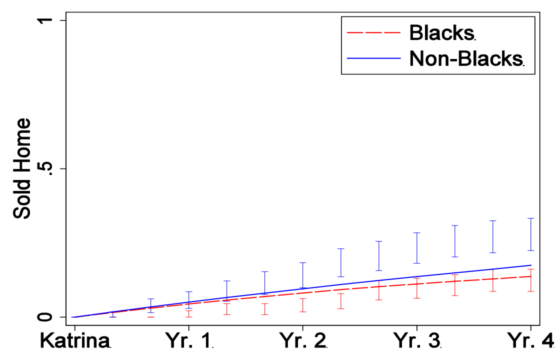
c. Living in the pre-Katrina home



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



e. Home has been sold



f. Home has been sold, by race

Note: This figure plots the estimated model's predicted resettlement trends (solid lines) and actual resettlement trends (depicted with vertical bars showing empirical 95% confidence intervals). Source: Author's Calculations using the estimated model and data from the Displaced New Orleans Residents Survey (DNORS) linked to administrative records from the Orleans Parish Assessor's Office property database.

Appendix I. Robustness

I next assess the robustness of the paper's baseline results to uncertainty as to whether RH grants fully compensated households for their uninsured losses. The baseline model's budget constraint specifies RH 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 RH program's implementation often included anecdotes claiming that RH grants fell short of fully compensating some households for their uninsured losses. To assess the robustness of this paper's findings to that possibility, I re-estimate the model and repeat the policy simulation experiments after replacing the baseline model's budget constraint with one in which RH grants are reduced by 20%.

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 magnitude of the variation in financial incentives assumed to generate the differences in observed behavior across households, 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.

Table 8 compares the results of policy experiments performed with the re-estimated model to the results of policy experiments performed with the baseline model. The policy experiments performed with the re-estimated model generate a very similar pattern of predicted impacts across population subgroups. The re-estimated model generates a slightly larger estimate of the RH program's impact on rebuilding (6.0 percentage points versus 4.0 percentage points), but the baseline conclusions of the simulation experiments remain unchanged. The program generated a modest impact on the city-wide rebuilding rate and significantly larger impacts among households with large uninsured losses and among households with limited access to credit. The baseline model specification and the re-estimated model both find that the program's largest impacts occurred among black households with uninsured losses above $75,000 (impacts of 17.0 percentage points and 18.1 percentage points respectively).

TABLE A1. ROBUSTNESS

Group	(1) No Grants	(2) Impact of Road Home	(3) No Grants	(4) Impact of Road Home
	Baseline model		Re-estimated model: Assumes a 20% Road Home shortfall	
All Households	48.0	***+4.0***	45.6	***+6.0***
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	***+3.0***	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	***+17.0***	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***

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.

Appendix II: Data (Online – Not For Publication)

A.I.1 Wage Offers

I compute period-specific household earnings offers in New Orleans (i.e. the wage offer w_{it}^1 received when $\ell_{it} \in \{1, 2\}$) and household earnings offers in the "outside option" (i.e. the wage offer w_i^0 received when $\ell_{it} = 3$) for each household by adjusting households' pre-Katrina labor earnings, recorded by the Displaced New Orleans Residents Survey (DNORS), using a year $\times$ labor market $\times$ occupation wage index estimated using data from the 2005-2010 American Community Survey.

I first estimate a year (τ) $\times$ labor market (m) $\times$ 2-digit occupation (occ) wage index $\theta_{occ,\tau}^m$ using 2004-2009 data from the American Community Survey (ACS). I restrict to observations from New Orleans $m = 1$ and from other metro areas in the Census South region $m = 0$, the modal location of pre-Katrina New Orleans residents who resettled away from New Orleans, and estimate a log-earnings regression of the form,

$$\ln(earn_{i,\tau}) = X_{i,\tau}' a + \theta_{occ(i,\tau),\tau}^m + e_{i,\tau}$$

where $earn_{i,\tau}$ is a worker's annual labor earnings, X is a vector of flexibly interacted demographic and human capital variables, and $\theta_{occ,\tau}^m$ are a fixed effects. I then apply this wage index to the pre-Katrina wage offer of each DNORS household head $w_{i,pre\text{–}K}^{head}$ and spouse $w_{i,pre\text{–}K}^{spouse}$ to construct post-Katrina household wage offers both in and away from New Orleans. Specifically, I compute,

$$\begin{aligned}
w_{it}^0 &= w_{i,pre\text{–}K}^{head} \left(\frac{\exp\left(\theta_{occ(i,head),\tau(t)}^0\right)}{\exp\left(\theta_{occ(i,head),2005}^1\right)} \right) + w_{i,pre\text{–}K}^{spouse} \left(\frac{\exp\left(\theta_{occ(i,spouse),\tau(t)}^0\right)}{\exp\left(\theta_{occ(i,spouse),2005}^1\right)} \right) \\
w_{it}^1 &= w_{i,pre\text{–}K}^{head} \left(\frac{\exp\left(\theta_{occ(i,head),\tau(t)}^1\right)}{\exp\left(\theta_{occ(i,head),2005}^1\right)} \right) + w_{i,pre\text{–}K}^{spouse} \left(\frac{\exp\left(\theta_{occ(i,spouse),\tau(t)}^1\right)}{\exp\left(\theta_{occ(i,spouse),2005}^1\right)} \right)
\end{aligned}$$

where $occ(i, head)$ and $occ(i, spouse)$ are the pre-Katrina occupations household i's head and spouse, and $\tau(t)$ is the calendar in which period t from model occurs.

A.I.2. 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.

A.I.3. 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.[31]

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.[32]

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.

A.I.4. 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.

[31] 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%.

[32] 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 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.

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).[33] 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.[34] 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 $p(x) = 0.25$ then $\widehat{F}_{A_0}^{-1}(p = .5|x)$ is the fitted 25th percentile of the conditional (on x) positive asset distribution.

[33]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.

[34]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 A2. CONSTRUCTION OF 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 indices (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 indices (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 uninhabitable 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 housing 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 A3. 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	No		Yes	
Observations	706,073		706,073	

Note: This table reports estimated housing price indices, relating housing prices in post-Katrina New Orleans and after Katrina in other Southern metro areas to housing prices in pre-Katrina New Orleans. Column (1) reports raw differences in housing rents, and column (2) reports differences in housing rents after controlling for a detailed set of building characteristics. New Orleans housing data come from the 2005-2009 American Community Survey (ACS) and housing data for other Southern metro areas comes from the 2006-2009 ACS.

TABLE A4. WAGE EQUATION

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

Note: This table shows the estimated wage equation, reporting deviations in individual workers' wages from the composition-adjusted average wage in the worker's occupation. The data are from all working New Orleans respondents to the 2005 American Community Survey pooled with the pre-Katrina earnings records for all Displaced New Orleans Residents Survey (DNORS) respondents who worked in the year prior to Katrina.