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

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Abstract

This paper examines the impact of wage subsidies and direct cash grants on the rebuilding choices of New Orleans homeowners following Hurricane Katrina. I estimate a dynamic discrete choice model of households' residential location, home repair, home sale, and borrowing/saving choices using a unique panel dataset that combines interview responses from the recently fielded Displaced New Orleans Residents Survey with administrative property assessment records from the Orleans Parish Assessor's Office. The model finds strong evidence of borrowing constraints among black households and among low income households. Using simulations of households' choices under counterfactual grant policies, I estimate that the Louisiana Road Home program's direct cash grants increased the fraction of homes that had been repaired or rebuilt within four years of Katrina by 14%. The program increased rebuilding rates by 18% among black households and by about 8% among non-black households. Also, I estimate that, on the margin, an increase in the amount of a direct grant has about 4.0 times the impact on rebuilding rates as an equal sized increase in the present value of New Orleans wages, and about 5.1 times the impact among black households. These findings suggest that following a disaster, any wage increases that might result from wage subsidies targeted to businesses are likely to have small effects on households' choices relative to direct rebuilding grants paid to households.

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1 Introduction

The federal government in the United States devotes significant resources to disaster relief, and disaster relief spending has followed a clear upward trend in recent decades. In addition to direct spending on clean up and infrastructure repair, U.S. disaster relief typically includes programs targeted directly to people and businesses in affected areas in hopes of dampening the negative shock of the disaster. While post-disaster programs presumably have important effects on resettlement choices and on individual welfare, the literature on disasters has devoted little attention to program evaluation.[1] The absence of program evaluation studies from this literature is not entirely surprising. Standard quasi-experimental research designs rely on the presence of an otherwise similar "control" group with which the group exposed to the program may be compared, but in a given disaster area the entire affected population often receives the policy's "treatment." Comparisons across disasters that received different varieties of relief are also problematic, because the types of relief chosen by localities are endogenous to the severity of damage in the locality and to distribution of damage within the locality. The literature on disasters has instead has focused primarily on assessing the impact of particular disasters or varieties of disaster on outcomes that include local prices, employment, migration, and measures of individual well-being.

Understanding the impacts of various post-disaster policies on households' welfare and resettlement choices is especially important because policymakers have considerable discretion over the nature of relief spending following a disaster. When the President has declared an area to be a major disaster area, homeowners and businesses become eligible for Disaster Relief Loans through the Small Business Administration (SBA), and individuals become eligible for small assistance grants from the Federal Emergency Management Administration (FEMA). In addition to these standing programs, a significant portion of disaster relief is allocated through block grants to local and state governments. Localities may use those grants in a number of ways, including to purchase damaged homes, to provide cash grants for repairs, to provide subsidized loans for rebuilding, and to provide grants for relocating away from unsafe areas. Another variety of disaster relief that has gained popularity in the past decade uses spatially targeted business subsidies to encourage capital investment and to stimulate demand for the labor of returning workers.

In this paper I assess the impact federal disaster relief on the resettlement choices of New Orleans homeowners following Hurricane Katrina. I do so by estimating a dynamic discrete choice model of households' residential location, home sale, home repair, and asset accumulation choices. I explicitly model the provisions of the Louisiana Road Home program, a program that paid cash

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

grants of up to \$150,000 to households to cover the cost of home repairs that were not covered by private insurance. Using the estimated model, I simulate households' choices under a variety of counterfactual scenarios that allow me to assess the impact of several programs that were enacted and to consider the impact of several alternative policies that were not enacted. I assess the impact of the Road Home program by comparing predicted household choices with and without the program in place. Also, I consider how choices would have differed if the Road Home grant program had been replaced by an expanded loan program or if the Road Home program had been replaced by an equally generous program that had simpler rules. Finally, I estimate an upper bound on the impact of the Gulf Opportunity Zone initiative, a package of subsidies to businesses operating in a large region along the Gulf coast, through its potential impact on New Orleans wages.

The structural modeling approach that I adopt provides several important advantages. First, the approach solves the identification problem described above. The structural model may be identified using variation in policy relevant variables even if there is no variation in program exposure. Second, with a structural model, one can distinguish between alternative explanations for a given program treatment effect. Many combinations of structural parameters that have quite different implications for the effectiveness of alternative policies could be consistent with a given "treatment effect." For instance, a rebuilding grant program might increase rebuilding rates by alleviating credit constraints among a group that strongly prefers to rebuild, or by inducing a group that has ample access to credit to rebuild when relocating was otherwise preferable. By estimating structural parameters that describe preferences for consumption, location preferences, and the effective borrowing interest rate, I am able to estimate the impact of enacted policies and consider how choices would have differed under counterfactual policies that were not actually implemented.

In the dynamic programming model, a unitary household must choose whether to repair its pre-Katrina home and where to reside. The household may choose to reside in its pre-Katrina home, elsewhere in New Orleans, or in a representative "other Southern metropolitan area" location.[2] However, a household whose home was damaged by Katrina may only reside in the pre-Katrina home if repairs have been purchased. For modeling purposes, the rebuilding choice can be thought of as an investment decision. The household weighs the up front cost of rebuilding against the net future benefit from location differences in labor wages and local amenities. The model allows for the possibility of borrowing constraints, which, if present, allow up front grant payments and gradually accruing wage benefits to have different impacts on household choices. The model also explicitly includes the key provisions of the Road Home program in the household budget constraint. The model's parameters describe preferences over consumption and local amenities and the effective interest rate at which the household may borrow.

[2]Among respondents to the Displaced New Orleans Residents Survey who were not residing in New Orleans at the time of interview, typically four to five years after Katrina, well over 90 percent were residing in the South and the vast majority in metropolitan areas.

The model is identified using variation across households in the cost of rebuilding, driven by differences in storm damage, and variation across households in the gap between expected wages in New Orleans and away from New Orleans, driven by substantial differences across occupations in post-Katrina New Orleans wages. Identification is aided by particular features of the Road Home program, though identification does not require variation across households in program exposure. Intuitively, the behavior of an agent who is credit constrained will be more responsive to a change in the up front cost of an investment than to a similar size change in the present value of the investment's gradually accruing stream of benefits. Also, if an investment opportunity is subsidized by a foreseen grant payment made at a future date t, a credit constrained agent is more likely to defer investment until after date t than an agent who may borrow cheaply.

I estimate the model using a unique data set constructed from two primary sources. The first source is a population representative survey of pre-Katrina New Orleans residents called the Displaced New Orleans Residents Survey (DNORS). The DNORS data provide information on households' demographic background traits, storm related home damage, insurance coverage, and migration during the first four years following Katrina. I augment this survey data by merging on records from the administrative property database from the Orleans Parish Assessor's Office (Assessment data) that correspond to each household's pre-Katrina home. I use the Assessment data to obtain a record of any post-Katrina home sales and to determine when any post-Katrina home repairs were made. Using these data sources, I construct a panel of households' residence locations, home repair status, and home ownership status at twelve points in time that span the first four years following Katrina. For estimation, I supplement these primary sources with several auxiliary sources. I obtain information on wages across locations from the Bureau of Labor Statistics Occupational Employment Statistics (OES). I obtain information on rents across location from the American Community Survey (ACS). I obtain information on the distribution of liquid asset holdings in Southern metro areas, separately by demographic group, from the Panel Study of Income Dynamics (PSID).

The data paint a picture of massive flooding damage that fell disproportionately on New Orleans' black population. About 75 percent of all home owning households and about 89 percent of black households experienced flooding. About 70 percent of all homes and about 87 percent of the homes of blacks were rendered uninhabitable. For households of all races, insurance payments typically did not cover the full cost of repairs. During the first two years following Katrina the rebuilding process occurred slowly, and large disparities emerged in repair rates across demographic groups. By the fourth anniversary of Katrina, repair rates across demographic groups had converged substantially. Most Road Home rebuilding grants were paid more than two years after Katrina, so this pattern suggests that many households waited until they had received a Road Home grant before choosing to rebuild.

The estimated model finds strong evidence of borrowing constraints among black households and finds that those constraints had important implications for the effectiveness of the various disaster relief policies at encouraging households to rebuild. Using simulations of households' choices under counterfactual grant and wage subsidy policies, I estimate that the Road Home rebuilding grant program increased the fraction of households with initially uninhabitable homes who had rebuilt within four years of Katrina by about 14%. That impact was about 18% among black households and about 8% among non-black households. Also, I estimate that, on the margin, an increase in the amount of a direct grant has about 4.0 times the impact on aggregate rebuilding rates as a similarly sized increase in the present value of New Orleans wages, and about 5.1 times the impact on rebuilding rates among black households. These findings suggest that following a disaster, any wage increases generated by a wage subsidy to businesses are likely to a have small effect on rebuilding rates relative to the effect of paying grants directly to rebuilding households.

This study extends the literature examining the economic consequences of disasters by estimating the first dynamic structural model of households' post-disaster resettlement choices. The model provides a framework within which the many types of U.S. disaster relief programs may be evaluated, and the program evaluations that are performed using the model are another important contribution of the paper. In addition to facilitating policy simulations, the model's parameter estimates themselves contribute to the narrow literature that has examined patterns of post-Katrina migration and resettlement[3]. Finally, by quantifying the relative importance of labor market opportunities, location preferences, and borrowing opportunities in a context in which those parameters separately identified, the paper informs the broader literatures on migration,[4] the adjustment of labor supply across locations in response to labor demand shocks,[5] and the literature examining the impact spatially targeted business subsidies on local population, employment, and wages.[6]

Methodologically, I build on a set of recent studies that have used explicit behavioral models to examine how migration choices respond to differences in wages across space (Kennan and Walker, forthcoming; Bishop, 2007; Gemichi, 2007). The model that I consider departs from those studies by including the agent's asset accumulation decision and allowing for the possibility that agents are borrowing constrained. Because the previous studies have treated utility as linear in consumption,

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

[4]See Greenwood (1997) for a survey.

[5]Topel (1986) and Blanchard and Katz (1992) consider labor flows as part of a dynamic stochastic spatial equilibrium. Using a conceptually similar model, Bound and Holzer (2000) examine heterogeneity in spatial labor supply elasticities, finding that those with lower education and blacks are less likely to move in response to differences in wages across locations. More recently, a group of studies have examined the sensitivity of migration decisions to earnings opportunities across locations using explicit dynamic behavioral models. These papers, including Kennan and Walker (forthcoming), Bishop (2007), and Gemichi (2007) estimate dynamic discrete choice models of optimal migration and find labor flows to be responsive to variation in wages across space.

[6]A group of studies including Papke (1993, 1994), Boarnet and Bogart (1996), Bondonio (2003), Bondonio and Engberg (2000), Elvery (2003), and Engberg and Greenbaum (1999) assess the impact of state Enterprise Zones, which typically consisted of tax breaks and capital investment subsidies, on local labor market outcomes like employment. Busso, Gregory, and Kline (2011) perform an equilibrium analysis of the incidence and efficiency of the round I federal Empowerment Zones program, which consisted of wage subsidies and social services block grants.

policy analysis conducted using those models necessarily predicts that two programs that have the same impact on the present value of income in a given location will similarly influence the attractiveness of living in that location. By modeling the borrowing/saving decision and allowing for the possibility of borrowing constraints, I am able to distinguish between the effects of subsidies that have the same present value but that differ in the timing of the benefits.

The remainder of this paper is structured as follow. Section 2 describes the dataset, Section 3 provides background on Hurricane Katrina's impact and the policies that were enacted in the years following Katrina, Section 4 presents a stylized model of the household rebuilding decision, Section 5 presents the dynamic structural model to be estimated; Section 6 describes the parameterization of the model for estimation and describes the estimation routine; Section 7 presents the structural parameter estimates and assesses the model's in sample fit, section 8 presents the results of counterfactual policy simulations, and section 9 concludes.

2 Data

For this analysis, I construct a unique household level panel data set containing a record of migration choices, home repair choices, and home sales during the first four years following Hurricane Katrina. To create the data set, I draw from two primary sources. The first source is a population representative survey of pre-Katrina New Orleans residents called the Displaced New Orleans Residents Survey (DNORS). The DNORS data provide information on households' demographic background traits, storm related home damage, insurance coverage, and migration during the first four years following Katrina. I augment this survey data by merging on records from the administrative property database from the Orleans Parish Assessor's Office (Assessment data) that correspond to each household's pre-Katrina home. I use the Assessment data to obtain records of any post-Katrina home sales and to determine when any post-Katrina home repairs were made. Using these data sources, I construct a panel of households' residence locations, home repair status, and home ownership status at twelve points in time that span the first four years following Katrina.

The Displaced New Orleans Residents Survey (DNORS) selected a random sample of pre-Katrina New Orleans dwellings and conducted interviews between July of 2009 and April of 2010 with the pre-Katrina occupants of those dwellings regardless of where they were residing at the time of the interview. As a result, the survey provides a record of the post-Katrina experiences for a representative sample of the New Orleans population just prior to Hurricane Katrina.[7] For each

[7] A final set of survey weights have not been completed for the DNORS sample. Comparing the distribution of demographic characteristics in DNORS to the distribution of demographic characteristics in the ACS finds that some groups, mainly younger households, are slightly under-represented. Final versions of the analysis in this paper will incorporate survey weights to account for differential response rates. However, I don't expect that including those weights will change the main conclusions of the current analysis. Also, subsequent versions of this paper will include

selected household, either one or two adults were interviewed. For every household an interview was conducted with an individual deemed the "household respondent," typically the household head or the spouse or partner of the head. An additional "adult respondent" was selected at random from all adults on the household's roster and an additional interview was conducted with that person if that person was not already the household respondent. Each "household respondent" was asked questions about the demographic and background traits of the full household roster, the characteristics of the pre-Katrina dwelling, any home or property damage caused by Katrina, the any insurance payments that were received, and the timing and destinations of post-Katrina moves. Both "household" and "adult respondents" provided information about their own traits and their own labor market experiences during the year prior to Katrina and during the year prior to the interview.

To supplement these survey data, I obtained property assessment records for all New Orleans properties for which a non-zero homeowners exemption was determined for tax year 2005 property taxes, indicating that the dwelling was owner occupied just prior to Hurricane Katrina. For each property, the Assessment data provide an annual assessment of the value of the land and of the value of any improvement (structures, etc.) for tax years 2005 through 2010. Each annual assessment reflects the Assessor's estimates of the home's value during the Fall of the year prior to the tax year.[8] I use these data along with survey responses to construct a continuous measure of the cost of needed repairs and a sequence of binary measures of whether repairs had yet occurred at twelve points in time during the first four years following Katrina.

The DNORS sample includes 808 households who reported having resided in an owner occupied single-family dwelling at the time of Katrina. Of these I restrict attention to the 733 households for whom at least one household head was employed during the year prior to Hurricane Katrina,[9] or for whom the male head was 65 or older in households with a male head present and for whom the female head was 65 or older when only a female head was present. Of these households, I analyze the records of the 578 whose records I matched to the Assessment data. [10]

Using these sources, I construct a retrospective panel of residence locations, housing damage states, and home ownership states. To facilitate estimation, the panel contains one observation per household in each of twelve evenly spaced periods (each four months wide) spanning the first

some more detail about the DNORS field process, but summary statistics like response rates have not yet been released.

[8]Orleans Parish bills home owners in advance of the relevant tax year and must, therefore, compute the assessment for year t at during the Fall of year $t-1$.

[9]Among working age households, I restrict attention to households with at least on head who was employed prior to Katrina so that I may treat pre-Katrina occupation as a source of variation in relative wages across locations.

[10]A DNORS record might fail to match with a corresponding Assessment record when a household's self-reported ownership status and the classification of ownership status using the 2005 homeowner exception figure do not agree. Also, a non-merge could reflect errors in the address information itself in either source or in both sources. Using a regression analysis I find that the likelihood with which a DNORS record successfully merged to the Assessor's data was statistically unrelated to a large set of household and dwelling characteristics that included flood exposure.

four years following hurricane Katrina. I also draw from both of these data sources to obtain measures of household composition, race, educational attainment, pre-Katrina employment status and occupation, pre-Katrina home value, the value of home damage caused by Hurricane Katrina, and the value of any insurance payments.

For estimation, I require information on several prices that are relevant to each household's resettlement choice. These include the cost of needed repairs, the value of the household's insurance settlement, the price of rental housing across locations, and the market value of the household's home. I compute a best estimate for each of these quantities from a combination of the survey and administrative data using methods described in Appendix II.

To estimate the model, I require additional information on the prices that households faced across locations during the sample period. To more precisely estimate slope coefficients in my wage equations, I augment the DNORS sample with public use (IPUMS) records of labor earnings from the 2005 American Community Survey. Also, I obtain mean wages by year, occupation, and MSA in all Southern MSAs from 2005 to 2009 from the Bureau of Labor Statistics Occupational Employment Statistics database.

To measures differences in housing costs across locations and across time, I obtained information on rental housing prices in the New Orleans MSA and in a pooled sample of other metropolitan areas in the Southern region from the public use (IPUMS) records from the 2005 to 2009 American Community Surveys.

Finally, because DNORS interviews did not collect information on households' liquid asset holdings, an important initial condition in the dynamic model, I use data from the 2005 Panel Study of Income Dynamics to estimate the distribution of households' liquid assets among Southern metropolitan homeowners in 2005, by demographic subgroup.[11] During the estimation routine, I condition this unobserved initial condition out of the likelihood function by computing the likelihood function for each household at a range of values for the initial liquid asset holding and then integrating with respect to the distributions estimated from PSID data.

Table 1 provides descriptive statistics for my sample of pre-Katrina homeowning New Orleans households. Survey weights have not yet been released for DNORS, so, in order to assess the representativeness of the sample, I tabulate the same outcomes using the 2005 ACS (both before and after applying survey weights). I also report these descriptive statistics among the DNORS sample before each of my sample restrictions is applied so that an apples-to-apples comparison with the ACS is possible. Comparing column 1 to column 6 finds that the DNORS sample contains a larger share of older households than the pre-Katrina population of New Orleans. Comparing

[11] I define liquid assets in the PSID as the sum of a households checking account balance, savings account balances, money market account balance, and the balance of non-retirement investment accounts.

column 5 to column 6 finds that older households are also over-represented in the unweighted ACS sample. This suggests that even under typical (non-disaster) circumstances non-response was higher among younger households. Presumable when DNORS sample weights become available, they will also correct for the under-representation of younger households.

3 Hurricane Katrina and Post-Katrina Policy Interventions

Hurricane Katrina struck New Orleans on August 29th, 2005. In the days following the storm's initial impact, the levees protecting the city failed and flood waters covered roughly 80 percent of the city (McCarthy, 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 the entire population of New Orleans, which had exceeded 400,000 residents prior to the storm, and many pre-Katrina residents spent a considerable amount of time away from the city (or never returned). Previous research has found that damage to housing was the most important factor influencing the rate of return migration (Groen and Polivka, 2010; Zissimopolous and Karoly, 2010; Vigdor, 2008; and Paxson and Rouse, 2008). However, even after accounting for differences in housing damage, demographic subgroups differed in their return migration patterns. Most notably, blacks returned to New Orleans more slowly than non-blacks.

For a household who owned its home prior to Katrina, reconstructing the damaged home was the most important hurdle to overcome before returning home to live full time. Table 2 describes the distribution of flood exposure and storm damage and describes the resources that were available to households to purchase repairs. About 75 percent of all home owning households and about 89 percent of black households experienced flooding. About 70 percent of all homes and about 87 percent of the homes of blacks were rendered uninhabitable. Among households with homes that were uninhabitable following Katrina, insurance payments typically did not cover the full cost of repairs. Table 3 provides a cross-tabulation of flood exposure and home damage categories. Both the self-reported measure of home damage from DNORS and a measure based on changes in appraised home values from the Assessor's data are highly correlated with flood exposure. Also, the two independent measures of home damage are highly correlated with one another.

In general, the process of reconstructing damaged properties occurred slowly, due in part to logistical difficulties and a lack of clear rebuilding regulations and in part to a lack of financial resources among many affected households. Figure 1 plots trends in several outcomes during the first four years following Hurricane Katrina. Figure 2 plots trends in those same outcomes but restricts attention to households whose homes were initially unlivable following Hurricane Katrina. By the fourth anniversary of Katrina, nearly 80 percent of households were living in New Orleans, and more than half were living in their pre-Katrina homes. During the first two years following

Katrina the rebuilding process occurred slowly, and large disparities emerged in repair rates across demographic groups. By the fourth anniversary of Katrina, repair rates across demographic groups had converged substantially. In the remainder of this section I highlight several disaster relief programs that increased New Orleans households' financial incentives to rebuild their homes and increased the resources that were available for rebuilding.

The **Louisianian Road Home (Road Home) Program** was a large scale federally-funded and state-administered[12] initiative to encourage pre-Katrina Louisiana residents to return home following Hurricanes Katrina and Rita by providing direct rebuilding grants to homeowners. Specifically, the program provided cash grants of up to $150,000 to offset any repair and rebuilding expenses of pre-Katrina (or pre-Rita) homeowners that were not covered by insurance (State of Louisiana, Office of Community Development, 2009). The program was advertised as the largest single housing recovery program in US history, and as of January 10, 2010, over $9.0 billion had been dispersed to homeowners and owners of small rental properties. The vast majority (over $8.6 billion) was allocated through the homeowner program. The Road Home program was first announced in February of 2006, about six months after Hurricane Katrina. The deadline for applying for a Road Home grant was July 31, 2007, almost two years after Katrina.

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

Each household that participated in the Road Home program selected from among three available packages of benefits, known as options 1, 2, and 3. A participating household's obligations under the program depended on which option the household selected. Table 4 describes the main provisions of each option and the number of households that participated under each option. The vast majority of participants selected option 1, the option that paid the most generous benefits. To receive an option 1 grant, the homeowner agreed to repair and reside in the pre-Katrina home within three years and to purchase any required flood insurance. The option 1 grant paid the estimated cost of repairs minus the value of any insurance payments already received, up to a maximum of $150,000 or the home's pre-Katrina value, whichever was smaller.[13]

Options 2 and 3 allowed a household to recover some or all of the pre-Katrina value of its home by selling the home directly to a public land trust. Option 2 paid a grant equal to the size of the option 1 grant and required the homeowner to purchase another home in Louisiana within three

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

[13] Because of New Orleans declining population prior to Katrina and the durability of housing stock, some homes were valued less than the cost to build them (Vigdor, 2007).

years. Option 3 paid a grant that was 40 percent smaller but did not impose any requirements about place of residence or purchasing another home. Participants under options 2 and 3 could not recover the as-is value of their home (because the deed was turned over to the state). Because option 1 participants maintained ownership of their homes, the combined value of the grant payment and the household's property holding was largest under option 1.

The difference between the option 1 grant package and the household's most lucrative option for selling the home, either selling the home privately or through an option 2 grant, can be thought of as the financial incentive rebuild. If a household accepted an option 1 grant, the household would own its home at plus cash equal to the cost of repairs (a combination of any insurance payments and the grant payment). If a household accepted an option 2 grant, the household would only hold cash equal to the cost of repairs. If the household sold its house on the open market, the household would end up with a cash holding equal to the home's depressed value (the sale price) plus any insurance payments that the household received.

Figure 1 provides a stylized illustration of how the financial incentive to rebuild varied depending on the level of home damage and on a household's insurance coverage. The horizontal axis describes the cost of needed repairs as a fraction of the home's value if it is repaired. One line plots total proceeds (grant plus insurance settlement) that the household would receive if it accepted a Road Home option 2 grant. The proceeds include an insurance settlement and a grant payment that combine to equal the value of needed repairs. Another line plots the total proceeds (insurance settlement plus proceeds from the sale) that the household would receive if it sold its home privately. The household would receive the home's full value if the home was undamaged. If the household was not fully insured, those proceeds decline with the total amount of damage. The total proceeds from the most lucrative option are lowest for homes with severe but not total damage. If the household accepts an option 1 grant and rebuilds, it owns the home at its full (non-damaged) value, therefore the financial incentive to rebuild was strongest for households with severe but not total damage.

Table 5 describes patterns of participation in the Road Home program. The micro-level participation data that I have at present classifies each household as either an option 1 participant, an option 2 or 3 participant (a single category), or a non-participant. Among households with initially uninhabitable homes, 75% participated in the Road Home program under one of its options. Only about 10% of participants selected option 2 or 3. Among participants, the groups least likely to select options 2 or 3 included those living in areas with that received less than two feet of flooding, those with comprehensive insurance, and those whose homes were uninhabitable but not destroyed.

About 18% of households with an initially uninhabitable home sold the home during the first four years following Katrina. Among households that sold their homes, households were more likely to sell their home privately if the home was moderately damaged and if the household had comprehensive insurance. Households were more likely to accept a Road Home option 2 or 3 grant if the home was destroyed and if a significant fraction of the household's losses were not covered by insurance.

The **Small Business Adminstration (SBA) Disaster Loan Program** is a standing program that provides loans to individual homeowners in federally declared disaster areas to cover the cost of home repairs (less any insurance payments) of up to $200,000. The terms of Disaster Loans are determined on a case-by-case basis based on an assessment of each borrower's ability to repay. Approved applicants who do not have access to other credit receive an interest rate that is no more than 4 percent, and approved applicants who could obtain credit elsewhere receive an interest rate that is no more than 8 percent. SBA's creditworthiness standards are marginally more lenient than a bank's standards, but not all applicants are approved.

For a household that did not have savings sufficient to cover the cost of needed repairs, the ability to borrow was crucial if the household wanted to repair its home without a long delay. The demand for SBA Disaster Loans following Hurricane Katrina was high, and by the end of 2005, about 276,000 Gulf Coast homeowners had submitted applications. However, nearly 82 percent of the applications were rejected due to insufficient income or a poor credit history by the applicant (New York Times, 2005). This rejection rate was higher than the rejection rates following other recent disasters, reflecting the fact that Gulf Coast homeowners on average had lower incomes and poorer credit histories than homeowners in less economically depressed regions. These figures corroborate the findings of the estimated model that many homeowners could not easily borrow to finance repairs.

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

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

The GO Zone initiative also included provisions that altered the tax treatment of capital investment in ways that were favorable to businesses. These provisions altered the time frame over which businesses could deduct various spending on clean-up, demolition, and acquiring property, allowed for the use of tax exempt bonds to raise capital, and provided tax credits to offset rehabilitation expenses. The literature studying the employment impacts of programs that rely primarily on tax breaks and capital subsidies (mainly state Enterprise Zones) finds little evidence of an aggregate impact on job creation or on wages.[14] Therefore, for my analysis of household outcomes, I restrict attention to the effects of the GO Zone's wage subsidies.

4 Simple Model

The programs that were enacted following Hurricane Katrina provided relief to households by reducing the out-of-pocket cost of rebuilding (Road Home program), increasing access to credit (SBA Disaster Loan program), and by increasing the demand for the labor of returning workers (GO Zone program). In this section I develop a simple model of the rebuilding choice in order to illustrate how these policies should be expected to influence rebuilding choices. The simple model is conceptually similar to the more complex model that I consider in the remainder of the paper, and I use the simple model to illustrate how several parameters of the more complex model are identified from data.

The model occurs in discrete time. There are three periods, $t = 1, 2, 3$. Period 1 and 2 are times of flux following the disaster and period 3 represents the household's final resettlement choice. There are two locations, $L = N$ (for New Orleans) and $L = S$ (for elsewhere in the South). Let L_t denote the household's location at time t. The household must choose a location sequence (L_1, L_2, L_3). The household owns a home in location N that is damaged, and repairing the home requires paying a repair cost K. The household may not live in N until the repair cost has been paid.

In periods 1 and 2 the household receives a labor wage of W if it resides in S and receives a labor wage of $W + \Delta_W$ if it resides in N. In period 3 the household receives a labor wage of $\frac{W}{1-\beta}$ if it resides in S and receives a labor wage of $\frac{W+\Delta_W}{1-\beta}$ if it resides in N. This treats period 3 wages as an infinite flow, discounted by a factor of β, of per-period wages that are the same as those available in periods 1 and 2.

[14] See Papke (1993, 1994), Boarnet and Bogart (1996), Bondonio (2003), Bondonio and Engberg (2000), Elvery (2003), and Engberg and Greenbaum (1999).

Each period, the household chooses a consumption quantity C_t, and the household's preferences over consumption are described by,

$$U^C = \ln C_1 + \beta \ln C_2 + \frac{\beta^2}{1-\beta} \ln \Big((1-\beta) C_3 \Big) \tag{1}$$

The household also receives utility from its chosen residence location. Normalizing the location utility in S to zero, the household receives total amenity utility equal to,

$$U^B = \mathbf{1}(L_1 = N)\Delta_B + \mathbf{1}(L_2 = N)\beta\Delta_B + \mathbf{1}(L_3 = N)\frac{\beta^2}{1-\beta}\Delta_W \tag{2}$$

Finally, the household faces a borrowing constraint, modeled as an interest rate when borrowing R_B that is larger than the interest rate when saving R_S. For simplicity, assume that $R_S = 1/\beta$. Let R_t denote the interest rate at which the household's asset holding grows between periods t and $t+1$, either R_B if the asset holding is negative or R_S if the asset holding is (weakly) positive.

Consider the household's optimal choice among four options of when to rebuild; pay the repair cost in period 1 and follow a residence location sequence (N, N, N), pay the repair cost in period 2 and follow a residence location sequence (S, N, N), pay the repair cost in period 3 and follow a residence location sequence (S, S, N), or not pay the repair cost and follow a residence location sequence (S, S, S).

The the household's problem is,

$$\max_{L_1, L_2, L_3, C_1, C_2, C_3} U = \Big(1-\beta\Big)\Big(U^C + U^B\Big) \tag{3}$$

subject to,

$$\begin{aligned} C_1 + \frac{1}{R_1}C_2 + \left(\frac{1}{R_1 R_2}\right)\frac{C_3}{1-\beta} + K \quad = \quad & W + \frac{1}{R_1}W + \left(\frac{1}{R_1 R_2}\right)\frac{W}{1-\beta} \\ & + \mathbf{1}\Big(L_1 = N\Big)\Delta_W \\ & + \mathbf{1}\Big(L_2 = N\Big)\frac{1}{R_1}\Delta_W \\ & + \mathbf{1}\Big(L_3 = N\Big)\left(\frac{1}{R_1 R_2}\right)\frac{\Delta_W}{1-\beta} \end{aligned} \tag{4}$$

An expressions for the indirect utility associated with each possible residence location sequence can be obtained by plugging the associated optimal consumption path into the household's objective function. The Euler equation that characterizes the optimal consumption path dictates that that the household's consumption is constant between any two periods in which the household is a net saver and that consumption grows at a rate of $R_B\beta$ between two periods in which the household is a net borrower. If the household goes into debt to finance repairs, an initially low consumption level is chosen and consumption rebounds as the debt is repaid. In the extreme case in which $R_B = \infty$, repairs must be entirely financed through reduced consumption or through saving. Finally, between periods in which the household neither borrows nor saves, consumption weakly increase but by no more than $R_B\beta$. This last case is a corner solution generated by the discontinuous change in the interest rate between borrowing and saving.

Assuming that interior solutions hold, the indirect utility associate with each residence location sequence is,

$$
\begin{aligned}
V_{NNN} &= \Delta_B \\
&\quad + \ln\left[\left(1 + \frac{1}{R_1} + \frac{1}{R_1 R_2 (1-\beta)}\right)\left(1-\beta\right)W + \left(1 + \frac{1}{R_1} + \frac{1}{R_1 R_2 (1-\beta)}\right)\left(1-\beta\right)\Delta_W - \left(1-\beta\right)K\right] \\
&\quad + \beta \ln\left(R_1\beta\right) + \beta^2 \ln\left(R_2\beta\right) \\
V_{SNN} &= \beta\Delta_B \\
&\quad + \ln\left[\left(1 + \beta + \frac{\beta}{R_2(1-\beta)}\right)\left(1-\beta\right)W + \left(\beta + \frac{\beta}{R_2(1-\beta)}\right)\left(1-\beta\right)\Delta_W - \beta\left(1-\beta\right)K\right] \\
&\quad + \beta^2 \ln\left(R_2\beta\right) \\
V_{SSN} &= \beta^2\Delta_B \\
&\quad + \ln\left[W + \beta^2\Delta_W - \beta^2\left(1-\beta\right)K\right] \\
V_{SSS} &= \ln\left[W\right]
\end{aligned}
$$

The household's utility is then given by,

$$
V = \max\left\{V_{NNN}, V_{SNN}, V_{SSN}, V_{SSS}\right\} \tag{5}
$$

The model's solution finds that rebuilding in periods 1 or 2 is only preferable to not rebuilding if rebuilding in period 3 is preferable to not rebuilding. That is because the per-period amenity returns and wage returns are the same each period, but financing early repairs requires a painful reduction in initial consumption. It is straightforward to show that rebuilding in period 3 is preferable to not rebuilding if,

$$\left(1+\beta^2\Big(\frac{\Delta_W}{W}-\frac{K}{W}\Big(1-\beta\Big)\Big)\right)\exp\Big(\beta^2\Delta_B\Big)>1 \tag{6}$$

For a household that is indifferent between rebuilding in period 3 and not rebuilding, rebuilding will become strictly preferable if K is reduced or Δ_W is increased. This suggests that the fraction of households that choose to rebuild should increase in response to a grant program that offsets the cost of rebuilding and in response to a policy that increased New Orleans wages by boosting labor demand.

If the households prefers to rebuild as opposed to living in S all periods, the optimal time to rebuild depends on how costly it is for the household to finance repairs. A household that is able to borrow at the market interest rate ($R_B = 1/\beta$) and that prefers to rebuild, even if only by a small margin, will prefer to rebuild in period 1, because doing so provides more time for the associated benefits to accrue and borrowing does not require that the household deviate from its preferred smooth consumption path. A household that faces an above market interest rate ($R_B > 1/\beta$) will prefer to rebuild in period 1 only if the wage- and/or amenity-returns to doing so are large, because financing the repairs through borrowing requires a painful reduction in initial consumption. Thus, a policy that increases credit access (reduces the effective borrowing interest rate) should increase the fraction of households that rebuild, especially in a disaster's immediate aftermath.

The model also finds that for households that face a borrowing constraint ($R_B > 1/\beta$), a policy that reduces the cost of rebuilding will have a larger effect on early rebuilding choices than a policy that provides a comparable increase in the present value of wages (computed at the market interest rate). To see this, compare the derivatives of the indirect value functions with respect to the present value of wages to the derivatives of the indirect value functions with respect to the rebuilding cost.

$$\begin{aligned}
\frac{\Big(1-\beta\Big)\times dV_{NNN}\Big/d\Delta_W}{-dV_{NNN}\Big/dK} &= \left(1+\frac{1}{R_1}+\frac{1}{R_1R_2(1-\beta)}\right)\Big(1-\beta\Big)\\
\frac{\Big(1-\beta\Big)\times dV_{SNN}\Big/d\Delta_W}{-dV_{SNN}\Big/dK} &= \left(1+\frac{1}{R_2(1-\beta)}\right)\Big(1-\beta\Big)\\
\frac{\Big(1-\beta\Big)\times dV_{SSN}\Big/d\Delta_W}{-dV_{SSN}\Big/dK} &= 1
\end{aligned} \tag{7}$$

If $R_B > 1/\beta$, the first term is less than the second term, and both terms are less than 1. This suggests that in the presence of a borrowing constraint the impact of a permanent wage boost is smaller than an equal sized reduction in the rebuilding cost. That is because a household that borrows at an above market interest rate to finance repairs will have a higher marginal utility of consumption in the period in which it makes the repairs than in subsequent periods. The benefits from a reduction in the direct cost of rebuilding are concentrated in the period in which they are needed most. This suggests that any wage increases that result from a program that stimulates labor demand will have a smaller impact than a similarly sized direct grant program if a large fraction of households are borrowing constrained.

This simple model also provides the intuition for the identification of preferences for locations and the effective borrowing interest rate in the full model. A similar decision rule to that described in Equation (6) exists in the larger model, and, roughly speaking, the best estimate of the value that households place on living in the pre-Katrina Home is the value that rationalizes the fraction who eventually rebuild given the financial benefit from doing so.

Next consider identification of the effective borrowing interest rate. If there had been no Road Home program, the effective interest rate would be identified from data describing how the timing of home repairs varied with changes in the cost of rebuilding and how the timing of home repairs varied with changes in the relative wages in New Orleans compared and away from New Orleans (after controlling for the fact that the cost of rebuilding is related to the benefit from place Δ_B). Identification would occur by inverting Equation (7). In the presence of the Road Home program, which paid rebuilding grants after a roughly two year delay, this identification argument becomes stronger. For a borrowing constrained household, the disproportionate effect of rebuilding costs on early rebuilding compared to the effect of labor wages on early rebuilding lasts only until rebuilding grants become available. The identification of the effective borrowing rate is aided by observing the change in rebuilding rate before and after the roll-out of the Road Home program.

5 Full Model

In the more complex model that I estimate, the household's problem is conceptually similar to the household's problem in the stylized model, but is more complex in a number of ways that are intended to make the model more realistic and to control for several factors that might confound identification. Most importantly, the household has the option to sell its home, the household must consider the cost of housing across markets, the household faces utility costs to various discrete actions like moving or repairing the home that proxy for logistical or regulatory hurdles, and the household must make its asset accumulation decision with the knowledge that its optimal future migration and rebuilding choices are uncertain. Also, the household selects between three residence locations; the pre-Katrina dwelling, elsewhere in New Orleans, and another Southern metro area.

5.1 Framework, Timing, and Preferences

I model the dynamic problem facing a home owning household in the aftermath of Hurricane Katrina using a finite horizon, discrete time framework. Periods are indexed by $t = 0, .., T$, where 0 is the period in which Hurricane Katrina struck, and T is the horizon of the household's optimization problem. Each period is four months long. An asset holding $A(t)$ and a vector $X(t) = [L(t), H(t), D(t)]$ characterize the state facing the household at time t; where $L \in \{1, 2, 3\}$ denotes location (1 indicates residence in the pre-Katrina home, 2 indicates residence in another New Orleans residence, and 3 indicates residence elsewhere), $H \in \{0, 1\}$ indicates ownership of the pre-Katrina home, and $D \in \{0, 1\}$ indicates the presence of any home damage caused by Hurricane Katrina.

Hurricane Katrina occurs at $t = 0$ at which time the household is endowed with an initial state $X(0)$ and an initial asset holding $A(0)$. Each period t the household observes its current state vector $X(t)$ and must select the subsequent period's state $X(t+1)$ subject to several feasibility constraints that limit the household's available options. The household may not hold negative assets at time T. The household may not re-purchase its home if it has been sold. The household may not reside in the pre-Katrina home if the home has been sold or if it is damaged.

Each period t the household derives constant relative risk aversion utility from its chosen consumption level $C(t)$ and derives utility from the amenities $B(L(t))$ associated with its chosen residence location. In addition, the household suffers a utility costs χ^M and χ^R from moving or rebuilding. These costs capture the difficulty of relocating (χ^M) and the logistical and regulatory hurdles associated with rebuilding (χ^R). An additively separable random utility shock $\epsilon\Big(X(t+1)\Big)$ that is drawn from the type I extreme value distribution is associated with each available choice $X(t + 1)$. These shocks represent unobserved deviations from the average benefit of the various actions, like a health condition or child's enrollment in school that makes relocating more difficult or the delay of a requested permit that delays home repairs. I assume that these shocks are uncorrelated across choices. In this current implementation, I assume that these shocks are i.i.d. across time and across choices. Future implementations will allow for persistent unobserved heterogeneity in $B(L = 1)$. The utility associated with a single period is,

$$\begin{aligned} u\Big(t\Big) \quad = \quad & \frac{1}{\alpha}\frac{C\Big(t\Big)^{1-\omega}}{1-\omega} \; + \; B\Big(L(t)\Big) + \epsilon\Big(x(t+1)\Big) \\ & - \chi^M \mathbf{1}\Big(L(t+1) \neq L(t)\Big) \\ & - \chi^R \mathbf{1}\Big(D(t+1) < D(t)\Big) \end{aligned} \tag{8}$$

The household repeatedly chooses its state $X(t)$ until the household age reaches 65, at which time its state is fixed. If the household is older than 65 when Katrina occurs or will reach age 65 within eight years of Katrina, the household may continue adjusting its state X throughout the first eight years following Katrina. Once the state $X(t)$ is fixed, the household derives utility during retirement until age 80 (labeled period T). During retirement the household derives utility from its residence location and the consumption associated with Social Security income plus a stream of annuity payments based on the household's asset holding at retirement minus any mortgage or rent payments associated with the chosen residential location. The household's objective is to maximize the present discounted value of future per-period utilities, denoted by U.

$$U = \sum_{t=0}^{T} \beta^t \, u\Big(t\Big) \tag{9}$$

where β is a subjective discount factor.

5.2 Prices and Budget Constraint

I assume that households are aware of relevant prices across time and locations, and that households are bound by an intertemporal household budget constraint that requires consumption plus net asset accumulation to equal income (wage earnings plus the proceeds from home sales or grant payments) minus expenses (home repair costs and rent or mortgage payments).

Each period, each working household head receives the market wage for his or her human capital level and occupation in the chosen residential location's labor market $W(L)$. Residence in locations $L = 1, 2$ places the household in the New Orleans labor market and residence in $L = 3$ places the household in a pooled "other metro South" labor market.

If $L(t) = 1$, the household derives housing services from the pre-Katrina home. However, if $L(t) = 2$ or $L(t) = 3$ the household must rent an equivalent flow of housing services at the market rate $RENT(L(t))$ in the chosen location. If the household owns its pre-Katrina home, the household must make a mortgage payment $M(t)$ if the home is not fully paid off.

If the household chooses to repair its home, it must pay a repair cost K. Partial repairs over multiple periods are not permitted, but the household may self finance by saving a portion of the total repair cost over several periods before purchasing repairs.

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

The household's budget constraint incorporates an approximation to the Road Home program's actual eligibility rules. To capture the availability of the option 1 package of benefits, a household that repairs or sells its home during the first two years following Katrina is reimbursed for uninsured repair costs in period 7, the first period after the second anniversary of Katrina. If the household purchases home repairs between periods 7 and 15 (during the third, fourth, and fifth years after Katrina), the household is reimbursed at the time the repairs are made. I define G_1 to be the size of the available option 1 grant. To reflect the possibility of participating under option 2 of the Road Home program, I define the term G_2 to be the size of the option 2 grant that is available to the household. If the household sells its home between periods 7 and 15, the household has receives the the option 2 grant or the market value of the home, whichever is larger.

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

$$G_2(t) = \begin{cases} \min\left[\$150,000\ ,\ K - INS\right] & \text{if } t \in [7, 15] \text{ and } H(t) < H(t-1) \\ 0 & \text{otherwise} \end{cases} \tag{10}$$

$$\tag{11}$$

These components enter household's intertemporal budget constraint as follows,

$$\begin{aligned} C(t) = & \overbrace{W\Big(L(t)\Big)}^{\text{wage income}} + \overbrace{\Big(\max\Big(G_2(t), P^H - D(t)K\Big) - PRINC(t)\Big)\Big(H(t) - H(t+1)\Big)}^{\text{proceeds from home sale}} + \overbrace{G_1(t)}^{\text{Option 1 grant}} \\ & - \underbrace{H(t)\ M(t)}_{\text{mortgage payment}} - \underbrace{RENT\Big(L(t)\Big)}_{\text{rent payment}} - \underbrace{K\Big(D(t+1) - D(t)\Big)}_{\text{repair costs}} - \underbrace{\Big(A(t+1)/(1+r)\ -\ A(t)\Big)}_{\text{change in asset holding}} \end{aligned} \tag{12}$$

I model the possibility of a borrowing constraint by allowing the interest rate faced when borrowing to exceed the interest rate faced when saving. That is,

$$\begin{aligned} A(t+1)\Big/(1+r) &= \begin{cases} A(t+1)\Big/(1+r^S) & \text{if } A(t+1) \geq 0 \\ A(t+1)\Big/(1+r^B) & \text{if } A(t+1) < 0 \end{cases} \\ r^B &\geq r^S \end{aligned} \tag{13}$$

5.3 Dynamic Programming Representation

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

$$
\begin{aligned}
V\Big(A(t), X(t), \epsilon\Big) &= \max_{A(t+1), X(t+1)} \Bigg\{ u\Bigg(X\Big(t\Big), X\Big(t+1\Big), A\Big(t\Big), A\Big(t+1\Big), \epsilon\Big(X(t+1)\Big)\Bigg) \\
&\quad + \beta\, \overline{V}\Bigg(A\Big(t+1\Big), X\Big(t+1\Big)\Bigg) \Bigg\} &(14) \\
\overline{V}\Bigg(A\Big(t+1\Big), X\Big(t+1\Big)\Bigg) &= \text{Emax}_{\epsilon} V\Bigg(A\Big(t+1\Big), X\Big(t+1\Big), \epsilon\Bigg) &(15)
\end{aligned}
$$

Because the choice specific ϵ shocks vary with $X(t+1)$ but not $A(t+1)$, the optimal asset accumulation policy is a deterministic function of the current state and the chosen state, and Equation (14) may be rewritten as,

$$
\begin{aligned}
V\Big(A(t), X(t), \epsilon\Big) &= \max_{X(t+1)} \Bigg\{ u\Bigg(X\Big(t\Big), X\Big(t+1\Big), A\Big(t\Big), A^*\Big(X(t), X(t+1), A(t), t\Big), \epsilon\Big(X(t+1)\Big)\Bigg) \\
&\quad + \beta\, \overline{V}\Bigg(A^*\Big(X(t), X(t+1), A(t), t\Big), X\Big(t+1\Big)\Bigg) \Bigg\} &(16)
\end{aligned}
$$

where $A^*\Big(X(t), X(t+1), A(t), t\Big)$ is the optimal asset accumulation policy conditional on the household's initial state (X, A) and chosen state (X).

$$
\begin{aligned}
A^*\Big(X(t), X(t+1), A(t), t\Big) &= \arg\max_{A(t+1)} \Bigg\{ u\Bigg(X\Big(t\Big), X\Big(t+1\Big), A\Big(t\Big), A\Big(t+1\Big), \epsilon\Big(X(t+1)\Big)\Bigg) \\
&\quad + \beta\, \overline{V}\Bigg(A\Big(t+1\Big), X\Big(t+1\Big)\Bigg) \Bigg\} &(17)
\end{aligned}
$$

This representation is convenient for estimation, because it allows for households' financial assets (which are not observed in the data) to be conditioned out of the likelihood function. In practice, I discretize the asset space, so for any current state and chosen state the definition of A^* in Equation (17) requires finding the maximal element of among a finite set.

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

$$
\begin{aligned}
&\overline{V}\Big(A(t), X(t)\Big) = \\
&\ln \Bigg\{ \sum_{X(t+1)} \exp\Big(\overline{u}\Big(X(t), X(t+1), A(t), A^*\Big(X(t), X(t+1), A(t), t\Big)\Big) + \overline{V}\Big(X(t+1)\Big)\Big) \Bigg\} + \gamma \qquad (18)
\end{aligned}
$$

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

$$
\begin{aligned}
&\mathrm{P}\Big(X(t{+}1)\Big|A(t),X(t)\Big) = \\
&\frac{\exp\Big[\overline{u}\Big(X(t),X(t{+}1),A(t),A^*\Big(X(t),X(t{+}1),A(t),t\Big)\Big)+\overline{V}\Big(A(t{+}1),X(t{+}1)\Big)\Big]}{\sum_{X'(t+1)}\exp\Big[\overline{u}\Big(X(t),X'(t{+}1),A(t),A^*\Big(X(t),X'(t{+}1),A(t),t\Big)\Big)+\overline{V}\Big(A(t{+}1),X'(t{+}1)\Big)\Big]}
\end{aligned}
\tag{19}
$$

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

6 Model Parameterization and Estimation

The parameters of the model to be estimated include a wage equation, a set of household preferences, and a parameter describing the interest rate at which households may borrow. I estimate the model sequentially. In the first step, I estimate the wage equation. In the second step, the first step's estimates are treated as a known input and I estimate the parameters that describe households preferences and the borrowing interest rate.

6.1 Wages

I assume that each period each household head who was employed during the year prior to Katrina receives a wage that reflects the value of his or her skills in the the worker's residence location. Let j index workers, k index a worker's three-digit occupation, l index the labor market in which the worker resides, and t indexes the period. I assume that the wage depends on the mean wage within the worker's occupation in the worker's residence location, the worker's observable human capital traits, and an unobserved worker fixed effect according to,

$$
\ln w_{jklt} = \ln \overline{w}_{klt} + x_j'\beta + \eta_j \tag{20}
$$

I obtain mean occupation wages by year and MSA $\overline{w}_{klt}$ from the BLS Occupational Employment Statistics. I then compute an estimate $\widehat{\beta}$ by regressing the log of annual earnings on the log of mean occupation wages (constraining the coefficient on that variable to be one) and the vector of human capital traits x using a pooled sample of pre-Katrina annual earnings records from DNORS and annual earnings records from New Orleans MSA respondents to the 2005 ACS. Finally I obtain estimates $\widehat{\eta}_j$ of the worker fixed effects by computing the residuals from this regression for all DNORS respondents who were employed during the year prior to Katrina.

6.2 Parameterizing household's preferences and the borrowing interest rate

Two parameters describe the consumption component of utility $\frac{1}{\alpha}\frac{C^{1-\omega}}{1-\omega}$; the coefficient of relative risk aversion ω and a scale parameter α that describes the importance of consumption utility relative to the unobserved utility shocks ϵ whose variance is normalized.

I normalize the borrowing interest rate $(1+r^B)$ to equal $1/\beta$ for non-black households in which at least one household head holds a bachelor's degree. I allow the borrowing rate to deviate from that quantity with an indicator that a household is black, with an indicator for no bachelor's degree, and indicators for pre-Katrina household income during the year prior to Katrina being $\$0-\$20k$ or $\$20k-\$40k$.

The term $B(L)$ reflects the utility derived from a chosen residence location L. I normalize $B(L=3)$ to zero. The value of $B(L=2)$ is a single parameter to be estimated. I allow $B(L=1)$ to depend on the level of damage to the household's neighborhood and on several factors that are typically associated with attachment to place. I classify neighborhood damage using the fraction of owner occupied homes on the same block segment[15] that were rendered uninhabitable by Katrina. I group this continuous measure into three groups; $0\%-50\%$, $50\%-90\%$, and $90\%-100\%$. I allow $B(L=1)$ to follow a linear time trend during the first five years following Katrina within the two higher damage categories. This parameterization allows for the possibility that living in a neighborhood that was heavily flooded might have been especially unappealing shortly after Katrina but may become more attractive as time passes. I also allow $B(L=1)$ to depend on when the household purchased its home and whether either head was born outside of Louisiana.

Following earlier structural migration papers (Kennan and Walker, forthcoming; Bishop, 2007) I allow the utility cost to moving χ^M to vary with the distance of the move. The utility cost of moving depends on an indicator for any change in location, an indicator that the move was to or from New Orleans (not within the city), and an indicator that the move occurred during the first period after a home repair. This parameterization allows for the possibilities that moving is more difficult if the destination is far away and that moving home is more likely immediately following a home repair.

I allow the utility cost to repairing one's home χ^R to depend on whether the household's home was destroyed or not. I also allow this utility cost to vary according to a linear time trend that may be different for destroyed and non-destroyed homes during the first five years after Katrina. This parameterization allows for the possibility that the logistical hurdles involved with rebuilding a destroyed home were more difficult to surmount than those associated with repairing a damaged but not destroyed home. The time trend captures initial regulatory uncertainty and difficulties with the process of obtaining repair permits that dissipated during the years following Katrina.

[15]DNORS sampling procedure involved randomly selecting block segments and then randomly selecting households from selected block segments. A block segment contained an average of around twenty owner occupied dwellings.

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

6.3 Estimation

To estimate the vector θ containing the utility function parameters and the borrowing rate parameters, assume that a sample of households $i = 1, ..., N$ solve the above model. For each household, I observe the sequence of choices $\{X_i(t)\}_{t=1}^T$. For each household, I estimate the distribution function $\widehat{F}^i_{A_0}(a)$ describing the CDF of the household's initial asset holdings conditional on the household's observable traits. Appendix I describes the method used to estimate these distribution functions, and during the discussion in this section I consider them to be known inputs. I do not observe households' realized initial financial asset holding or the choice specific utility shocks ϵ.

Conditional on an asset holding at time zero, the subsequent asset holding A^* is a latent variable whose path is determined within the model. This feature of the model allows for the likelihood of an observed panel to be computed from observed choices if the initial asset holding is known. Because the initial asset holding is unobserved, I compute the likelihood of each household's observed choices at a range of initial asset values and then integrate those conditional likelihoods with respect to each households estimated distribution of initial asset holdings $\widehat{F}^i_{A_0}(a)$.

I compute the latent asset variable associated with an initial asset holding $A(0)$ and a household's observed choices using,

$$\widehat{A}_i\Big(t\Big|\Big\{X_i(\tau)\Big\}, \theta, A(0)\Big) = \begin{cases} A_i(0) & \text{if } t = 0 \\ A^*\Big(X_i(t-1), X_i(t), A_i(t-1), t-1\Big) & \text{if } t > 0 \end{cases} \tag{21}$$

where the function $A^*()$ is defined in Equation (17). This asset path may then be used when computing the likelihood function for a given household. For the $5th$, $15th$, ..., $95th$ percentiles of the distribution of $A_i(0)$, I compute.

$$l\Big(\theta\Big|\{X_i(t)\}_{t=1}^T, A(0)\Big) = \Pi_{t=0}^{11} \mathrm{P}\Big(X_i(t+1)\Big|\widehat{A}_i(t|A(0)), X_i(t), \theta\Big) \tag{22}$$

Next, I recover a likelihood function for a given household that depends only on observable variables by integrating with respect to the household's distribution of initial asset holdings.[16]

$$l\Big(\theta\Big|\{X_i(t)\}_{t=1}^T\Big) = \int \Big[\Pi_{t=0}^{11} \mathrm{P}\Big(X_i(t+1)\Big|\widehat{A}_i(t|a_0), X_i(t), \theta\Big)\Big] d\widehat{F}^i_{A(0)}(a_0) \tag{23}$$

[16] In practice, I approximate $F^i_{A(0)}(a_0)$ using ten equally weighted discrete points of support, as described in Appendix I. As a result, this integral is computed as a sum across those ten support points weighted by $dF^i_{A(0)}(a_0) = .1$.

Finally, I construct the likelihood for the full panel by computing the product of the individual household likelihood.

$$l\Big(\theta\Big|\{X(t)\}_{t=1}^{T}\Big) \quad = \quad \Pi_{i=1}^{N}\int\Big[\Pi_{t=0}^{11}\mathrm{P}\Big(X_i(t+1)\Big|\widehat{A}_i(t|a_0),X_i(t),\theta\Big)\Big]d\widehat{F}_{A(0)}^{i}(a_0) \qquad (24)$$

Using this expression, I compute a nested fixed point estimator of θ. An "inner loop" computes a numerical solution to the model and obtains a sample log-likelihood at a given guess of θ, and an "outer loop" searches the parameter space for the likelihood maximizing parameter vector $\widehat{\theta}$.

7 Parameter Estimates and Model Fit

Tables 6 presents estimates of the labor wage equation.

Table 7 provides estimates of the full model's structural parameters. Recall that the borrowing interest rate was normalized to equal the saving interest rate for non-black households with a bachelor's degree and income above \$40k per year. The estimated borrowing rate parameters find a 35 log-point higher effective borrowing interest rate for black households and a 7 log-point higher effective borrowing interest rate for households with an income during the year prior to Katrina that was below \$20k. These estimates suggest that black households and low-income households faced substantial barriers to credit.

The estimated parameters for $B(L)$ suggest that households had a significant preference for returning to New Orleans, and that households in the lowest and highest damaged areas had a significant preference for returning to the pre-Katrina home in the long term. Residing in a heavily damaged area appears, not surprisingly, to have been an unattractive option in Katrina's immediate aftermath. Households with a head born away from New Orleans received a significantly lower utility from returning to the pre-Katrina home. I do not find any systematic difference in the utility from returning to the pre-Katrina home associated with the year in which the home was purchased.

I find that the utility cost to repairing a destroyed home was significantly higher than that of repairing an unliveable (but not destroyed) home. Also, there was a large and statistically significant negative time trend in the disutility to repairing a home during the first five years following Katrina. That trend suggests that the logistical hurdles involved with repairing a home were especially difficult in Katrina's immediate aftermath.

Table 8 assesses the model's fit. I compare the actual prevalence of four outcomes on the first four anniversaries of Katrina with the prevalence of those same outcomes predicted by the estimated model. For each comparison, I report a chi-squared test statistic associated with the null that the predicted moment and the sample moment are equal. The model predicts many key features of the data, but the model's fit is not exact in a number of places. While the imperfect fit of a simple structural model is not surprising, I anticipate that the model's fit will improve in future implementations that include several additional explanatory variables in the equation for B and allow for persistent unobserved heterogeneity.

8 Counterfactual Simulation Experiments

This section presents the results of two sets of counterfactual policy simulation experiments that assess how households' rebuilding choices might have been influenced by the programs enacted in the aftermath of Katrina. First, I conduct a set of simulations that are designed to assess the impact of the Road Home program on aggregate rebuilding rates. Then, I compute a set of simulations to compare the marginal impact of an increase in New Orleans wages on rebuilding rates to the marginal impact of providing a direct grant of equal present discounted value (computed at the savings interest rate). I use this second set of simulations to compute an upper bound on the impact that wage increases associated with the Gulf Opportunity Zone's wage subsidies might have had on rebuilding rates.

Under each scenario that I consider, I compute $2,000$ simulated panels for each household. For each simulated panel, the household begins with its true initial location L, home damage status D, and owning its home $H = 1$. One tenth of each household's simulations are computed using each of the 5th, 15th, ..., 95th percentiles of the household's estimated distribution of initial of initial liquid asset holdings as a starting value for its initial asset holding. When computing mean outcomes from the simulated data, I weight each simulated panel by the ex-post probability that a household falls at the assumed initial asset holding conditional on its observed choice sequence.[17]

8.1 The impact of Road Home program

To assess the partial equilibrium impact of the Road Home program, I compare households' choices under four scenario's. In the first scenario, no grants are paid to households but all other parameters of the model are left at their estimated values. In the second scenario, no grants are paid to households, but all households are given the ability to borrow at the market interest rate $1/\beta$. In the third scenario, all households receive the Road Home grant at $t = 7$ (the first period after the second anniversary of Katrina) regardless of their rebuilding, home sale, or residency choices.

[17] The ex-post probability that a household held a given initial asset level $A(0)$ among the 10 support points of the approximated distribution is equal $.1 \times l\Big(\theta \Big| \{X_i(t)\}_{t=1}^T, A(0)\Big)/l\Big(\theta \Big| \{X_i(t)\}_{t=1}^T\Big)$, that is, the ex-ante weight (.1) times the ratio of the household's panel's likelihood conditional on the initial asset level $A(0)$ to the household's panel's unconditional likelihood.

Other parameters, including the borrowing interest rate, are set to their estimated values. In the fourth scenario (the baseline scenario), households face the Road Home program's rules as they were approximated in the estimated model, and all model parameters are set to their estimated values.

Comparing households choices across scenarios provides an estimate of the impact of the Road Home program on household's resettlement choices. The comparisons also provide estimates of the relative importance of various components of the program. I consider the difference in rebuilding rates between scenarios one and four to be an estimate of the Road Home program's partial equilibrium impact. I use the difference between scenarios one and two to assess the fraction of the Road Home program's total impact that was attributable to relaxing borrowing constraints, an impact that in principal could have been achieved with a loan program. I consider the difference in rebuilding rates between scenarios three and four to be an estimate of the portion of that impact that can be attributed to the program's rules that conditioned grant payments on households' behavior.

Table 9 describes the results of these simulations. The simulations find that the Road Home program increased the fraction of households that repaired or rebuilt severely damaged within four years of Katrina by 14.2 percent (from 39.6 percent to 45.3 percent).

The model also finds large differences in the impact of the Road Home program across race and education groups, presumably because of differences across groups in financial resources and in borrowing opportunities. I estimate that the Road Home program increased rebuilding rates among black households by the fourth anniversary of Katrina by 17.6 percent. The Road Home program increased rebuilding rates among non-black households by just 8.1 percent. Similarly, the Road Home program increased rebuilding rates among households without a bachelor's degree by 18.4 percent compared to a 9.2 percent impact among households with a bachelor's degree.

The simulations of households' choices in the second scenario illustrate the importance of borrowing constraints in shaping post-Katrina rebuilding patterns. In that scenario, no grant payment is available, but all households are allowed to borrow at the market rate ($1/\beta$). This scenario approximates an expansion of the SBA Disaster Loan program to all homeowners. The simulations find that expanding credit access in the absence of a grant program would have had an impact on the rebuilding rate within four years of Katrina that was about 80% the size of the Road Home program's impact. Also, a larger fraction of rebuilding occurred during the first two years following Katrina, as some credit constrained households that would have waited for Road Home grants before rebuilding were able to rebuild earlier when provided with access to credit.

The simulations of households' choices in the third scenario assess what fraction of the Road Home program's impact is attributable to the program's rules that provided more generous grants to households who agreed to rebuild. The simulations find that the impact of the Road Home program would have been essentially unchanged if the rebuilding requirement was removed and all households that with uninsured damages were provided with an option 1 grant. The simulations find that the program's aggregate impact on rebuilding within four years was only about 2.5% smaller when the rebuilding requirement was removed. The simulations find that the rebuilding requirement had a similarly small impact across demographic subgroups. The Road Home program's rules provided the strongest financial incentive to rebuild among households that had moderately damaged homes and small insurance settlements. The model finds that these households strongly preferred to return to their pre-Katrina homes. Conditional on having the financial resources to repair the damaged home, the constraint that those funds be used for rebuilding did not bind in most cases. To the extent that the Road Home program's slow roll-out can be attributed to its complex rules, these findings suggest that a simpler program that was rolled out more quickly could have increased welfare substantially without causing a large drop in rebuilding rates.

8.2 The marginal impact of wage subsidies and direct grants

Next, I compare the impact of an increase in New Orleans wages during the first four years following Katrina to the impact of a similarly sized (in present discounted value terms) grant payment made at time 0. I present the results of these simulations in Table 10. This comparison allows me to directly assess the extent to which, in the presence of financing constraints, lump sum payments influence behavior differently than wage benefits that accrue gradually over time. Under a first scenario (no wage subsidy), I remove $2,400 per worker from New Orleans wages spread uniformly over the first four years following Hurricane Katrina. I consider this wage change to be an upper bound on the impact of the Gulf Opportunity Zone's Work Opportunity and Employee Retention tax credits on wages, since it assumes that employers claimed an employment credit for 100% of workers and that the incidence of the subsidy fell completely on workers. Under a second scenario (baseline simulations), I return wages to their original levels. Under a third scenario (wage subsidy replaced by grant), I hold wages at $2,400 per worker below their true levels and provide each household with a $2,400 grant at time 0 that does not depend on their resettlement choices.

Comparing simulated choices with and without wage subsidy finds that the wage subsidy increased the fraction of homes that were rebuilt by the fourth anniversary of Katrina by about 0.15 percentage points. The small size of this impact relative to the impact of the Road Home program is not surprising given the difference in the absolute size of the incentives provided by the programs. To assess the relative effectiveness of wage subsidies and direct grants, one should compare the impact of a wage increase to the impact of a similarly sized grant. The simulations find that implementing the direct grant (in place of the wage subsidy) increased rebuilding rates by the fourth anniversary of Katrina by about 3.8 times the amount that the wage subsidy did. This finding suggests that borrowing constraints have large practical implications for policy, as programs whose costs are roughly equivalent have dramatically different impacts.

Not surprisingly, the simulations find that the difference between the impact of wage subsidies and the impact of direct grants was especially large among black households and households with low education, the groups estimated to face the most severe borrowing constraints. Among black households, the impact of the grant program is 6.0 times the size of the impact of the equivalent wage subsidy. Among households with no bachelor's degree, the impact of the grant program is 5.6 times the size of the impact of the equivalent wage subsidy. These findings suggest that in a post-disaster context, policymakers choices of how to subsidize returning residents could have a significant impact on both the size and the demographic composition of the rebuilding group.

9 Conclusion

This paper develops and estimates a dynamic structural model of pre-Katrina New Orleans households' post-Katrina rebuilding choices and uses the model to assess the impacts of various government interventions on rebuilding rates. During the first two years following Hurricane Katrina, black households and households with lower educational attainment rebuilt severely damaged homes at a much lower rate than non-black households and college educated households. By the fourth anniversary of Katrina, the disparities across demographic groups in the fraction of severely damaged homes that had been repaired had closed substantially. The structural model finds that these patterns are best rationalized by a model that includes large financing constraints for black households households and low income households.

Using the estimated model, I compute a series of counterfactual policy simulation experiments to assess the impact of the Road Home program on households' rebuilding choices and to assess the relative effectiveness of wage subsidies and rebuilding grants at increasing rebuilding rates. The simulation experiments suggest that the Road Home program increased the fraction of households with severely damaged homes who had rebuilt within four years by about 14 percent. The largest impact occurred among black households who, on average, had less comprehensive insurance coverage, had fewer available liquid assets with which to self finance repairs, and appear to have faced significant borrowing constraints. A second set of simulation experiments suggest that, on the margin, direct grants increase rebuilding rates by roughly three times the amount of similarly sized (in present value terms) wage subsidies the accrue evenly over four years.

Because of the many drawbacks involved with providing direct grants to households, the findings of this study suggest that there is no silver bullet for effectively subsidizing households to return and rebuild in the aftermath of a disaster. Implementing a direct grant program like the Road Home program takes a considerable amount of time, is potentially vulnerable to fraud, and involves the usual dead weight loss involved with raising public funds. Further, a direct grant program is more likely to introduce moral hazard to households' subsequent insurance decisions than wage subsidies if households who neglected to obtain full insurance before the recent disaster receive larger grants. Given these drawbacks, policymakers might prefer other types of subsidies if those other types of subsidies generated similar impacts on rebuilding rates. The results of this study suggest, however, that other forms of subsidy are simply less effective than direct grants.

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

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Appendix I: Imputed Asset Distribution

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

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

I compute a measure of each PSID household's liquid asset holding by adding the values of the household's of non-IRA stock holdings, bond holdings, and holdings in checking accounts, savings accounts, money market accounts, and CDs. I then compute the required quantiles of the asset distribution for each DNORS household given the household's observable characteristics using a two step procedure. First, I estimate a household level logistic regression of an indicator for a positive asset holding on a large set of household covariates.[18] Denote with $p(x)$ the predicted probability of having a positive asset holding conditional on a particular combination of these covariates x. I set $F^{-1}_{A(0)}(p|x) = 0$ for each $p < p(x)$.

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

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

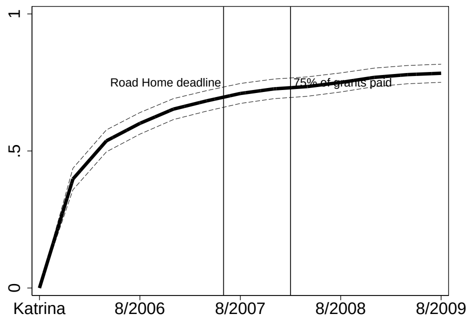
Appendix II: Computing Price Variables

See Table $A1$ for a full list of variable definitions.

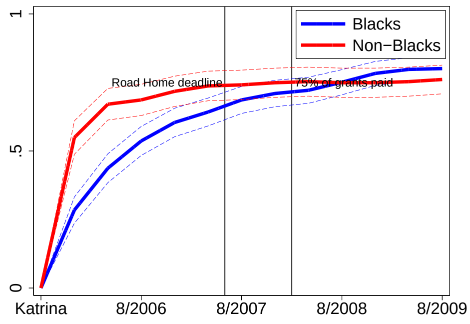
Several of these variables are computed using a set of rental price indices. I compute rental price indices that relate the price of housing in post-Katrina New Orleans and in the metro South to the price of housing in pre-Katrina New Orleans using a regression based procedure. I construct a data set of rental properties and building characteristics for three distinct housing markets; the market in pre-Katrina New Orleans, the market in post-Katrina New Orleans between from 2006-2009, and pooled sample of "other Southern metro" areas from 2006-2009. I then regress the log of rent on a set of building characteristics and housing market fixed effects. I normalize the price index in pre-Katrina New Orleans to one, and compute indices for the two other markets by exponentiating the difference between the market's estimated fixed effect and the pre-Katrina New Orleans fixed effect.

Appendix table $A2$ presents estimates of housing price indices across locations. After adjusting for building characteristics, I find that post-Katrina New Orleans rents exceeded pre-Katrina rents by 35 log points, while rents in other Southern metros during the post-Katrina period exceeded those in pre-Katrina New Orleans by 23 log points.

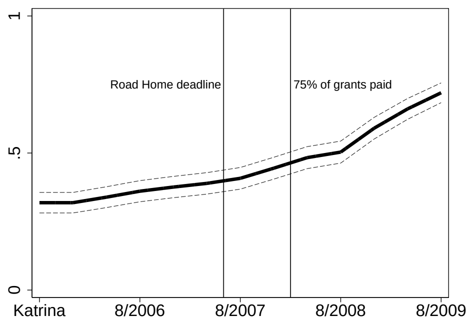
Figure 1: Outcome Trends — all pre-Katrina New Orleans Home Owning Households



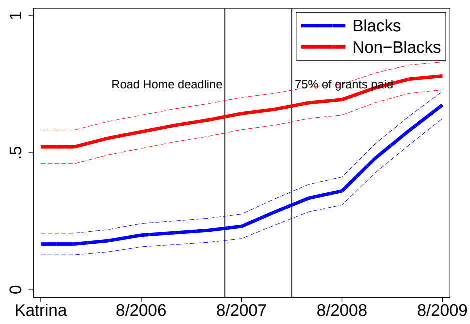
(a) Living in New Orleans



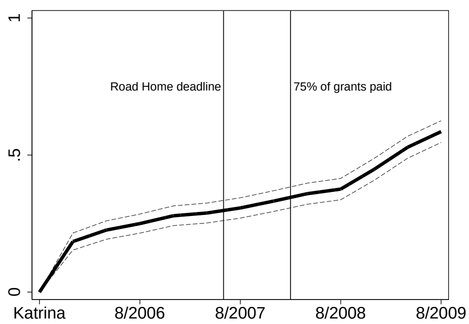
(b) Living in New Orleans - by race



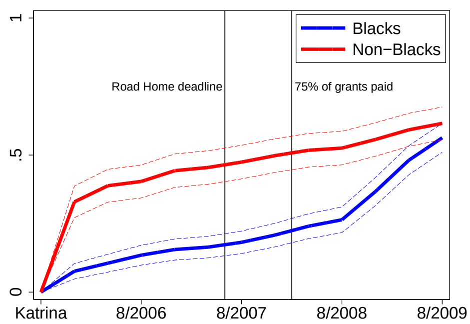
(c) Repaired pre-Katrina home



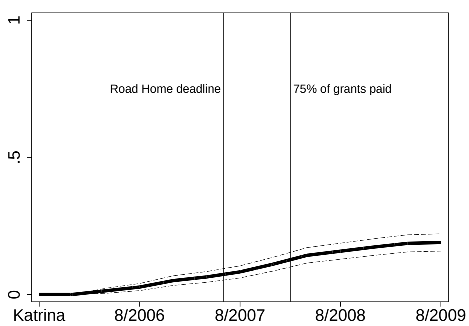
(d) Repaired pre-Katrina home - by race



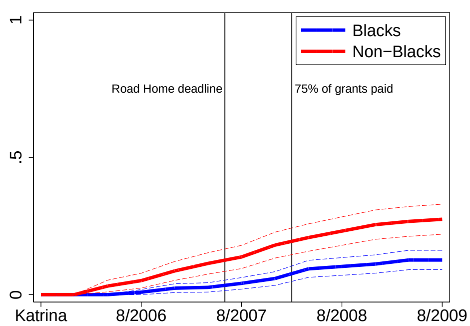
(e) Residing in pre-Katrina home



(f) Residing in pre-Katrina home - by race



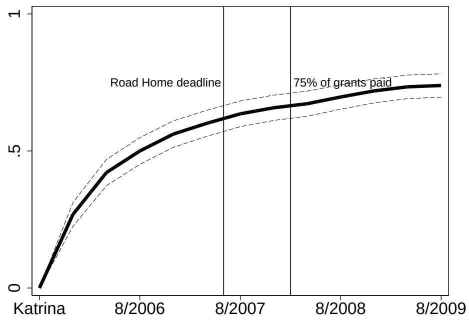
(g) Sold pre-Katrina home



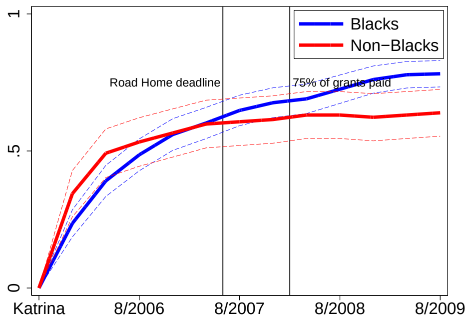
(h) Sold pre-Katrina home - by race

Note: Solid lines provide sample means and the dashed lines provide 95% confidence intervals. Source: DNORS and Orleans Parish Assessor's Office property database

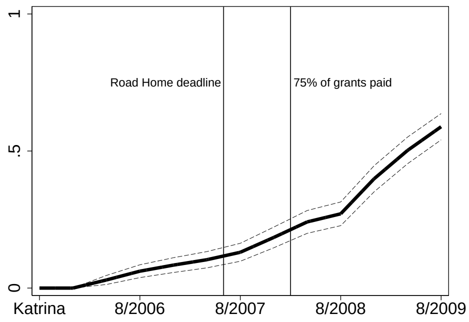
Figure 2: Outcome Trends — pre-Katrina homeowning households with initially unliveable homes



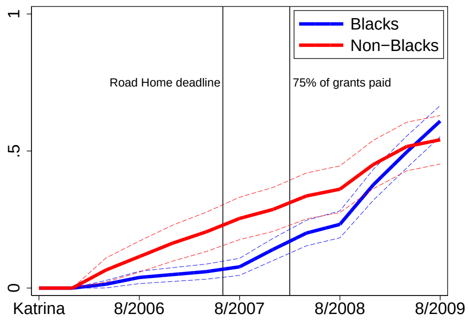
(a) Living in New Orleans



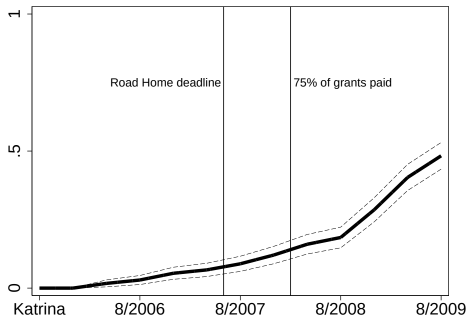
(b) Living in New Orleans - by race



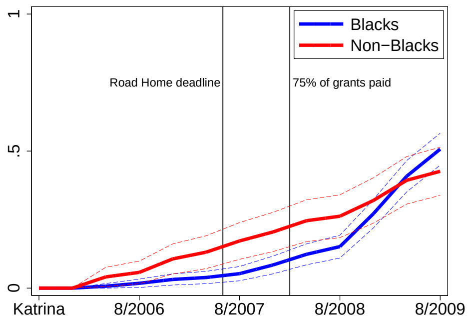
(c) Repaired pre-Katrina home



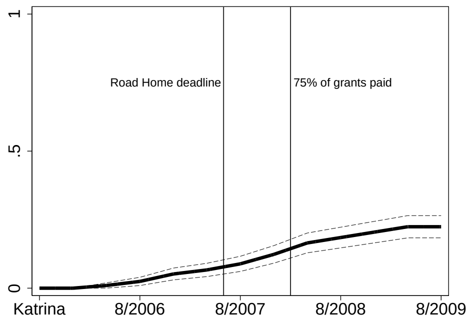
(d) Repaired pre-Katrina home - by race



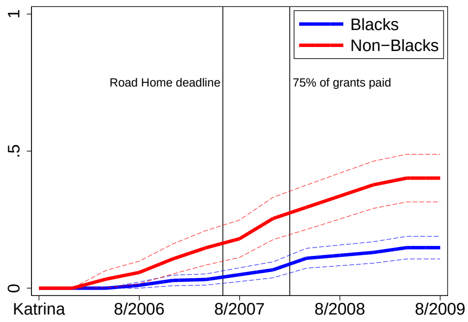
(e) Residing in pre-Katrina home



(f) Residing in pre-Katrina home - by race



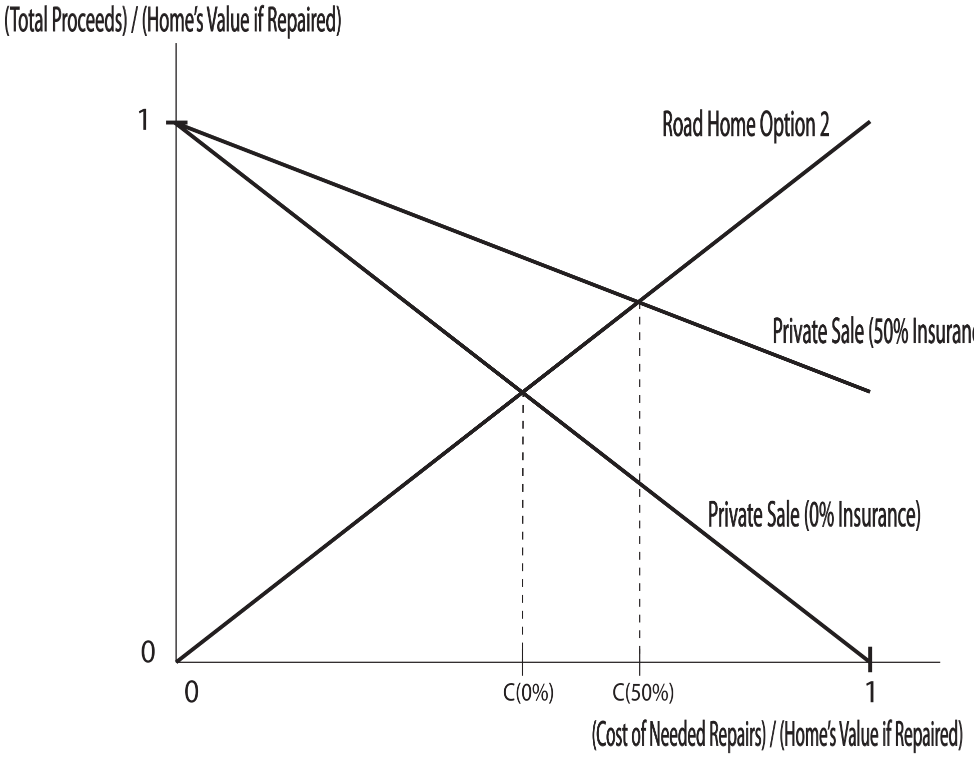
(g) Sold pre-Katrina home



(h) Sold pre-Katrina home - by race

Note: Solid lines provide sample means and the dashed lines provide 95% confidence intervals. Source: DNORS and Orleans Parish Assessor's Office property database

Figure 3: Proceeds from Accepting a Road Home Option 2 Grant Compared with Proceeds from Selling a Home Privately



Note: If a household accepts an option 2 Road Home rebuilding grant, the sum of insurance payments and the grant payment equal the cost of repairs needed for the home. If a household sells its home privately, it receives any insurance proceeds plus the home's sale price, which reflects the home's as is value. This figure plots these two quantities as fractions of the home's value if it was fully repaired to illustrate when a household would prefer an option 2 grant and when a household would prefer to sell its home privately. A household that sells its home was best off accepting an option 2 Road Home rebuilding grant if its home is heavily damaged and/or few of the home's damages were covered by insurance.

Table 1. Household Background Characteristics

	DNORS (unweighted)				2005 ACS (IPUMS)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Homeowners	Single family homes	Drop < 65 with no workers	**Merged with assessor's data**	Unweighted homeowners	Weighted homeowners	Drop < 65 with no workers
Composition							
Solo male headed	21.2	20.7	19.5	**18.9**	18.3	19.1	16.8
Solo female headed	39.7	38.6	37.0	**37.4**	36.7	36.0	36.3
Couple headed	39.1	40.7	43.5	**43.8**	45.0	45.0	46.9
Race							
Either head is black	56.5	57.2	56.3	**56.7**	46.9	54.5	52.7
Neither head is black	43.5	42.8	43.7	**43.3**	53.1	45.5	47.3
Education of most educated head							
H.S. dropout	11.3	10.3	9.8	**9.5**	11.9	10.2	8.8
H.S. graduate	19.0	19.6	19.1	**19.2**	17.2	21.1	20.6
Some college	25.1	25.0	24.7	**24.2**	20.7	19.7	17.9
Bachelor's degree or higher	44.3	44.8	46.0	**47.1**	50.2	49.0	52.7
Household age †							
Under 40	11.0	11.1	10.4	**9.0**	15.5	18.0	18.3
40-49	15.5	15.2	16.0	**13.8**	19.2	23.8	24.4
50-64	38.6	39.1	35.6	**36.3**	35.8	35.4	32.3
65 or older	34.9	34.5	38.1	**40.8**	29.5	22.8	25.0
Assessed home value in 2005							
Less than $60k				**33.7**			
Between $60k and $120k				**40.5**			
Between $120k and $180k				**9.5**			
More than $180k				**16.3**			
Observations	948	808	733	**578**	733	733	633

† Household age is defined to be the age of the male household head if present and the age of the female head otherwise.

Note: This table reports the sample means of household background variables for the sample of pre-Katrina New Orleans households that I use to estimate the dynamic model (column 4), and compares those means to similar calculations from the American Community survey. Survey weights have not yet been released for DNORS. Comparing columns 1 and 5 finds that DNORS respondents are somewhat older on average than ACS respondents. Comparing columns 5 and 6 suggests that ACS survey weights place less weight on older households suggesting that non-response is higher among younger hoseholds. Presumable DNORS weights will apply a similar correction when they become available.

Source: Columns 1-3 come use DNORS data. Column 4 uses DNORS data and Assessor's data. Columns 5-7 use ACS data.

Table 2. Storm Damage and Resources Available for Repairs

		Race		Education	
	All households	Blacks	Non-Blacks	No bachelor's	Bachelor's
Distribution of storm damages (N=578)					
Flood exposure					
No flooding	26	12	46	17	37
0-2 feet	13	12	15	12	14
2-4 feet	21	28	11	29	11
> 4 feet	39	48	28	42	37
Self-reported home damage category					
Still liveable	31	13	54	20	43
Unliveable	48	60	33	54	42
Destroyed	21	27	14	27	15
Severe storm damage; >30% decline in appraised value	71	86	52	81	60
Repair costs ($1000s)					
Repair costs - all households	65	66	63	60	71
Repair costs - those with severe damage (N=411)	88	78	114	72	114
Financial resources, among those with uninhabitable homes (N=411)					
Insurance coverage for home and property damage					
Few/none of losses covered	24	26	18	31	13
Some/half of losses covered	48	48	47	47	50
All/most of losses covered	29	25	36	23	37
Mean percentiles from households' imputed liquid assets distributions ($1000s)					
5th percentile	0	0	0	0	0
25th percentile	1	0	4	0	3
50th percentile	7	2	18	2	14
75th percentile	30	10	76	12	59
95th percentile	214	105	465	104	386

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

Table 3. Distribution of Storm Damage by Flood Exposure

	Self-reported home damage			Measure based on property appraisals	
Flood exposure	Still inhabitable	Unihabitable but not destroyed	Destroyed	Still inhabitable	Unihabitable
No flooding	91	9	0	93	7
0-2 feet	30	61	9	29	71
2-4 feet	11	69	20	9	91
> 4 feet	1	59	39	3	97

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

Table 4. Main Provisions of the Road Home Homeowner Grant Program

	Option 1	Option 2	Option 3
Formula used to compute grant payment	Type 1 evaluation: ($130 x (area under roof) + $550) x 1.02 Type 2 evaluation: estimate of actual repair costs Grant equals Type 1 estimate if (Type 1)/(Type 2)>51% Grant equals Type 2 estimate if (Type 1)/(Type 2)<51%	Equal to option 1 grant	Equal to 60% of option 1 grant
Houehold maintains ownership?	Yes	No, deed turned over to the Road Home Corporation	No, deed turned over to the Road Home Corporation
Household must repair home and reside in home within three years of grant payment?	Yes	No	No
Household must purchase another home in Lousisiana within three years of grant payment	No	Yes	No
Household must purchase required flood insurance	Yes	Yes	N/A
Number of participants in New Orleans	41,478	3,800	1,696
Fraction of participants (from New Orleans)	88.3%	8.1%	3.6%

Note: Households whose homes required repairs that were not covered by insurance were eligible for rebuilding grants from the Louisiana Road Home program. Participating households were required to select from among several options that differed in the grant benefit paid to the household and the set of obligations with which the household agreed to comply. This table describes the main provisions of each option. Source: Program provisions come from "The Road Home Homeowner Program Policies, version 6.2". Program participation figures come from the Road Home's "Homeowner Assistance Program, Weekly Situation and Pipeline Report, Week 185".

Table 5. Participation in the Road Home Homeowner Program Among Households with an Initially Uninhabitable Home

	Status four years after Hurricane Katrina				
	Still owns home		Sold Home		
Group	Option 1	Non-participant	Option 2 or 3	Non-Participant (Sold Privately)	Total
All households with damaged homes	67	15	8	10	100
Not destroyed but unihabitable	68	17	5	10	100
Destroyed	75	5	14	6	100
Few/none of losses covered	78	9	12	2	100
Some/half of losses covered	71	13	9	7	100
All/most of losses covered	51	25	3	21	100
No flooding	0	82	0	18	100
0-2 feet	60	25	0	15	100
2-4 feet	75	12	5	8	100
> 4 feet	68	11	12	9	100
<50% neighbors' homes uninhabitable	29	71	0	0	100
50%-90% of neighbors' homes uninhabitable	53	29	8	11	100
<50% neighbors' homes uninhabitable	71	11	8	10	100
Observations					397

Note: This table describes patterns of participation in the Road Home Homeowner program within the DNORS sample analyzed in this study.

Table 6. Model Parameter Estimates - Wage Equations

Dependent variable: ln(earning)-ln(avg. occ. earnings)	(1)	
Age	0.137***	[0.005]
Age squared	-0.001***	[0.000]
Race		
non-Black	---	
Black	-0.114***	[0.028]
Gender		
Male	---	
Female	-0.291***	[0.026]
Education		
High school dropout	-0.331***	[0.044]
High school graduate	---	
Some college	0.045	[0.034]
Bachelor's+	0.177***	[0.034]
Intercept	-3.375***	[0.102]
Observations	5,099	

Note: This table reports estimates of a regression equation explaining the difference between individual workers' earnings and the average earnings in each worker's three-digit occupation. The sample includes all working respondents to the 2005 American Community Survey from the New Orleans metropolitan area and all DNORS respondents who were working prior to Katrina. The dependent variable is the log of the workers annual earnings minus the log of the mean earnings in the worker's three-digit industry in New Orleans (as measured in the BLS Occupational Employment Statistics).
Source: Author's calculations using ACS, DNORS, and OES data.

Table 7. Structural Parameter Estimates - Utility function and borrowing rate parameters

Parameter:	(1) (a) Long run	(1) (b) Trend during first five years following Katrina
Flow benefit from residence location, b		
Residence in a Southern metro area besides New Orleans	0.00 [normalized]	
Residence in New Orleans		
Intercept	0.045 [0.01]	
Residence in pre-Katrina home		
Intercept (long run)	0.275 [0.024]	
50%-90% of homes on the household's block segment uninhabitable	-0.253 [0.035]	-0.158 [0.024]
>90% of homes on the household's block segment uninhabitable	-0.138 [0.024]	0.077 [0.02]
Purchased home 10-20 years before Katrina	0.017 [0.017]	
Purchased home > 20 years before Katrina	-0.013 [0.022]	
Neither head born in Louisiana	-0.063 [0.024]	
Repairing/rebuilding cost - χ^R		
Intercept (long run)	2.485 [0.292]	-0.331 [0.066]
Home destroyed by Katrina	0.877 [0.362]	-0.113 [0.087]
Moving utility cost - χ^M		
Intercept (within New Orleans move)	2.847 [0.082]	
Additional cost to moves to/from New Orleans	1.173 [0.135]	
Additional cost to moving home the first period home is repaired	-4.019 [0.211]	
Coefficient of relative risk aversion, ω	4.843 [0.606]	
Scale of shocks relative to u(c), α	4.494 [6.355]	
Log of Borrowing interest rate - $\ln(1+r^B)$		
Non-black and has a bachelor's degree	$\ln(1/\beta)$ [normalized]	
Black	0.349 [0.009]	
No bachelor's degree	-0.024 [0.031]	
Annual household income before Katrina < $20,000	0.071 [0.026]	
Annual household income before Katrina $20,000 to $40,000	-0.036 [0.028]	
Observations - household-periods	6,936	
Observations - households	578	
Log-Likelihood	-2,717.1	

Note: These estimates were computed using the nested fixed point estimator described in Section 6. Source: Author's calculations using DNORS and Assessor's data.

Table 8. Model Fit

	Uncoditional of Home Damage								
	All Households			Blacks			Non-Blacks		
Moments - Percentage of households	Empirical	Predicted	χ^2	Empirical	Predicted	χ^2	Empirical	Predicted	χ^2
Home Liveable									
1st Anniversary	36.2	39.3	2.41	19.5	23.4	3.18	58.0	60.3	0.54
2nd Anniversary	41.2	45.7	4.83	23.2	30.8	10.63	64.8	65.3	0.03
3rd Anniversary	50.9	53.3	1.33	36.6	40.5	2.15	69.6	70.2	0.04
4th Anniversary	73.0	61.9	36.13	69.5	51.7	49.03	77.6	75.3	0.76
Living in pre-Katrina home									
1st Anniversary	25.4	22.2	3.12	13.4	14.1	0.14	41.2	33.0	6.94
2nd Anniversary	30.8	32.5	0.78	18.3	22.3	3.51	47.2	45.9	0.17
3rd Anniversary	37.9	39.8	0.89	26.8	30.3	2.05	52.4	52.2	0.00
4th Anniversary	59.2	45.5	44.91	57.9	38.2	52.22	60.8	55.2	3.29
Living in New Orleans									
1st Anniversary	60.9	55.1	8.17	54.6	44.2	14.31	69.2	69.5	0.01
2nd Anniversary	71.3	63.8	15.89	69.5	54.6	34.35	73.6	75.9	0.68
3rd Anniversary	75.3	71.0	5.75	75.9	63.8	26.25	74.4	80.4	4.73
4th Anniversary	78.4	76.9	0.77	80.5	71.6	16.55	75.6	83.8	9.11
Sold pre-Katrina home									
1st Anniversary	3.1	3.9	1.23	0.9	4.4	43.69	6.0	3.3	3.26
2nd Anniversary	8.5	7.3	0.98	4.3	8.2	12.14	14.0	6.2	12.54
3rd Anniversary	15.6	10.5	11.42	9.8	11.6	1.26	23.2	9.1	28.05
4th Anniversary	19.0	13.8	10.16	12.5	15.0	1.87	27.6	12.2	29.67
Households	578			328			250		

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

Table 9. The Impact of Counterfactual Policies on Rebuilding Rates Among Households with Initially Unliveable Homes

Group	Rebuilding Rate Predicted by the Estimated Model				
	No grant program	100% Acceptance for SBA Loans	Road Home grant formula - no rebuilding/residence requirement	Road Home Program	% Impact of Road Home Program
All households					
2nd anniversary	19.81	22.62	22.10	22.01	11.07
4th anniversary	39.66	43.09	45.16	45.30	14.21
Black households					
2nd anniversary	16.11	20.26	18.41	18.41	14.24
4th anniversary	36.69	41.80	42.96	43.14	17.59
Non-Black households					
2nd anniversary	28.35	28.06	30.60	30.31	6.91
4th anniversary	46.52	46.06	50.22	50.27	8.07
No bachelor's degree					
2nd anniversary	17.29	21.02	19.94	19.89	15.02
4th anniversary	36.76	41.73	43.15	43.40	18.04
Bachelor's degree					
2nd anniversary	23.75	25.12	25.47	25.31	6.59
4th anniversary	44.18	45.20	48.29	48.26	9.24

Note: This table provides the results of simulation experiments designed to assess the impact of the Road Home program in partial equilibrium. The first column reports simulated rebuilding rates in a scenario with no grant payments. The second comuln reports simulated rebuilding rates in a scenario in which Road Home grants were made but without the condtion that the grant be used for home repairs. The third column reports simulated rebuilding rates in the baseline scenario in which the Road Home program was fully implemented.

Table 10. The Impact of Wage Subsidies and Similarly Sized Direct Grants on Rebuilding Rates

Group	Wages $2,400 per worker below baseline	Baseline	Wages $2,400 per worker below baseline, $2,400 per worker grant payment at t=0	d(%repaired) / dln(NOLA wages yr 1-4)	(Impact of cash grant) / (Impact of wage boost)
All working age households					
2nd anniversary	18.47	18.61	18.89	0.38	2.90
4th anniversary	48.49	48.61	48.95	0.11	4.02
Black working age households					
2nd anniversary	16.04	16.22	16.61	0.43	3.23
4th anniversary	48.24	48.37	48.90	0.11	5.08
Non-Black working age households					
2nd anniversary	24.48	24.54	24.54	0.20	0.99
4th anniversary	49.10	49.18	49.11	0.12	0.06
No bachelor's degree					
2nd anniversary	15.81	15.98	16.40	0.41	3.38
4th anniversary	47.43	47.52	48.16	0.07	7.71
Bachelor's degree					
2nd anniversary	21.56	21.67	21.78	0.31	2.06
4th anniversary	49.72	49.86	49.88	0.17	1.13

Note: This table reports the results of the simulation experiments designed to compare the effectiveness of wage subsidies and similarly generous direct grants. See text for details.

Table A1. Computing Price Variables

Variable	Description	Method	Data source
Monthly mortgage payment for pre-Katrina home	Mortgage payment associated with a standard 30 year fixed rate mortgage	Computed using home's purchase date and purchase price assuming a thirty year fixed rate mortgage with a 20% down payment	-Assessor's data
Monthly rent for a different New Orleans residence	Estimate of the cost of renting housing that is comparable to the household's pre-Katrina home	Step 1: impute the home's rental value in pre-Katrina New Orleans 0.0785 x (appraised pre-Katrina value) / 12. Step 2: adjust that for differences in rental prices between pre-Katrina New Orleans and post-Katrina New Orleans using regression adjusted price indeces (see Appendix II for details on computing rental price indices)	-Pre-Katrina appraised home values come from Assessor's data -Housing price indices are computed using information on rental prices and building characteristics from the American Community Survey
Monthly rent for a residence in another Southern metro	Estimate of the cost of renting housing that is comparable to the household's pre-Katrina home	Step 1: impute the home's rental value in pre-Katrina New Orleans 0.0785 x (appraised pre-Katrina value) / 12. Step 2: adjust that for differences in rental prices between pre-Katrina New Orleans and the post-Katrina market in other Southern metro areas using regression adjusted price indeces (see Appendix II for details on computing rental price indices)	-Pre-Katrina appraised home values come from Assessor's data -Housing price indices are computed using information on rental prices and building characteristics from the American Community Survey
Cost of repairing home damage	Estimate of the cost of repairing the household's home if the home was damaged but not destroyed, and an estimate of the cost of rebuilding the household's home if it was destroyed	-If home was destroyed, repair cost is imputed to be the appraised pre-Katrina improvement value multiplied by a price index that reflects the difference in housing prices between pre-Katrina and post-Katrina New Orleans (this assumes that post-Katrina housing prices more accurately reflect building costs than pre-Katrina prices (Vigdor, 2008)) -If home was unihabitable but not destroyed, repair cost is imputed to be the difference between the appraised pre-Katrina improvement value and the appraised improvement value immediately following Katrina multiplied by a price index that reflects the difference in housing prices between pre-Katrina and post-Katrina New Orleans	-Appraised home values come from Assessor's data -Housing price indices are computed using information on rental prices and building characteristics from the American Community Survey
Insurance payment	Estimate of the insurance payment made to the household to cover damage to the household's home	Imputed by multiplying the household's repair costs by a fraction based on the household's categorical response to the DDNORS 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	Estimate of the price at which the household's home would sell following Katrina if it were fully repaired	Imputed by multiplying the home's appraised pre-Katrina value by an estimated price index reflecting the difference in housing prices between pre-Katrina and post-Katrina New Orleans	-Pre-Katrina appraised home values come from Assessor's data -Housing price indices are computed using information on rental prices and building characteristics from the American Community Survey

Table A2. Housing Price Index Regressions

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

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