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Bailing Out Homeowners: Government Aid and Mortgage Default after Natural Disasters

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Abstract

Natural disasters destroy substantial parts of homeowners' wealth and often prompt large-scale government aid. This aid might crowd out private disaster insurance. However, homeowners already hold implicit insurance through the option to default on mortgages. This option shapes the welfare effects of government aid in two opposing ways. On the one hand, default already provides partial coverage, reducing the marginal value of aid. On the other hand, anticipating default leads households to underinsure. This underinsurance raises their financing costs and generates a commitment problem that the government can resolve. To quantify the welfare effects of post-disaster government aid, specifically, rebuilding grants and foreclosure moratoria, I develop a structural general equilibrium model. The model embeds natural disaster shocks within an incomplete markets framework, which features two degrees of mortgage default: delinquency and foreclosure. Calibrated to the U.S. economy over 2000-2020, the model yields three main results. First, government aid increases uninsured losses by 36 percentage points and increases owner-occupied housing in disaster-prone areas by 14 percent compared with no aid. Second, government aid generates 0.25 percent aggregate welfare gains in consumption-equivalent terms, mainly benefiting households in high-risk regions. Third, for equal fiscal cost, the greatest welfare gains occur when rebuilding transfers are provided independently of insurance coverage, thereby limiting crowding out of private disaster insurance.

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1 Introduction

Natural disasters impose substantial economic costs on the U.S. economy. Over the past three decades, they have generated losses of about \$2.27 trillion, while the federal government has provided around \$347 billion in government aid through the Disaster Relief Fund (Congressional Budget Office, 2022). Housing is particularly vulnerable to natural disasters due to its immobility. Home equity represents 62 percent of homeowners’ net worth (Survey of Income and Program Participation, 2023), yet private disaster insurance covers only roughly 43 percent of total economic losses (Swiss RE, 2024). The gap is larger for flood risk, where an estimated 70 percent of losses remain uninsured (Amornsiripanitch et al., 2025). Since climate change raises both the frequency and severity of natural disasters (IPCC, 2022), the fiscal and economic importance of government aid may continue to grow. At the same time, the design and provision of government aid have been questioned as empirical evidence suggests that expectations of federal support reduce private disaster insurance demand (Raschky et al., 2013; Kousky et al., 2018), but eliminating aid altogether would leave many households financially exposed (Gallagher and Hartley, 2017; Kousky et al., 2020).

Beyond private disaster insurance and precautionary savings, mortgage default functions as an additional, implicit insurance mechanism. Periods of temporary nonpayment (delinquency) can buffer short-term expenditure shocks, and when lenders face limited recourse, foreclosure shields borrowers from large property losses by extinguishing their outstanding debt. This dual role of default creates two opposing forces for the welfare effects of government aid. The first is an implicit insurance channel. Since mortgage default already provides partial coverage, there may be a reduced need for government intervention. The second is a commitment channel. Households who anticipate defaulting after a disaster may choose to remain uninsured *ex ante*, which raises their mortgage financing costs. Government aid, by reducing the attractiveness of default, can act as a commitment device. This may improve financing conditions and raise welfare even in the absence of insurance market imperfections.

In this paper, I evaluate the design of government aid in the presence of interactions between government aid, private disaster insurance, and mortgage default. I develop a quantitative general equilibrium model that integrates these mechanisms to address two central questions: in the presence of the implicit insurance channel as well as the commitment channel, (i) what are the aggregate and distributional effects of existing government aid, and (ii) how do alternative policy designs compare to current government aid programs?

To analyze the scope for government intervention, I develop a tractable model of insurance choice with endogenous default. The framework illustrates how default opportunities weaken

demand for private disaster insurance and how government aid can improve welfare even in the absence of insurance market imperfections. In the model, government aid, in terms of rebuilding grants, lowers households’ reconstruction burden and can crowd out private disaster insurance. Yet, the expectation of receiving rebuilding grants also diminishes the value of default as an insurance mechanism. This increases the ex ante incentive to insure and improving financing conditions for homeowners by reducing default risk. In addition, I provide novel empirical evidence on U.S. mortgage performance following natural disasters over the past two decades. The results match the mechanisms I propose. Delinquencies increase sharply, but are not accompanied by rises in foreclosures in counties hit by natural disasters. This pattern is consistent with a crucial role of government aid provided and the quasi-insurance role of temporary delinquency, as many loans appear to subsequently cure. Allowing for temporary mortgage nonpayment in the quantitative model is therefore crucial for capturing this dynamic and for replicating the observed household responses.

The quantitative model features a two-region heterogeneous-agent economy with incomplete markets. Regions differ in their exposure to natural disasters, but jointly finance a federally funded aid program. Within each region, local housing markets include both homeowners and renters, and housing capital is subject to stochastic, partial destruction by natural disasters. Households hit by a disaster shock also obtain a reduced flow of housing services and incur reconstruction costs, with the latter being an expenditure shock. Combined with potential negative home equity, this constitutes a “double-trigger” event that can precipitate mortgage default.¹ Agents face uninsurable idiosyncratic income risk and make consumption-saving choices under a borrowing constraint. Households choose their home size and ownership states. Home purchases are financed with mortgages whose prices reflect individual default risk. Mortgage holders may temporarily suspend payments without immediate foreclosure (i.e., enter delinquency). Recourse is limited: not all foreclosed borrowers are liable for outstanding mortgage balances (e.g., via wage garnishment), so lenders cannot always recover losses. Homeowners can purchase private disaster insurance, but insurance premiums exceed actuarially fair rates due to intermediation costs. The rest of the economy consists of a competitive housing sector, a financial intermediary, an insurance firm, and a government that runs a balanced budget. In line with existing U.S. aid programs, I model government aid as foreclosure moratoria and rebuilding grants proportional to rebuilding costs, net of private disaster insurance coverage. In equilibrium, the availability of delinquency and foreclosure substitutes for precautionary coverage. Combined with limited recourse and the insurance wedge, homeowners buy less private disaster insurance even in

¹Empirical evidence suggests that households facing both affordability shocks and negative equity are especially prone to default; see Foote et al. (2008) and Ganong and Noel (2023).

the absence of government aid.

I calibrate the quantitative model to the U.S. economy and the incidence of natural disasters over 2000-2019, using data from the American Housing Survey, the American Community Survey, and Fannie Mae loan-level records, among other sources. I classify U.S. counties into high-risk and low-risk regions based on their Expected Annual Loss Rate from FEMA's National Risk Index. The model matches key moments of the U.S. housing market and replicates qualitative regional heterogeneity. I use the calibrated model to analyze current government aid and conduct policy counterfactuals.

First, I analyze the redistributive and aggregate welfare effects of eliminating the existing government aid. The results show that government aid raises the share of losses uncovered by private disaster insurance by 36pp while increasing the owner-occupied housing stock in disaster-prone areas by 14%. Even with these distortions, government aid increases aggregate welfare by 0.25% in consumption-equivalent variation (CEV), with the largest gains accruing to low-income households in high-risk regions. This is surprising: low-income households have lower homeownership rates and therefore indirectly subsidize the rebuilding of wealthier homeowners. However, for low-income homeowners in high-risk areas, aid especially reduces the likelihood of displacement after a natural disaster for these households. In the low-risk region, the welfare effects differ: for low- and middle-income households, the general-equilibrium costs (higher house prices and lower transfers due to cross-subsidization) outweigh the direct insurance value of the aid.

Second, I assess whether welfare can be improved by raising the maximum grant level currently provided by the government. The welfare gains of government aid depend on the size of rebuilding grants. While increasing the maximum grant raises welfare when starting from a no-aid scenario, the gains plateau and eventually reverse. Once aid covers a sufficiently large share of rebuilding costs, additional transfers reduce aggregate welfare as the resulting distortions channel larger transfers toward high-risk regions.

Third, I evaluate a set of counterfactual policy designs aimed at addressing shortcomings of existing programs, such as the crowding out of private disaster insurance and the overaccumulation of housing in risky areas.

Relative to current government aid, the largest welfare gains (+0.21% CEV) occur when rebuilding grants are provided independently of private disaster insurance coverage, reducing direct crowding-out. In contrast, eliminating government aid and reallocating the same funds to subsidize private disaster insurance reduces aggregate welfare (-0.18% CEV), with the largest losses among low-income households in high-risk regions. The subsidy fails to make private insurance sufficiently appealing, so these households continue to rely on default as an implicit form of insurance and are displaced after major disasters. Targeting rebuild-

ing grants exclusively to low-income households yields modest aggregate gains (+0.04% CEV), as gains for low-income households are offset by the losses among middle- and high-income households who previously benefited from government aid. Financing government aid through a housing tax produces aggregate welfare gains of +0.16% CEV by discouraging overinvestment in risky regions; however, low-income households experience welfare losses in both low- and high-risk areas due to reduced housing affordability.

Fourth, I examine the recourse regime and find that whether foreclosed homeowners remain liable for outstanding mortgage debt determines which households gain and which lose under alternative policies. Under strict enforcement, insurance-independent aid is the only alternative policy design that generates welfare gains. Moreover, welfare losses from removing government aid become concentrated among low- and middle-income households, for whom foreclosure serves as an informal insurance mechanism, which becomes more costly under strict recourse.

Lastly, I quantify the welfare effects and fiscal costs of maintaining the current government aid in a scenario with heightened risk of extreme events due to climate change. I simulate a steady state with a 10% increase in the frequency of large-scale damages, holding constant the share of affected households in each period. As households adjust their housing choices, maintaining current aid levels increases expenditures by only 0.1%, and aggregate welfare falls only by around 0.2% CEV.

Related literature The paper relates to three strands of literature. First, it contributes to a growing literature on adaptation and rebuilding after natural disasters. As I show in the paper, mortgage default serves as an important implicit insurance mechanism and, therefore, is relevant to include when assessing the effects of natural disasters on homeowners. To the best of my knowledge, the only paper combining government aid and mortgage default in a unified framework is Aron-Dine (2025). While her analysis focuses on migration and housing markets, it confines the welfare assessment to aid recipients and treats disasters as one-off, unanticipated shocks. In this paper, I develop a general-equilibrium framework that internalizes fiscal costs and cross-regional transfers, thereby capturing welfare effects for all agents who fund or benefit from disaster assistance. I further explicitly model household delinquencies and private insurance choices that jointly determine effective insurance in the economy—two key mechanisms absent from her work. Allowing for recurrent disasters and anticipation of aid, my analysis moves beyond partial-equilibrium welfare comparisons to evaluate how the design of government aid shapes private disaster insurance coverage and housing-market outcomes. Empirical studies document that government aid can influence

private insurance and housing market behavior (Raschky et al., 2013; Kousky et al., 2018).² Hence, accounting for these interactions is essential when quantifying welfare effects. Other studies, apart from Aron-Dine (2025), have not included mortgage default or government aid in frameworks with natural disasters. Abstracting from default, recent work examines government aid in post-disaster rebuilding (Gregory, 2017; Fu and Gregory, 2019), residential sorting (Henkel et al., 2022), or adaptation incentives (Fried, 2022; Hsiao, 2023; Rickard, 2025), while Van Der Straten (2023) incorporates mortgage default but omits government aid.³ This paper extends the literature by explicitly modeling the joint role of government aid and mortgage default as interacting insurance mechanisms.

Second, the paper relates to empirical research on the immediate impact of natural disasters on mortgage performance and household finance (Gallagher and Hartley, 2017; Issler et al., 2019; Calabrese et al., 2024; Biswas et al., 2023)).⁴ While most studies find modest or transitory effects, these average estimates mask heterogeneity: vulnerable households, those with low pre-disaster credit scores or incomes, are disproportionately affected (Billings et al. (2022)). The crucial role of insurance and government aid in mitigating losses is also well documented (Gallagher and Hartley, 2017; Kousky et al., 2020).⁵ This paper contributes by providing a general-equilibrium assessment of ex-post government aid and by empirically analyzing household financial responses to multiple disaster types across the entire United States over the past two decades, rather than focusing on single events.

Lastly, the paper builds on the literature on incomplete markets with mortgage default and foreclosures (Campbell and Cocco, 2015; Chatterjee and Eyigungor, 2015; Corbae and Quintin, 2015; Mitman, 2016; Kaplan et al., 2020; Herkenhoff and Ohanian, 2019). It is the first to introduce natural disasters and government aid in such a setting while explicitly modeling delinquencies. Drawing on this literature, the model endogenizes mortgage pricing, allowing government interventions to affect homeowners' financing conditions by altering

²Related work quantifies frictions in insurance uptake and welfare effects of proposed reforms in natural disaster insurance markets (Wagner, 2022). In addition, Ospital (2025) and Ostriker and Russo (2024) focus in the effect of government regulation and hazard exposure of households.

³More broadly related are papers on adaptation to climate change (Bilal and Känzig, 2024; Bilal and Rossi-Hansberg, 2023), pricing of climate risk in the housing market ((Bakkensen and Barrage, 2022; Gourevitch et al., 2023)). Another related strand investigates the design of government insurance in the presence of correlated regional risks (Charpentier and Le Maux, 2014; Hassan et al., 2022) and debates welfare concepts for evaluating government aid (Jaffee and Russell, 2013).

⁴More broadly, the paper relates to empirical research on the macroeconomic effects of natural disasters, such as Eickmeier et al. (2024), and the role of government aid for regional recovery (Fernández-Gallardo and Pappa, 2026).

⁵The paper also relates to empirical research on household exposure to natural-disaster risk. To illustrate, papers study who is exposed to such risks (Qin and Voorheis, 2026), who returns after natural disasters (Paxson and Rouse, 2008), who selects into insurance (Bradt et al., 2021), and how homeowner insurance premiums evolve (Keys and Mulder, 2024).

default risk.

The paper is organized as follows. In Section 2, I provide empirical evidence on the role of mortgage default after natural disasters. Section 3 presents a simple model to analyze how mortgage default interacts with private disaster insurance and government aid. In Section 4, I develop the full quantitative model. I describe the calibration strategy and validate the model using empirical estimates in Section 5. Building on this framework, I evaluate a set of policy counterfactuals and assess their implications for household welfare in Section 6. The final Section 7 concludes, and an Appendix follows.

2 Role of Mortgage Defaults after Natural Disasters

In this section, I provide empirical evidence on mortgage performance after natural disasters in the United States from 2000 to 2020. I document a temporary rise in delinquencies after natural disasters that is not matched by a rise in foreclosures. This holds true especially for large disasters that triggered federal disaster aid and foreclosure moratoria. These results motivate the explicit modeling of a delinquency period and highlight the implicit insurance provided by mortgage default.

I use the *Spatial Hazard Events and Losses Database for the US* (SHELDUS), which provides estimated monthly county-level USD in damages caused by a wide range of natural disasters, including geophysical and hydrological perils. The *Fannie Mae Single-Family Mortgage Performance Dataset* provides monthly mortgage-level performance data since 2000, including information on the properties' Metropolitan Statistical Area (MSA) of location. The final sample is a month-MSA-state panel spanning 2000 to 2020, including around 100,000 observations and 409 different MSAs. To construct delinquency and foreclosure measures $Delinquency_{mst}$ and $Foreclosure_{mst}$, I aggregate monthly loan-level data to the MSA-state level.

$$Delinquency_{mst+h} = \frac{\text{value of delinquent mortgages in MSA } m \text{ and state } s \text{ at time } t+h}{\text{total value of mortgages in } m \text{ and state } s \text{ at time } t-1}$$

$$Foreclosure_{mst+h} = \frac{\text{value of properties foreclosed in } m \text{ and state } s \text{ at time } t+h}{\text{total value of mortgages in } m \text{ and state } s \text{ at time } t-1}$$

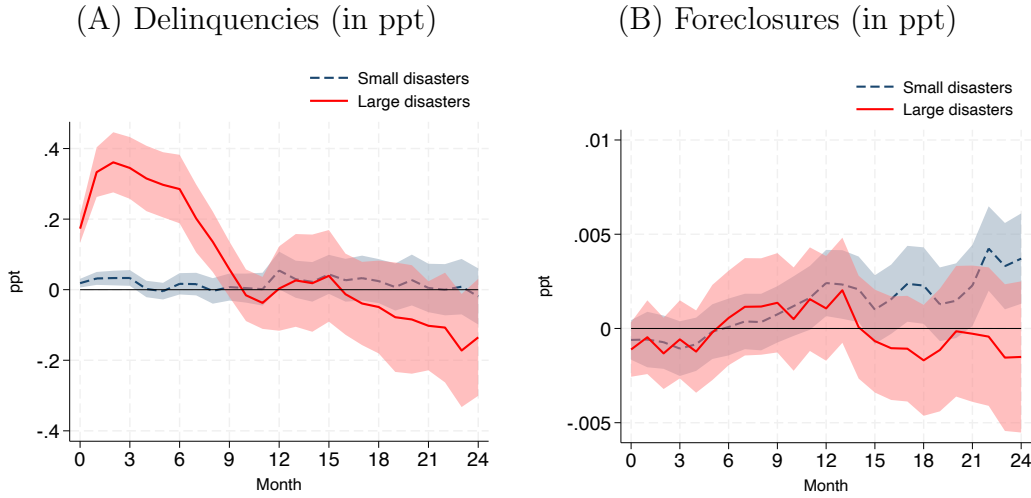
To examine size-dependent responses, I group natural disasters by realized USD per capita damage, defining disasters as small (S) if per capita damage is below the 75th percentile and large (L) if per capita damage exceeds this threshold. I define the dummy variable $D_{ms,t}^i$ to equal one if, in MSA m and state s at time t , a disaster of size $i \in \{S, L\}$ occurred. Then, I estimate impulse response functions by running local projections as proposed by Jordà

(2005):

$$\Delta_h Y_{ms,t+h} = \beta_h^S D_{ms,t}^S + \beta_h^M D_{ms,t}^M + \beta_h^L D_{ms,t}^L + \gamma_h \mathbf{X}_{ms,t} + \alpha_{ms}^h + \alpha_t^h + \epsilon_{ms,t+h} \quad (1)$$

with $\Delta_h Y_{ms,t+h} = Y_{ms,t+h} - Y_{ms,t-1}$ and $Y_{ms,t+h} \in \{Delinquency_{ms,t+h}, Foreclosure_{ms,t+h}\}$. $\mathbf{X}_{ms,t}$ represents time-varying, region-specific controls.⁶ Conditional on the location and common time trends, the timing of disaster realizations provides a plausibly exogenous source of variation. Therefore, I include region-fixed effects (α_m) to account for region-specific exposure to natural disasters and MSA-specific regulations for disaster mitigation. Additionally, sorting of households into disaster-prone areas and differences in industry structure might be correlated with damages and financial performances, but should be covered by the fixed effects. Time fixed effects account for aggregate movements in house prices and the increase in delinquencies during the Great Financial Crisis.

Figure 1: Mortgage Default after Natural Disasters



Note: Shaded areas are 90 percent confidence bands. Standard errors are clustered at the MSA level. Regression includes time and MSA fixed effects. Small damages are non-zero values below the 75th percentile; large damages are above the 75th percentile. The regression is estimated without region-specific controls. Figure A.1 plots impulse response functions for the estimated regressions, including region-specific controls.

Figure 1 depicts the impulse response functions of mortgage delinquencies and foreclosure rates following a natural disaster. Notably, households do not exhibit a discernible response to small disasters on average, but delinquencies surge after large disasters. However, this effect is transient. For large disasters, there is even a negative, but insignificant, impact

⁶At the MSA level, the controls comprise personal income per capita, the employment rate, the median debt-to-income ratio, and the median loan-to-value ratio at origination.

on delinquencies after one year. In contrast, foreclosure rates exhibit a delayed response, increasing within the first 15 months following small disasters, but not after large disasters. Hence, for large-scale natural disasters, the rise in delinquencies is not matched with a proportional rise in foreclosures. This pattern is consistent with mortgage holders becoming performing after one year, and the temporary suspension of mortgage payments may function as a form of quasi-insurance against sudden expenditure shocks. This highlights the critical importance of incorporating delinquencies into the model to accurately capture the observed patterns in mortgage performance after natural disasters.

3 A Simple Model

Having shown that households respond to natural disasters with increased mortgage default, I develop a tractable framework to assess how the option to default creates scope for government intervention. In this section, I develop a tractable static model in which an agent chooses insurance coverage and retains the option to default following a natural disaster. The availability of default reduces the value of private insurance: without this option, the second welfare theorem holds, and there is no room for government aid. With default, however, the theorem fails, a commitment problem arises, and policy intervention can be optimal for certain parameter values, even in the absence of an explicit insurance wedge.

Model environment The agent lives for one period and receives an endowment y . He derives utility from consuming a non-durable good c . Within this period, the agent faces a sequence of decisions. At the beginning of life, he purchases a house of size h at price $p_h h$, financed by a mortgage m , priced at q . After purchasing the house, he chooses proportional insurance coverage $\iota \in [0, 1]$ at the unit price p_ι . With probability π_δ , a natural disaster occurs and destroys a fraction δ of the house value. After the disaster is realized, the agent decides whether to stay or to default. If he stays, he sells the house and repays the mortgage at the end of the period. If he defaults, he becomes a renter: he incurs a utility cost $\log(\kappa)$, pays rent $p_r h_r$, and avoids both repayment of the mortgage and the house sale. Insurance claims are paid only conditionally on rebuilding. Independent of the disaster realization, homeowners pay a proportional maintenance cost ξ . Since mortgages are priced at zero expected profit, q reflects the endogenous default risk. The government can intervene by imposing an income tax, τ , to finance government aid covering a fraction, τ_δ , of the rebuilding investment.

Removing default First, I eliminate the default option and show that with efficient insurance markets, government intervention is not warranted. Without default, mortgages are risk-free and, thus, $q = 1$. As agents cannot default, the outside option of renting is no longer relevant. The agent maximizes utility by optimally choosing insurance coverage ι :

$$\begin{aligned} & \max_{\iota} (1 - \pi_{\delta}) \log(c^B) + \pi_{\delta} \log(c^{ND}) \\ \text{s.t. } & c^B = (1 - \tau)y - p_{\iota} \iota p_h \delta h - \xi p_h h \\ & c^{ND} = (1 - \tau)y + (1 - p_{\iota}) \iota p_h \delta h - (1 - \tau_{\delta}) p_h \delta h - \xi p_h h, \end{aligned} \quad (2)$$

where c^B denotes consumption in the absence of a natural disaster and c^{ND} denotes consumption following a disaster event.

Proposition 1: *Without default, agents choose insurance coverage to maximize (2).*

- (i) *Without government intervention, agents buy full insurance $\iota = 1$ for actuarially fair insurance prices ($p_{\iota} = \pi_{\delta}$). If there exists a positive insurance wedge ($p_{\iota} > \pi_{\delta}$), agents underinsure $\iota < 1$.*
- (ii) *Under actuarially fair insurance ($p_{\iota} = \pi_{\delta}$), government aid crowds out private insurance one-to-one, $\iota = (1 - \tau_{\delta})$, and welfare remains unchanged.*

Proof: See Appendix B.1.

Role of default With the default option, government intervention may improve welfare for a range of default costs. Allowing default makes mortgages risky: the mortgage price q depends on the probability of default in the disaster state, which in turn depends on insurance coverage. Households anticipate default when choosing insurance, but do not internalize its effect on the mortgage price q . The optimization problem extends to

$$\begin{aligned} & \max_{\iota} (1 - \pi_{\delta}) \log(c^B) + \pi_{\delta} \max \{ \log(c^{ND}), \log(c^D) - \log(\kappa) \} \\ \text{s.t. } & c^B = (1 - \tau)y - (1 - q)m - p_{\iota} \iota p_h \delta h - p_h \xi h \\ & c^{ND} = (1 - \tau)y - (1 - q)m + (1 - p_{\iota}) \iota p_h \delta h - p_h (\xi + (1 - \tau_{\delta}) \delta) h \\ & c^D = (1 - \tau)y - p_h h + qm - p_r h_r - p_{\iota} \iota p_h \delta h, \end{aligned} \quad (3)$$

where c^D denotes consumption under default. To focus on the role of the default option, I assume that insurance markets are efficient, so insurance prices are actuarially fair.

Proposition 2: *With default, agents choose insurance coverage to maximize (3).*

(i) *Conditional on default costs κ and without government intervention $\tau_\delta = 0$, agents choose corner solutions of insurance coverage and mortgage prices respond accordingly*

$$\iota = \begin{cases} 0 & \text{if } \kappa < \bar{\kappa}(0) \\ 1 & \text{else} \end{cases} \quad \text{and} \quad q = \begin{cases} 1 - \pi_\delta & \text{if } \kappa < \bar{\kappa}(0) \\ 1 & \text{else} \end{cases}$$

(ii) *Providing government aid of size τ_δ can improve welfare if $\kappa \in (\max\{\underline{\kappa}, \bar{\kappa}(\tau_\delta)\}, \bar{\kappa}(0))$.*

Proof: See Appendix B.2 for the proof and the definition of the threshold values on κ .

The intuition behind Propositions 2.i and 2.ii can be summarized as follows. If default costs are sufficiently low ($\kappa < \bar{\kappa}(0)$), households may optimally choose to remain uninsured and default in the event of a disaster. In this case, default is not optimal under full insurance, but it is ex ante optimal to forgo insurance altogether. Anticipating this behavior, lenders reduce mortgage prices, resulting in higher financing costs ($q < 1$). By contrast, when default costs are sufficiently high ($\kappa > \bar{\kappa}(0)$), the default option is unattractive, and households optimally purchase full insurance, restoring first-best outcomes.

In this environment, government intervention can eliminate default by taxing households and providing government aid, which in this simple setting is equivalent to mandatory insurance. Government aid then acts as a commitment device, restoring favorable financing conditions ($q = 1$). Such an intervention of size τ_δ improves welfare whenever default is sufficiently costly, and the aid is large enough to render default unattractive. Figure 2 summarizes these results.

If default costs are very low ($\kappa < \kappa_0$), government intervention is ineffective, as households always default regardless of aid. If default costs are very high ($\kappa > \bar{\kappa}(0)$), households never default, even without insurance, and any aid simply crowds out private coverage.

The interesting case arises in the intermediate range $\kappa \in (\kappa_0, \bar{\kappa}(0))$. In this region, each level of government aid τ_δ defines a threshold value $\bar{\kappa}(\tau_\delta)$. For default costs above this threshold, households avoid default in the disaster state and purchase optimal insurance, replicating the no-default benchmark (violet area in Figure 2). For costs below the threshold, households anticipate default and choose zero coverage (light blue area in Figure 2). This default threshold is decreasing in the size of government aid provided, as $\frac{\partial \bar{\kappa}(\tau_\delta)}{\partial \tau_\delta} < 0$. Intuitively, a higher conditional transfer by the government reduces the incentive to default as lower default costs are required to make default attractive. By defaulting, the household

[illegible]

loses access to the government aid to which it would otherwise have contributed independently of the default. For utility costs below this threshold, government aid is too small to shift households' default incentives.

While the simple model clarifies the core mechanism that government aid can enhance welfare by mitigating default risk, it abstracts from key features needed for quantitative assessment. In practice, aid is federally financed, generating cross-regional and renter-to-homeowner transfers. Households are heterogeneous and face incomplete markets, so insurance values differ across income and wealth levels. A heterogeneous-agent framework is therefore essential to capture welfare distributional effects, not just aggregate outcomes. Moreover, private insurance is priced above actuarially fair levels, creating an insurance wedge critical for matching observed take-up. Finally, delinquencies, foreclosure moratoria, and recourse regulations jointly shape how mortgage default operates as implicit insurance. To incorporate these elements, I next develop a quantitative two-region heterogeneous-agent model.

4 Quantitative Model

Time is discrete, and the economy is populated by a continuum of measure-one households. There are two regions that differ in their exposure to natural disasters. Agents face two sources of idiosyncratic risk: a persistent labor productivity shock and a natural disaster shock that destroys housing capital, temporarily disrupts housing services, and requires rebuilding.⁷ Each region comprises a perfectly competitive final-goods producer, a financial intermediary, a rental agency, and a construction company. Labor is perfectly mobile across sectors within a region, but immobile across regions.⁸ The government balances its budget across regions, financing government aid and transfers through labor income taxes.

The model features incomplete markets and housing as in Kaplan et al. (2020) and extends this framework along several key dimensions. First, I include natural disaster shocks and ex-post government aid. These shocks differ from standard idiosyncratic house price shocks, as they simultaneously affect household wealth, expenditure, and the flow of utility from housing services. Second, I account for regional heterogeneity in disaster exposure to analyze cross-regional redistribution through government aid. Third, I add a private insurance firm to capture the availability of market-based coverage as an alternative to government aid. Fourth, I explicitly model delinquency as a temporary suspension of mortgage payments without immediate foreclosure. This feature is necessary to replicate empirically observed patterns of rising delinquencies alongside stable foreclosure rates following natural disasters and to analyze the effects of foreclosure moratoria. Lastly, I incorporate housing market frictions by limiting the probability of a successful home sale. This mechanism generates mortgage defaults even in the absence of natural disasters, without requiring additional shocks.

⁷In this analysis, I focus on the direct impact of natural disasters on homeowners and abstract from labor market effects. This approach allows me to remain agnostic about potential changes in labor demand, which could operate in either direction—rising with rebuilding needs or falling due to production disruptions.

⁸A limitation of the no-mobility assumption is that it abstracts from endogenous sorting across risk regions. If households in high-risk areas respond to policy changes by migrating to low-risk areas, the welfare costs of removing aid could be partially offset by relocation. However, as the whole U.S. is partitioned into two regions, those regions are sufficiently large to make this assumption less strict. In addition, empirical studies document some mobility responses after natural disasters, though these are often not directed toward safer regions (Wang, 2024) or are concentrated among renters (Millock, 2025). Government aid may also shape migration: Wang (2024) finds that recipients of financial aid are more likely to move, albeit not systematically, to safer areas. At the same time, the anticipation of aid can create moral hazard. To keep the analysis tractable, I abstract from mobility. The model still captures moral hazard through the potential overconsumption of housing in risky regions. When interpreting the welfare results, it is important to note that excluding mobility likely overstates the welfare gains from government aid. For evidence on how government aid affects rebuilding choices, see Gregory (2017).

4.1 Households

Households are born in region k and cannot move between regions. Every period, agents face a constant probability of death $1 - \pi_S$. Simultaneously, a mass of new agents equal to $1 - \pi_S$ enters the economy as renters, thus maintaining a constant total population. Previously occupied houses of deceased agents re-enter the housing market. In every period, a natural disaster shock realizes and destroys a constant share of the housing capital δ . Aggregate destruction is constant each period; thus, there is no aggregate risk.⁹ The probability of being affected by a natural disaster differs across regions. Individual damages δ of a homeowner living in region k are defined as

$$\delta = \begin{cases} \delta_{low} & \text{with probability } \pi_{low,k} \\ \delta_{high} & \text{with probability } \pi_{high,k} \\ 0 & \text{with probability } 1 - \pi_{low,k} - \pi_{high,k} \end{cases}$$

In the following, I drop the subscript k for readability. I will reintroduce k when specifying the government budget constraint.

Preferences Households derive utility from non-durable consumption c and housing services s in every period t . The expected lifetime utility of a household is represented by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} [\pi_S \beta]^t u(c_t, s_t), \quad (4)$$

where β is the discount factor and π_S the survival probability. The agent's period utility function is defined as follows

$$u(c, s) = \frac{(c^\alpha s^{1-\alpha})^{1-\sigma}}{1-\sigma},$$

where α represents the preference weight on non-durable consumption relative to housing services, and $1/\sigma$ gives the intertemporal elasticity of substitution.

Income Households supply inelastically one unit of labor and face idiosyncratic, persistent shocks to labor productivity z which follows an AR(1) process $\log(z') = \rho_z \log(z) + \epsilon'_z$. Agents earn a wage rate w per efficiency unit of supplied labor. Newborn agents draw initial liquid wealth from an income-specific distribution of initial assets $\mathcal{B}_{initial}$,

⁹The regions represent 75 percent and 25 percent of the U.S. economy. At this scale, the macroeconomic effect of a natural disaster is negligible: between 2004 and 2018, the average U.S. landfalling hurricane caused damages of less than 0.1% of GDP Fried (2022).

Housing Households choose their housing ownership status $\mathcal{O}$. In particular, they decide to either rent ($\mathcal{O} = \text{rent}$) or own ($\mathcal{O} = \text{own}$) a house, and choose a house size from the corresponding discrete set of rental houses $\mathcal{H}_R = \{h_R^1, \dots, h_R^{N_R}\}$ or owner-occupied houses $\mathcal{H}_O = \{h_O^1, \dots, h_O^{N_O}\}$. Renters pay a unit price of rent p_r and owners purchase housing units at price p_h . Every period, the housing stock depreciates at a rate ζ independent of natural disaster realizations, and homeowners pay a maintenance cost $p_h \zeta h$ to offset this depreciation. The owner-occupied housing market is frictional. First, owners can sell their house only with probability π_H .¹⁰ Likewise, prospective home buyers can successfully find a suitable home only with a probability of π_H . Second, housing is illiquid due to transaction costs ϵp_h associated with selling the house. Housing services s enter the utility function and are proportional to the house size h , but depend on home tenure $\mathcal{T}$ and the realization of the natural disaster shock δ :

$$s = \begin{cases} \psi_h(1 - \delta)h & \text{if } \mathcal{O} = \text{own} \\ h & \text{if } \mathcal{O} = \text{rent}, \end{cases} \quad (5)$$

where the parameter $\psi_h > 1$ represents a utility gain from homeownership. Rebuilding after a natural disaster takes time. Hence, the damages caused by the natural disaster reduce contemporaneous utility flow from housing services for homeowners. Renters do not experience reduced utility flows from housing services after natural disasters.¹¹ However, renters are indirectly affected by exposure to disasters as the expected rebuilding expenses of the rental agency increase the rental price (see Equation 20). I assume that, if hit by a natural disaster, homeowners are forced to restore the initial conditions of the house by investing $p_h \delta h$ in the same period. Homeowners receive rebuilding grants that reimburse uninsured damages up to a maximum grant $\bar{\tau}_\delta$ (for more details see Section 4.6). Consequently, a natural disaster can be viewed as both an expenditure shock and a negative impact on the utility derived from homeownership. Additionally, a natural disaster is a shock to housing wealth, potentially leaving households with negative home equity if the outstanding mortgage balance exceeds the house's remaining value. Thus, when making housing choices, agents trade off the utility gains from homeownership, the illiquidity of housing, and the direct exposure to natural disaster shocks.

¹⁰I incorporate this friction since above-water defaults and foreclosures are often driven by housing market frictions (Ganong and Noel, 2023). Accounting for this mechanism allows the model to better match the average delinquency rate observed in the data.

¹¹Agents can move between rental units without incurring moving costs. Therefore, if they experienced disutility from living in a damaged rental unit, they would simply relocate to an intact one. As a result, it is equivalent to assuming that renters face no utility loss from disasters, while a constant share of rental units is destroyed by the natural disaster.

Portfolio choice Agents can hold one-period bonds b and choose next period's bonds b' subject to a borrowing constraint $b' \geq b_{min}$. Households can finance the purchase of a house with a multi-period mortgage m , subject to a collateral constraint $m \leq \lambda p_h h$ at issuance. Mortgages are modeled as infinitely running contracts with decaying payments μm , where the mortgage evolves according to $m' = (1 + r_m - \mu)m$.¹² The per-period mortgage payment μm does not depend on idiosyncratic borrower characteristics. Instead, the mortgage pricing function is borrower-specific: at issuance, the household receives a total amount of $q(b', h, m, z, k, M)m$ and makes the first mortgage payment in the following period. The full mortgage pricing function is stated in Equation 13.

The present value of future mortgage payments is then $(1 + r_m)m$, and agents own home equity $e = p_h(1 - \delta)h - (1 + r_m)m$.¹³ Despite the loan-to-value limit, mortgage holders can end up with negative home equity following a natural disaster.

Delinquency and foreclosure A homeowner with a mortgage m can choose either to make or to miss the mortgage payment μm . Missed mortgage payments alter the outstanding mortgage balance, with $m' = (1 + r_m)m$. Conditional on having missed a mortgage payment, the mortgage remains delinquent with probability $\pi_D(\delta, M)$ or is foreclosed with probability $1 - \pi_D(\delta, M)$ within the same period. M is a policy parameter that indicates whether a foreclosure moratorium is imposed. This moratorium limits the bank's ability to foreclose on households affected by natural disasters, thereby increasing the likelihood of delinquency. Details on this moratorium are provided in Section 4.6. Both delinquency and foreclosure are associated with social stigma, which I model as a utility cost κ incurred by households in either state.

A previously delinquent homeowner can become performing again in the next period. In the event of foreclosure, the bank sells the house to recover the outstanding mortgage. A foreclosed homeowner becomes a renter and is excluded from both the mortgage market and the owner-occupied housing market as long as a foreclosure flag remains on her credit record. The bank can recover only $(1 - \epsilon_F)p_h(1 - \delta)h$ of the collateral due to an inefficient foreclosure technology ϵ_F . Home equity after foreclosure is defined as $\tilde{e}(h, m, \delta) = (1 - \epsilon_F)p_h(1 - \delta)h - (1 + r_m)m$. If the recovered collateral is insufficient to cover the mortgage ($\tilde{e}(h, m, \delta) < 0$), mortgage holders remain liable for the outstanding balance with probability π_R .¹⁴ Figure 3

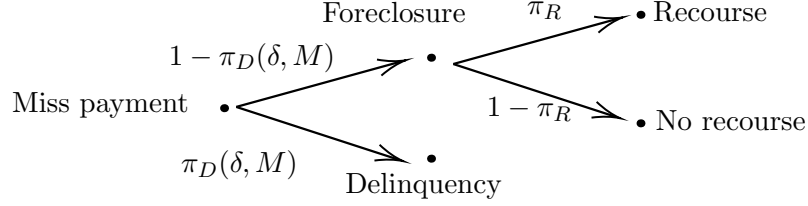
¹²The assumption, similar to that in Chatterjee and Eyigungor (2009), Herkenhoff and Ohanian (2019), and Luzzetti and Neumuller (2012), preserves tractability by ensuring that mortgage maturity does not enter the state space.

¹³In the first period, no payment is made, so at time 1 the outstanding balance is $m_1 = (1 + r_m)m$. From period $t \geq 1$, a share μ of the current outstanding principal is paid. The present value (PV) of the stream of discounted payments is $PV = \mu m \sum_{t=0}^{\infty} \left(\frac{1+r_m-\mu}{1+r_m} \right)^t = (1 + r_m)m$.

¹⁴The parameter π_R can be interpreted as the strictness of the recourse regime. A value of $\pi_R = 0$ means

summarizes the different within-period outcomes after having missed a mortgage payment.

Figure 3: Consequences of Mortgage Default



Note: This figure summarizes the potential end of period outcomes for a homeowner who decides to miss the mortgage payments at the beginning of a period. Both $\pi_D(\delta, M)$ and π_R are exogenous probabilities where the moratorium indicator M is a policy choice and δ is the natural disaster shock.

Under recourse, the bank can seize liquid assets above the exemption limit b_{exemp} and garnish a share $\omega(b, \tilde{e}(h, m, \delta), z)$ of the households' labor income to recover the outstanding mortgage amount in expectation.¹⁵

The amount of negative home equity after foreclosure, $\tilde{e}(h, m, \delta)$, liquid assets that can be seized, $b - b_{\text{exemp}}$, as well as the expected labor income over the wage garnishment period, $\bar{y}(z)$, determine the share of income that is garnished (see Section 4.2). For tractability, households exit the wage garnishment state with a constant probability π_P .

Private disaster insurance Homeowners can purchase one-period insurance contracts that cover realized natural disaster damages up to ι at unit price p_ι . At the beginning of each period, after observing their idiosyncratic labor productivity shock, homeowners choose the optimal insurance contract ι . Regardless of whether a natural disaster occurs, homeowners pay the insurance premium $p_\iota \iota$. In the event of a natural disaster, the insurance firm pays a claim equal to $\min\{\iota, p_h \delta h\}$ within the same period. This allows us to define the homeowner's net insurance payments after the disaster, taking into account rebuilding expenditures as well as public and private disaster insurance payouts:

$$i(\iota, \delta) = \min\{\iota, p_h \delta h\} + \max\{0, \min\{p_h \delta h - \iota, \bar{\tau}_\delta\}\} - \iota p_\iota. \quad (6)$$

This modeling choice reflects the U.S. disaster aid system, in which individuals are eligible for FEMA grants only for their uninsured damages. Consequently, private disaster insurance coverage ι directly reduces the amount of financial disaster aid received.

that households are not liable for any outstanding mortgage payments after a foreclosure. A value of $\pi_R = 1$ corresponds to full recourse, meaning all outstanding mortgage debt must be repaid.

¹⁵Liquid assets after foreclosure are then defined as $b_F = \max\{b + \tilde{e}(h, m, \delta), \min\{b_{\text{exemp}}, b\}\}$.

Budget constraints Agents pay tax τ on their labor income wz , choose net savings $(b' - (1+r)b)$, and pay ownership-specific housing costs depending on house size h , realized damages δ , and the mortgage amount m . The budget constraints read as follows

$$c = \begin{cases} (1-\tau)wz + (1+r)b - b' + i(\iota, \delta) - \mu m - p_h(\delta + \zeta)h & \text{Owner} \\ (1-\tau)wz + (1+r)b - b' - p_r h & \text{Renter} \\ (1-\tau)wz + (1+r)b - b' - p_r h + (1-\epsilon)p_h h^- - (1+r_m)m^- & \text{Renter, previous owner} \\ (1-\tau)wz + (1+r)b - b' + q(b', h, m, z, k, M)m - (1+\zeta)p_h h & \text{Buyer, previous renter} \\ (1-\tau)wz + (1+r)b - b' + q(b', h, m, z, k, M)m - (1+\zeta)p_h h & \text{Buyer, previous owner} \\ +(1-\epsilon)p_h h^- - (1+r_m)m^- & \\ \max\{\underline{y}, (1-\omega(b, e, z))(1-\tau)wz\} + (1+r)b - b' - p_r h & \text{Foreclosed owner,} \end{cases}$$

where $\underline{y}$ is the subsistence level of income that the government ensures via targeted transfer payments to households under wage garnishment, and h^-, m^- refer to housing and mortgages in the previous period.

Decision problem of a homeowner Given the vector of state variables (b, h, m) and the realization of the labor productivity shock z , a homeowner ($\mathcal{O} = own$) chooses contemporaneous insurance coverage $\iota \in [0, \bar{\iota}]$ to maximize expected life-time utility

$$\max_{\iota} \mathbb{E}V^{own}(b + i(\iota, \delta), h, m, z, \delta) \quad (7)$$

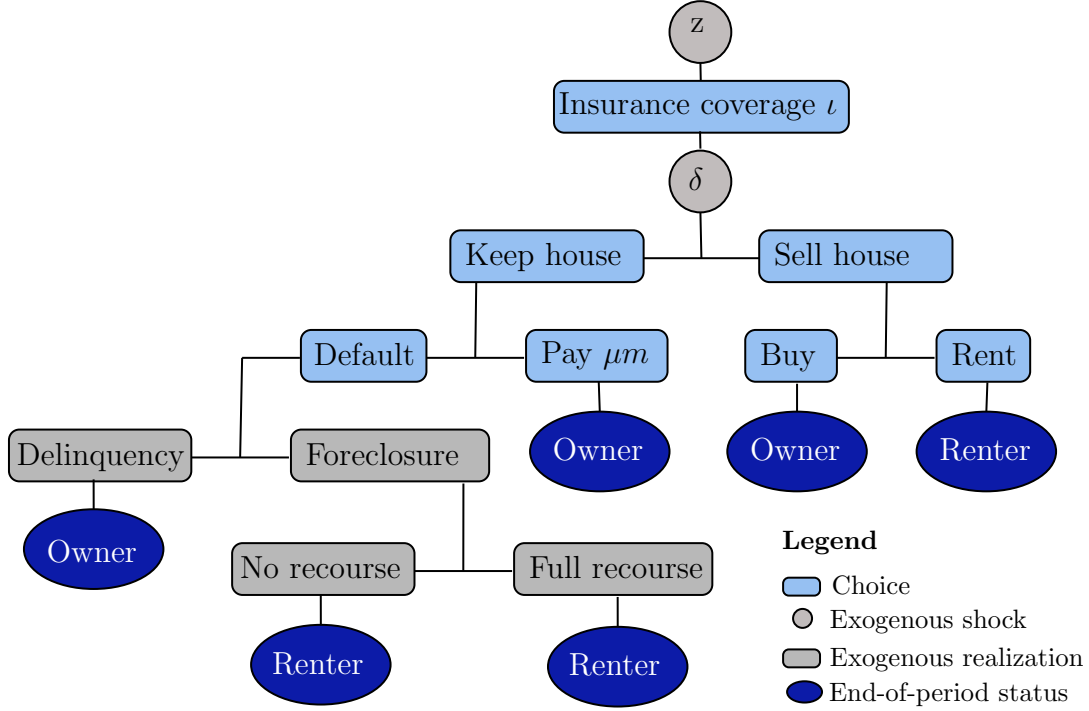
The value function of a homeowner V^{own} summarizes two sequential discrete decisions as summarized in Figure 5. After choosing the insurance coverage and observing the natural disaster, the homeowner decides whether to sell ($S = 1$) or keep ($S = 0$) the house.

$$\mathbb{E}V^{own}(b, h, m, z, \delta) = \max_{S \in \{0,1\}} \left\{ (1-S) [\mathbb{E}V^{keep}(b, h, m, z, \delta) + \sigma_S \varepsilon_S(0)] + S [\mathbb{E}V^{sell}(b_S(h, m, \delta), h, m, z, \delta) + \sigma_S \varepsilon_S(1)] \right\}, \quad (8)$$

where $b_S(h, m, \delta)$ reflects liquid assets after selling the house and repaying the mortgage, and ε_S are Type-I extreme value taste shocks with smoothing parameter σ_S .¹⁶ They smooth choice probabilities for computational tractability and capture unobserved relocation motives such as changes in family circumstances or job opportunities.

¹⁶Liquid assets after selling a house are defined as $b_S(h, m, \delta) = b + \frac{1}{1+r} [p_h(1-\epsilon)(1-\delta)h - (1+r_m)m]$.

Figure 4: Consequences of Mortgage Default



Note: This figure summarizes the timing of the main decisions taken by a homeowner within one period. The decisions and exogenous realizations lead to different end-of-period housing tenure states. Exogenous income shock z and natural disaster shock δ are realized. μm represents the per-period mortgage payments conditional on having a mortgage of size m . For simplicity, I abstract from the probability of actually being able to sell the house, π_H .

Figure 5: Within-period timing of decisions and exogenous realizations of a homeowner

If the homeowner decides to keep her house ($S = 0$), she then chooses whether to make mortgage payments ($D = 0$) or to default on her mortgage ($D = 1$).

$$\begin{aligned}
 \mathbb{E}V^{keep}(b, h, m, z, \delta) = \max_{D \in \{0,1\}} & \left\{ (1 - D) \left[W_{perf}^{own}(b(\iota, \delta), h, m, z, \delta) + \sigma_D \varepsilon_D(0) \right] \right. \\
 & + D \left[\pi_D(\delta, M) W_{del}^{own}(b, h, m, z, \delta) + (1 - \pi_D(\delta, M)) \right. \\
 & \left. \left(\pi_R W_{for}^{rent}(b_F, \omega(b, e, z), z) \right. \right. \\
 & \left. \left. + (1 - \pi_R) W_{for}^{rent}(b, \omega = 0, z) \right) + \sigma_D \varepsilon_D(1) \right] \left. \right\}
 \end{aligned} \tag{9}$$

where b_F denotes liquid assets after foreclosure under recourse, and ε_D are Type-I extreme

value taste shocks with smoothing parameter σ_D . These taste shocks capture additional default triggers beyond natural disaster and income shocks, such as health shocks or divorce.¹⁷ Since $\mathbb{E}V^{keep}(b(\iota, \delta), h, m, z, \delta)$ is the ex-ante value before the realization of the taste shock, there is no need to include the realization of the taste shock as a state variable.¹⁸ The household anticipates that, in the event of default, it may either remain delinquent or face foreclosure. Conditional on foreclosure, the probability of entering recourse and being liable for the outstanding mortgage debt is included in the expectation. In the absence of recourse, the household is excluded from the mortgage market and the owner-occupied house market – as long as the credit flag is removed with exogenous probability π_P – but is not subject to asset seizure $b_F = b$ or wage garnishment $\omega = 0$.

If, instead, the homeowner decides to sell the house ($S = 1$), she finds a suitable buyer with probability π_H . Upon a successful sale, she can either purchase a new house ($R = 0$) or become a renter ($R = 1$).¹⁹ If the agent is unsuccessful in finding a suitable buyer, she faces the same decision problem as in equation (9).

$$\begin{aligned} \mathbb{E}V^{sell}(b, h, m, z, \delta) = & (1 - \pi_H)\mathbb{E}V^{keep}(b, h, m, z, \delta) \\ & + \pi_H \max_{R \in \{0,1\}} \left\{ R[W_{perf}^{rent}(b_S(h, m, \delta), z) + \sigma_R \varepsilon_R(1)] \right. \\ & \left. (1 - R)[W^{buy}(b_S(h, m, \delta), z) + \sigma_R \varepsilon_R(0)] \right\}, \end{aligned} \quad (10)$$

where ε_R are Type-I extreme value taste shocks with smoothing parameter σ_R included for computational tractability. New renters or home buyers choose their house size (and mortgage size) optimally. For a complete definition of the corresponding value functions W^{buy} , W_{perf}^{rent} , W_{for}^{rent} , W_{perf}^{own} , and W_{del}^{own} , see Appendix C.1.

Decision problem of a renter A renter with a good credit history can either remain in the rental unit ($R = 1$) or become a homeowner ($R = 0$). A renter finds a suitable home

¹⁷Only about 40 percent of delinquent borrowers report income loss as the primary reason for delinquency (Cutts and Merrill, 2008), while most defaults arise from so-called ‘double-trigger’ events (Ganong and Noel, 2023). In the model, natural disasters are the only shocks that can be interpreted as such an event. Since these disasters are rare, I introduce additional taste shocks to generate default rates consistent with the data.

¹⁸If a mortgage owner cannot afford to stay delinquent due to rebuilding costs, i.e. she would face a negative consumption stream, she automatically enters foreclosure. I call this “consensual” foreclosure in contrast to “involuntary” foreclosures, where homeowners hoped to enter delinquency but ended up being evicted. For simplicity, I abstract from this feature in the model description.

¹⁹The option to buy the same house size with a different mortgage amount implicitly allows for refinancing of mortgages in the model.

with probability π_H . The expected value function can be summarized as

$$V_{perf}^{rent}(b, z) = \max_{R \in \{0,1\}} \left\{ R[W_{perf}^{rent}(b, z) + \sigma_R \varepsilon_R(1)] \right. \\ \left. + (1 - R)[\pi_H W^{buy}(b, z) + (1 - \pi_H)W_{perf}^{rent}(b, z) + \sigma_R \varepsilon_R(0)] \right\},$$

where ε_R are Type-I extreme value taste shocks with smoothing parameter σ_R , included for computational tractability.

Decision problem of a foreclosed owner Finally, a renter who was previously a foreclosed homeowner and currently holds a credit flag exits this state with probability π_P and is no longer excluded from the owner-occupied housing market. Her expected lifetime utility is defined as

$$\mathbb{E}[V_{for}^{rent}(b, \omega, z)] = \pi_P W_{perf}^{rent}(b, z) + (1 - \pi_P)W_{for}^{rent}(b, \omega, z)$$

Renters choose their housing size every period without frictions. Hence, the current size of their home is not a state variable. For a detailed exposition of the full decision problem and the definition of the value functions W_{perf}^{own} , W_{del}^{own} , W_{for}^{rent} , W_{perf}^{buy} , W_{perf}^{rent} , see Appendix C.1.

4.2 Financial intermediary

The financial intermediary accepts bonds, issues mortgages, and can borrow or lend abroad at the exogenously given risk-free interest rate r . Bonds are free of default risk, and competition is perfect; therefore, the intermediary pays the risk-free rate on bonds. Mortgages are priced to yield zero expected profit on a loan-by-loan basis. Specifically, the intermediary issues $q(b', h, m, z, k, M)$, m and receives a stream of decaying payments μm , where the outstanding balance evolves according to $m' = (1 + r_m - \mu)m$. The intermediary observes each household's portfolio choices (b', m, h) , as well as its labor productivity type z and region k . These factors determine the household's likelihood of default and, consequently, the expected return on a mortgage. Although government policy does not enter directly into the default decision rule, household default behavior depends on disaster aid. As a result, changes in disaster aid or in recourse regulation indirectly affect mortgage pricing by affecting default probabilities and the expected return under foreclosure.

To present the mortgage pricing condition, I define a vector of relevant state variables $x = (b, h, m, z, k, M)$. If the mortgage continues to be performing, $D(x') = 0$, the bank receives mortgage payment $\mu m'$ as well as the continuation value of the mortgage $q(\cdot)m'$.

When the house is sold, $S(x') = 1$, the mortgage is paid in full.

If a household suspends mortgage payments, $D(x') = 1$, and enters delinquency, the bank receives the continuation value $q_{del}(\cdot)m'$. In the event of foreclosure, the bank can recover $F(x)$, which represents the value of the underlying collateral after sale, together with any liquid assets that can be seized and the wages that can be garnished under recourse:

$$F(x) = \min \{ (1 + r_m)m, (1 - \epsilon_F)p_h(1 - \delta)h + \pi_R [\max(b - b_{exemp}, 0) + \omega(x)\bar{y}(z)] \}, \quad (11)$$

where the share of garnished income is defined as follows

$$\omega(x) = \max \left\{ 0, \min \left\{ \bar{\omega}, -\frac{\tilde{e}(h, m, \delta) + \max\{0, b - b_{exemp}\}}{\bar{y}(z)} \right\} \right\}, \quad (12)$$

with a maximum wage garnishment $\bar{\omega}$.²⁰ The intermediary prices mortgages by discounting the expected stream of repayments at the rate r_m , resulting in the following pricing function:

$$\begin{aligned} q(x)m = & \mu m + \frac{1}{1 + r_m} \mathbb{E}_{\delta', z'} \left(S(x')\pi_H(1 + r_m)m + [(1 - S(x')) + S(x')(1 - \pi_H)] \right. \\ & \cdot \left. \left[[1 - D(x')]q(x')m' + D(x')[\pi_D(\delta', M)q_{del}(x')m' + (1 - \pi_D(\delta', M))F(x')] \right] \right) \end{aligned} \quad (13)$$

The present value of a delinquent mortgage q_{del} is defined accordingly, taking into account that a delinquent mortgage holder does not make any contemporaneous payments but might become performing again in the next period.²¹

4.3 Housing

The housing sector builds on Kaplan et al. (2020), incorporating a construction firm and a rental agency. The construction firm is necessary to allow for policy-driven variations in housing stock levels across different steady states. Including a rental sector is crucial as

²⁰The n -period ahead expectation about labor income conditional on labor productivity z_t can be expressed as follows $E[z_{t+n} | z_t] = z_t^{\rho^n} \exp(\frac{\sigma_\epsilon^2}{2} \frac{1 - \rho^{2n}}{1 - \rho^2})$. Hence, the expected income over the wage garnishment period is defined as $\bar{y}(z_t) = \sum_{n=0}^{\infty} (1 - \pi_P)^n z_t^{\rho^n} \exp(\frac{\sigma_\epsilon^2}{2} \frac{1 - \rho^{2n}}{1 - \rho^2})$.

²¹The present value of a delinquent mortgage is defined as follows

$$\begin{aligned} q_{del}(x)m = & \frac{1}{1 + r_m} \mathbb{E} \left(S(x')\pi_H(1 + r_m)m + [(1 - S(x')) + S(x')(1 - \pi_H)] \right. \\ & \cdot \left. \left[[1 - D(x')]q(x')m' + D(x')[\pi_D(\delta', M)q_{del}(x')m' + (1 - \pi_D(\delta', M))F(x')] \right] \right). \end{aligned} \quad (14)$$

an outside option after foreclosure. Labor is assumed to be perfectly mobile across sectors within a region. For clarity, regional subscripts are omitted in this section.

4.3.1 Construction Sector

In every region, the construction sector is perfectly competitive and produces new owner-occupied housing units using labor N_H and land $\bar{L}$ as input factors based on the following technology

$$H^{new} = [\Theta N_H]^\xi \bar{L}^{1-\xi} \quad (15)$$

where Θ represents labor productivity. As production takes time, housing units become available in the next period. Land has a fixed supply each period, and the government sells the right to use land at a competitive price q_L such that the construction sector makes zero profit in equilibrium. The construction firm solves the following problem

$$\max_{N_H} p_h [\Theta N_H]^\xi \bar{L}^{1-\xi} - w N_H - q_L \bar{L} \quad (16)$$

Under perfect competition and free entry, the first order condition holds in equilibrium $w = p_h \xi \Theta^\xi \bar{L}^{1-\xi} N_H^{\xi-1}$. Accordingly, labor demand in the construction sector, N_H , and the total units constructed, H^{new} , are defined as follows:

$$N_H = \left(\frac{w}{\xi p_h \Theta^\xi} \right)^{\frac{1}{\xi-1}} \bar{L} \quad \text{and} \quad H^{new} = \left(\frac{w}{\xi p_h} \right)^{\frac{\xi}{\xi-1}} \Theta^{\frac{\xi}{1-\xi}} \bar{L} \quad (17)$$

Finally, free entry determines the price for the building permits that is paid to the government:

$$q_L = (w \Theta)^{\frac{\xi}{\xi-1}} p_h^{\frac{1}{1-\xi}} \left[\xi^{\frac{\xi}{1-\xi}} - \xi^{\frac{1}{1-\xi}} \right] \quad (18)$$

4.3.2 Rental Sector

In both regions, a competitive rental agency owns housing units H_R and trades units on the housing market at price p_h to rent them to households at rental price p_r . The rental agency faces per-period operating costs of q_R per unit rented, and undertakes per-unit maintenance investment to offset depreciation of the rental housing stock at the constant rate ζ . A natural disaster destroys a fraction $\sum_{i \in S, L} \pi_i \delta_i$ of the beginning-of-period housing stock H_R . The rental agency chooses next period's housing stock, H'_R , by purchasing

$H'_R - (1 - \sum_{i \in S,L} \pi_i \delta_i) H_R$. The optimization problem can be expressed in recursive form:

$$R(H_R) = \max_{H'_R} (p_r - q_R - p_h \zeta) H'_R - p_h \left(H'_R - \left[1 - \sum_{i \in S,L} \pi_i \delta_i \right] H_R \right) + \frac{1}{1+r} R(H'_R) \quad (19)$$

Solving for the optimal investment into the rental housing stock yields a no-arbitrage condition that links the equilibrium rental rate to the rental agency's operating costs, depreciation from natural disasters, and current and future house prices. In a stationary equilibrium, house prices are unchanged, and the following no-arbitrage condition must hold:

$$= q_R + \left[(1 + \zeta) - \frac{1 - \sum_{i \in S,L} \pi_i \delta_i}{1 + r} \right] p_h. \quad (20)$$

4.4 Final-Good Sector

In each region, a perfectly competitive final-good producer operates a constant returns to scale technology $Y_C = \Theta_C N_C$ and uses labor N_C as the only input at cost w to produce non-durable consumption goods. The final-good producer maximizes profit as follows

$$\max_{N_C} \Theta_C N_C - w N_C.$$

4.5 Private insurance firm

A perfectly competitive private insurance company offers households one-period contracts at the unit price $p_\iota(\iota)$. In expectation, the insurer earns zero profit on each contract. For every unit of coverage sold, the insurance company incurs intermediation costs q_ι , such as administrative fees and operating expenses. Imposing the zero-profit condition, the marginal price of an additional unit of insurance depends on the unit price $p_\iota(\iota)$ as well as the region-specific probability of small disasters $\pi_{S,k}$ and large disasters $\pi_{L,k}$:

$$p'_\iota(\iota) = \begin{cases} (1 + q_\iota)(\pi_{S,k} + \pi_{L,k}) & \text{for } \iota \leq p_h \delta_{small} h \\ (1 + q_\iota) \pi_{L,k} & \text{for } p_h \delta_{small} h < \iota \leq p_h \delta_{large} h \\ 0 & \text{else.} \end{cases} \quad (21)$$

Then, the total price of insurance coverage i can be expressed in the step-wise linear function

$$p_\iota(\iota) = \begin{cases} (1 + q_\iota)(\pi_{S,k} + \pi_{L,k})\iota & \text{for } \iota \leq p_h \delta_{small} h \\ (1 + q_\iota)[(\pi_{S,k} + \pi_{L,k})\delta_{small} p_h h + \pi_{L,k}(\iota - \delta_{small} h)] & \text{for } p_h \delta_{small} h < \iota \leq p_h \delta_{large} h \\ (1 + q_\iota)[(\pi_{S,k} + \pi_{L,k})\delta_{small} p_h h + \pi_{L,k}(\delta_{large} - \delta_{small} h)] & \text{else.} \end{cases} \quad (22)$$

4.6 Government

The government runs a balanced budget. It levies a labor income tax τ , collects revenue from selling land permits q_L , provides rebuilding grants that reimburse uninsured damages up to a maximum grant $\bar{\tau}_\delta$, and redistributes the remaining amount plus the home equity of deceased agents via a lump-sum transfer Γ_k . Moreover, the government provides welfare payments to guarantee a minimum income level of $\underline{y}$. Revenue from land permit sales is used locally, while disaster aid is financed jointly by both regions. Following a natural disaster, the government supports affected homeowners by providing financial aid up to $\bar{\tau}_\delta$. Hence, region-specific lump-sum transfers Γ_k in region k are defined as follows:

$$\begin{aligned} \Gamma_k = & \underbrace{\Gamma_G}_{\text{lump-sum transfer to all HHs}} + \underbrace{q_L(k)\bar{L}(k)}_{\text{regional revenue from land permits}} \\ & + \underbrace{\int \eta_{i,k} di}_{\text{home equity of deceased agents}} \end{aligned} \quad (23)$$

with

$$\begin{aligned} \Gamma_G = & \underbrace{\sum_k \pi_k \int \tau w z_{i,k} di}_{\text{labor income tax}} - \underbrace{\sum_k \pi_k \int \min\{\bar{\tau}_\delta \delta_{i,k}, p_h \delta_{i,k} h_{i,k} - \iota\} di}_{\text{damage-dependent grants}} \\ & - \underbrace{\sum_k \pi_k \int \max\{0, \underline{y} - (1 - \omega_{i,k})(1 - \tau) w z_{i,k}\} di}_{\text{welfare payments}} \end{aligned} \quad (24)$$

where π_k represents the location-specific population mass with $\sum_k \pi_k = 1$.

Government aid has a second margin: the government imposes a foreclosure moratorium ($M = 1$), during which the mortgages of affected homeowners are protected from foreclosure. Hence, the probability that a mortgage remains delinquent depends on both whether the

household was affected by a natural disaster ($\delta > 0$) and whether a foreclosure moratorium is in effect ($M = 1$):

$$\pi_D(\delta, M) = \begin{cases} 1 - \pi_F \pi_M & \text{if } \delta > 0 \text{ and } M = 1 \\ 1 - \pi_F & \text{else} \end{cases} \quad (25)$$

where π_M reflects the length of the foreclosure moratorium. An additional policy tool is the strictness of the recourse regime π_R .

4.7 Equilibrium

Agents take the risk-free interest rate r and wages w as a given. A stationary equilibrium consists of house pricing functions p_h and p_r that clear housing markets and ensure the rental agency makes zero profit. Households maximize utility given prices. The equilibrium is a fixed point in pricing schedules for mortgages, such that given prices, households maximize, and given optimal default behavior of households, intermediaries make zero profit in expectation. Insurance contracts are priced to cover expected payouts, while firms in construction and production maximize profits. Labor and goods markets clear, and government policies and transfers adjust to balance the budget. The formal definition of equilibrium is given in Appendix C.2.

5 Calibration and Computation

The model is calibrated to the United States from 2000 to 2020, with each model period representing half a year. The primary objective is to match aggregate statistics of the U.S. housing market and to capture default behavior following natural disasters, accounting for the institutional framework specific to the U.S. context.

5.1 Computation

I follow Druedahl (2021) and solve the household problem using the nested endogenous grid method with upper envelope (NEGM) adapted for multiple continuous and discrete choices. A key computational improvement comes from separating the consumption–savings decision from other choices, allowing pre-computation of continuation values. I do not treat insurance coverage as a state variable; instead, the optimal coverage is determined by interpolating the value function of a homeowner V^{own} with respect to liquid assets $b(\iota)$. I solve the consumption–savings problem for owners, renters, and foreclosed owners, while the buyer

problem reduces to a two-dimensional choice over housing and mortgage, conditional on the owner solution. Detailed grids and solution methods are provided in Appendix D.

5.2 External calibration

Table E.2 summarizes all externally calibrated parameters.

Demographics A period length is set to half a year. Households die with a constant probability $1 - \pi_S = 0.01$. This implies an average length of working life of 50 years.

Preferences Individuals discount future utility flows by $\beta = 0.98$. I assume constant relative risk aversion with an intertemporal elasticity of $1/2$ ($\sigma = 2$). Following Mitman (2016), I set the Cobb-Douglas parameter $\alpha = 0.859$ to match a 14.1 percent share of housing in total consumption.

Income Following Kaplan et al. (2020), I assume a persistence of labor productivity $\rho^z = 0.97$ and a standard deviation of shocks to labor income $\sigma_z = 0.2$. I approximate the income process by a three-state Markov process. Median labor productivity is normalized to one. Newborn agents draw from an initial asset distribution disciplined by data from the Survey of Consumer Finances (2019) to match the correlation between liquid asset holdings and income (see Appendix E.1 for details).

Housing To define a housing grid, I categorize rental and owner-occupied housing separately in the AHS, grouping them into four size categories. For each group, I calculate the median home market value. Rental unit values are imputed based on owner-occupied homes of the same size. Drawing on housing choices observed in the 2021 American Housing Survey (AHS) (see Figure E.1), I assume the housing market is imperfectly segmented, leading to distinct grids for owner-occupied and rental units. The number of grid points and their spacing are determined based on AHS data, while the minimum rental house size, h_{min} , is internally calibrated. Transaction costs for selling a house, ϵ , are set at 7% of the house's value (Kaplan et al., 2020), and housing maintenance costs, ζ , which include depreciation and taxes, are set at 1.5% (Kaplan et al., 2020). To calibrate the probability of successfully selling a house, I use the Median Number of Months on Sales Market for Newly Completed Homes reported by the U.S. Census Bureau. Excluding the U.S. housing crisis, the average time-to-sell between 2000 and 2020 is estimated at 3.8 months. Assuming a constant monthly sale probability, this implies a 64% probability of selling a house within one period.

Production As in Kaplan et al. (2020), the construction technology parameter ξ is set to 0.6, implying a price elasticity of housing supply of 1.5, which is the median value across MSAs estimated by Saiz (2010). I normalize labor productivity to one ($\Theta_H = \Theta_C = 1$).

Financial Instruments and Regulation Agents are restricted to holding non-negative liquid assets, i.e., agents cannot borrow $\underline{b} = 0$. The annual risk-free rate r is set at the average Fed funds rate over the model period (1.78 percent). Following Mitman (2016), I set the proportional interest rate wedge $\frac{r_m}{r} - 1$ to 0.33. Mortgage holders can select a loan-to-value (LTV) ratio below the LTV limit of 0.8 (Berger et al., 2018), and repay a constant 5 percent of their outstanding mortgage balance annually ($\mu = 0.025$).

The probability of a non-performing mortgage being foreclosed depends on the occurrence of a disaster and is externally calibrated based on loan-level data from Fannie Mae ($\pi_F = 0.015$). Consistent with Mitman (2016), I set the foreclosure loss parameter, ϵ_F , to 0.22 reflecting the additional loss incurred in a foreclosure. In the event of personal bankruptcy, federal law protects certain amounts of cash and other property. Under Federal Wildcard Exemptions, individuals can shield up to USD 1,825 in cash, plus any unused homestead exemption of up to USD 13,950. Consequently, I define the amount of exempt assets relative to median income as $b_{exemp} = 0.46$. According to the Federal Wage Garnishment Law, up to 15 percent of labor income can be garnished. Similar to the 5-year repayment period under Chapter 13 bankruptcy, agents remain in the wage garnishment state for an average of 5 years, implying a transition probability of $\pi_P = 0.1$.

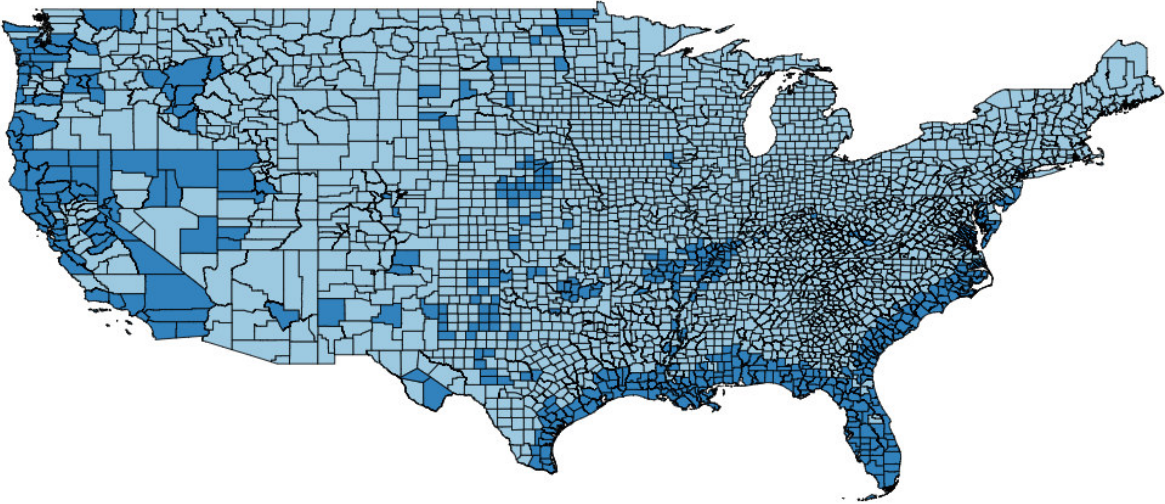
Natural disasters The model consists of two types of regions ($N_k = 2$) that differ in disaster exposure: low exposure regions and high exposure regions. To identify average risk exposure for each region type, I group U.S. counties by Expected Annual Loss Rate (EALR) as defined in the National Risk Index Database.²² The EALR represents the average proportional economic loss to building infrastructure resulting from natural hazards each year. This measure combines the annualized frequency of natural disasters with the historical percentage of building value destroyed by them. I sort regions by their EALR and define the

²²The National Risk Index, developed by the Federal Emergency Management Agency (FEMA), combines risk for 18 natural hazards into an index at the county level. The key component *Expected Annual Loss* for each county c is constructed as $EAL_c = \sum_{h=1}^{18} EAL_{c,h}$ with $EAL_{c,h} = Exposure_{c,h} \cdot AnnualizedFrequency_{c,h} \cdot HistoricLossRatio_{c,h}$ where h represents a hazard-type. The index is based on various data sources. The historical loss rate based on SHELUS and building exposure values is based on values recorded in Hazus 6.0. The annualized frequency is based on hazard-specific datasets, e.g., USDA, Forest Service Fsim Burn Probability and Fire Intensity Level Source for wildfires, and SPC Severe Weather Database (NOAA) for strong winds. For more technical details, see <https://www.fema.gov/flood-maps/products-tools/national-risk-index> and for further details on National Risk Index methodology and results see Zuzak et al. (2022).

cut-off loss rate such that the low-risk regions constitute 75 percent of the U.S. population. Figure 6 provides a map of the classified regions. The regional-specific disaster risk is then the average EALR of all low-risk (high-risk) counties with $EALR_{low} = 0.0004$ (and $EALR_{high} = 0.0023$).

To estimate the average relative housing destruction, I use OpenFEMA data on NFIP claims transactions, which provide detailed information on property-level flood damage and the actual cash value of affected properties. After trimming the bottom and top one percent of observations, I compute the average share of property damage relative to the property's cash value. I then cluster these relative damages using k-means clustering. The first cluster, representing 72.69 percent of observations, has a mean damage share of 0.12, while the second cluster, representing 27.31 percent of observations, has a mean of 0.66. These values provide the estimates $\delta_{small} = 0.12$ and $\delta_{large} = 0.66$. To calculate the share of affected homeowners for each region type, I divide the region-specific EALR by the corresponding average property damage share and convert the result to a bi-annual frequency by dividing by two. On average, 0.45 percent of homeowners in high-risk regions and 0.08 percent in low-risk regions are affected in each period.

Figure 6: Low- and high-risk counties in the U.S.



Note: County-specific disaster risk is based on the National Risk Index (see main text for details). Counties with dark-blue coloring are classified as high-risk regions. 25 percent of the total U.S. population lives in these high-risk regions.

Government The baseline income tax is set to 13.6 percent to match the average income tax paid in the U.S. Consistent with Mitman (2016), I set the probability of a deficiency

judgment after foreclosure, π_R , to 0.1. In the baseline, the government imposes a foreclosure moratorium for homeowners who are affected by natural disasters ($\mathbf{M} = 1$) and financial disaster aid that covers uninsured damages up to a maximum coverage amount $\bar{\tau}_\delta$. The maximum coverage amount provided by FEMA for a single disaster under the individual housing assistance program is USD43,600. Normalizing this by the median household income gives an upper bound on ex-post financial aid of $\bar{\tau}_\delta = 1.26$. In case of a foreclosure moratorium, all homeowners affected by a natural disaster are protected against foreclosures, normally for 90 days post-disaster, i.e., $\pi_M = 0.5$.

Insurance I externally calibrate the insurance wedge using data on the expected costs and premiums of the NFIP in 2017. Rate-based receipts account for 75 percent of premiums, whereas additional charges (reserve fund assessment, surcharges, and federal policy fee) amount to 25 percent (Congressional Budget Office, 2022). These numbers are in line with expense ratios of about 26 percent of homeowner insurance premiums as documented by the Insurance Information Institute (2023). Hence, I set the insurance wedge q_ι equal to 0.33.

5.3 Internal calibration

I calibrate the remaining seven parameters ($h_{min}, \psi_h, \kappa, \bar{L}, q_R, \sigma_D, \sigma_S$) jointly to match seven aggregate moments. Using the preference for homeownership ψ_h and the minimum house size h_{min} , I target the following moments: the average homeownership rate ($\approx 66\%$, FRED) and the ratio of mean house sizes of homeowners to renters (1.5 according to Chatterjee and Eyigungor (2015)). I target the homeownership rate of low-income households ($\approx 46\%$, FRED) with the per-unit costs of operation of the rental agency q_R . The values of land permits $\bar{L}$ are set to reflect the construction sector’s relative size in the U.S. ($\approx 5\%$ of total employment, FRED). Using the variance of taste shocks on selling the house σ_S , I aim at the average share of homes sold each period (0.1 following Kaplan et al. (2020)). Lastly, I target the average U.S. delinquency rate (1.7%) and the average home equity share (58%, FRED 2000-2020) with the disutility of default κ and the variance of the taste shock on default σ_D .²³ I use loan-level data from Fannie Mae Single-Family Mortgage containing the outstanding mortgage amount as well as the length of delinquency. I construct a delinquency rate to align the data with the model, where one period represents half a year. Since most delinquencies last less than six months, I adjust for their duration when calculating the target delinquency rate. Specifically, I determine the relative value of mortgages that are

²³In the model, defaults outside of natural disaster events are entirely driven by taste shocks. Income shocks are relatively persistent, and households cannot experience negative home equity in the absence of a disaster. Hence, a negative income shock leads them to sell rather than default.

delinquent over the course of a year, weighting delinquencies by their length. For each month and region, I calculate the value of mortgages delinquent for 30–90 days, 90–180 days, and more than 180 days. To account for their shorter duration, I scale down delinquencies of 30–90 days by multiplying by $1/2$. The delinquency rate is then calculated as the weighted value of delinquent mortgages divided by the total value of all active mortgages. Excluding the financial crisis period, this results in an average delinquency rate of 1.7%.

The model successfully replicates several key features of the U.S. housing and mortgage market. Panel (A) of Table 1 summarizes its performance against aggregate targeted moments. The model closely matches both the aggregate homeownership rate and the proportion of low-income households residing in rental units. Consistent with the data, which show that owner-occupied homes are on average 1.5 times larger than rental units, the model produces a comparable ratio of 1.7. In addition, the model’s aggregate mortgage delinquency rate aligns exactly with the empirical target of 1.7 percent. At the same time, the model underestimates the relative size of the construction sector and the average home equity ratio. Finally, the fraction of homes sold each period in the model is broadly consistent with the observed annual turnover rate in the housing market.

5.4 Model validation

Aggregate moments The model successfully replicates key untargeted aggregate moments of the U.S. housing market. Mortgage payments amount to 6 percent of income (not conditioning on mortgage holders), closely aligning with 7 percent reported in the 2019 AHS, while total owner costs, including mortgage payments, represent 7 percent compared to 9 percent in the data. The ratio of liquid assets to income is 13 percent, slightly above the 11 percent reported in the 2019 SCF. The model also matches the low observed foreclosure rate: 87 percent of affected homeowners remain in their homes after a disaster, consistent with the empirical estimate from Gallagher and Hartley (2017) following Hurricane Katrina. Although the model does not explicitly include a rebuilding decision, this outcome corresponds to the share of homeowners who do not relocate to a different-sized house after a disaster. The median income ratio of owners to renters in the model is 1.3, which is below the 1.8 observed in the 2019 AHS. Similarly, the home value-to-income ratio of 2.2 falls short of the empirical ratio of 3.7 based on purchase values from the 2019 SCF, and high-income households are less likely to own homes (70 percent in the model versus 84 percent in the data). The model underestimates the private insurance uptake: the economy features an insurance protection gap of 73 percent compared to 58 percent observed in the data (Swiss

Table 1: Model validation - Targeted and untargeted moments

Moments	Model	Data
(A) Target Moments		
Homeownership rate (all)	66%	66%
Homeownership rate (below median income)	48%	46%
Delinquency rate	1.7%	1.7%
Mean house size (owners/renters)	1.7	1.5
Average home equity ratio	0.44	0.57
Relative size of construction sector	0.02	0.05
Annual fraction of homes sold	0.13	0.10
(B) Untargeted Moments		
Liquid asset share	0.13	0.11
Mortgage payment over income (only homeowners)	0.06	0.07
Owner costs over income (w/ mortgages)	0.07	0.09
Foreclosure rate	0.02%	0.01%
Rebuilding after ND	87%	87%
Median income (owners/renters)	1.3	1.8
Insurance protection gap	73%	58-70%
Homeownership rate (high income)	70%	84%
Home value over income	2.2	3.7

Note: The table compares key moments generated in the model with corresponding moments in the data. For details on the sources, please see the main text.

RE, 2024). However, the model estimate is close to the protection gap observed specifically for flood insurance, which stands at around 70 percent (Amornsiripanitch et al., 2025). More broadly, estimates of insurance coverage regarding non-flood hazards should be interpreted with caution due to data limitations in the U.S.²⁴

Regional differences As documented in Table F.1, low-risk and high-risk regions exhibit substantial differences in their housing markets. These differences are also qualitatively captured by the model (see Table 2). Since GDP per capita does not differ significantly across regions, I assume the same income processes for both region types. Housing costs are higher in high-risk areas, even though people live in smaller homes. Homeownership rates are lower in high-risk regions, and homeowners are less likely to carry mortgages.²⁵

²⁴To the extent that the model overstates the insurance protection gap relative to the true aggregate, it likely overstates the welfare gains from government aid, as a larger share of households would benefit from the provision of publicly backed coverage.

²⁵Although the model captures these qualitative differences in the housing market, it does not match the quantitative gap in owner costs and size of homes. This gap might be generated by differences in amenity values of regions that are not captured by my model, but lead to different region-specific house prices.

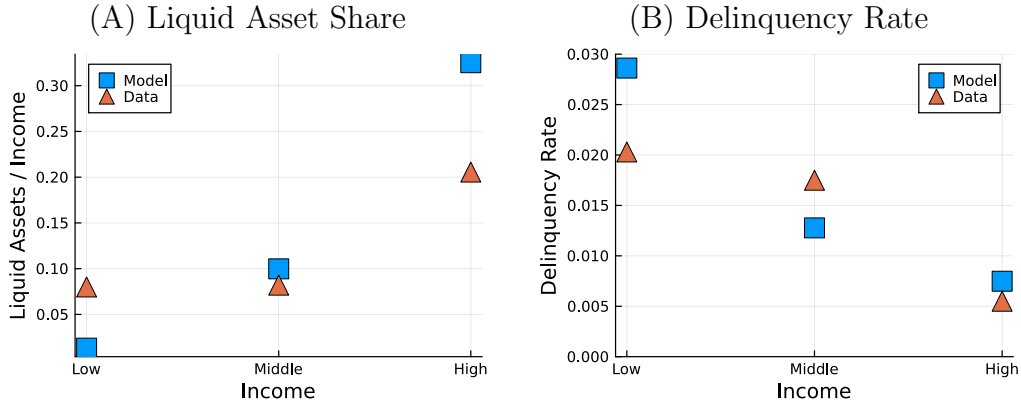
Table 2: Model Fit - Regional Differences

	Data	Model
Owner costs (w/o mortgage)	57.11%	21.01%
House size	-8.62%	-2.09%
Percent with mortgage	-6.48%	-6.09%
Homeownership rate	-2.81%	-1.12%

Note: Regional differences are expressed in percentage deviations from the low risk region. House size is measured as the number of rooms in the data. In the model, owner costs without mortgage payments are defined as per-period maintenance costs and rebuilding expenditures.

Distributional Moments The model reproduces two important distributional patterns observed in the economy: liquid assets and delinquency rates along the income distribution. Panel (A) of Figure 7 illustrates the gradient of liquid asset holdings with respect to income: higher-income households hold a larger share of liquid assets relative to their income than lower-income households. Panel (B) shows that delinquency declines with income.

Figure 7: Liquid Asset and Delinquency over the Income Distribution



Note: The figure plots data moments against moments generated by the model for each income group. Panel (A) plots the median share of liquid assets over income. Panel (B) plots the share of mortgage holders who are behind on their mortgage payments against the model's delinquency rate. Data moments are based on the Survey of Consumer Finances 2019 and the American Housing Survey 2019.

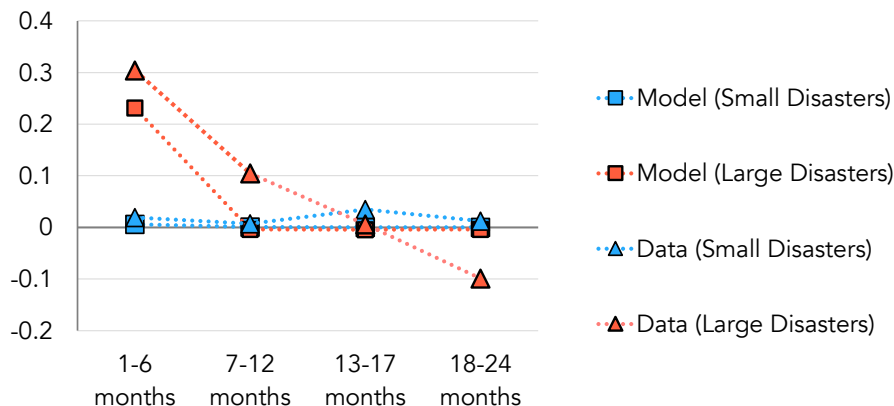
Given the limited availability of data on insurance coverage against natural disasters by income, I validate the model using payments for homeowner insurance policies that cover both disaster-related and non-disaster damages. As shown in Figure F.1, the model reproduces the same inverse-U relationship observed in the data: middle-income homeowners make the largest insurance payments relative to the value of their homes. Low-income households cannot afford extensive insurance coverage, whereas high-income households hold sufficient

liquid assets to self-insure against potential damages.

Response to Natural Disasters To compare model-generated impulse response functions with their empirical counterparts, I need to translate the model’s disaster shock into an empirically observed share of affected households, since there is no direct mapping between the two. Using property damage and housing value data from the AHS (2000–2020) and SHELDDUS, I compute the ratio of total property damage to total housing value at the county level and take the median across counties (0.98 percent). I then simulate the model’s response to a small (large) disaster under the assumption that 0.98 percent of households are hit by a small (large) shock. See Appendix F.1 for details on the simulation. Figure 8 plots the empirical impulse response functions alongside the model-based ones.

The model replicates the empirically observed response of delinquency rates reasonably well. After small disasters, delinquency rates barely respond—a pattern visible in both the model and the data. After large disasters, delinquency rates spike within the first six months but return to pre-disaster levels within a year; point estimates beyond that horizon are not statistically significant (see Figure 1).

Figure 8: Mortgage Delinquency after Natural Disasters



Note: The figure plots empirical and model-based impulse response functions for mortgage delinquency rates (in percentage points) in response to small and large natural disasters. The empirical estimates are presented in Section 2. For the model-based IRFs, I assume that 0.98 percent of homeowners are affected, based on the median relative destruction derived from AHS and SHELDDUS data. See the main text for further details on the simulation.

6 Results

The results are presented in five parts. First, I evaluate the effects of existing policies by removing the rebuilding grant and foreclosure moratoria. Second, I run a series of revenue-neutral policy counterfactuals that alter either the design of government aid or its financing source. Third, I assess how welfare responds to changes in the maximum grant size, asking whether providing full rebuilding grants would be welfare-improving. Fourth, I investigate the role of the recourse regime by comparing the welfare effects of policy reforms under a strict recourse regime with those under a very lenient regime. Lastly, I simulate a climate change scenario and assess the welfare effects of an altered disaster risk. To compare welfare among different steady states under counterfactual policy regimes, I use ex-ante expected utility and express welfare changes in consumption equivalence variation (see Appendix C.3). By comparing steady states, this welfare measure represents long-run outcomes and does not account for the costs and gains accruing to households during the transition.

6.1 Removing existing government aid

This section analyzes the welfare and distributional effects of the existing government aid policy. It asks whether government aid distorts housing and insurance markets and, if so, whether eliminating aid would improve welfare by reducing these distortions. Because removing aid also ends cross-subsidization across regions and from renters to homeowners, I further examine how the reform affects different income groups. To isolate the effects of both types of government aid, Table 3 reports all statistics of how the insurance gap (the share of disaster losses not covered by private insurance) and housing choices respond under the following counterfactual policies: first, I remove only the rebuilding grant $\bar{\tau}_\delta = 0$ and maintain the foreclosure moratorium $M = 1$ (column 1). Second, I only remove the foreclosure moratorium $M = 0$ while maintaining the rebuilding grant $\bar{\tau}_\delta = 1.26$ (column 2). Third, I remove both measures of government aid (column 3).

Government aid distorts both the housing and insurance markets. In its absence, the insurance protection gap would be almost 50 percent lower (corresponding to a 36pp decline), and the owner-occupied housing stock in the risky region would be about 12 percent smaller. The decline in owner-occupied housing indicates adjustments along both margins: fewer households choose to own, and those who do select smaller housing units per capita (Table 3, column 3). Removing government aid also triggers region-specific responses. While the insurance gap declines by a similar magnitude in both regions, the contraction in owner-occupied housing is concentrated in the high-risk region. In the low-risk region, homeownership rates and the aggregate housing stock increase slightly, by about 0.5 percent (Table

G.7). Several mechanisms drive these patterns. Without aid, user costs of housing increase because mortgage financing conditions worsen and households lose access to cross-subsidized insurance. At the same time, house prices fall. In the low-risk region, lower house prices and higher unconditional transfers more than offset the increase in financing costs, leading to a small rise in homeownership. In contrast, in the high-risk region, the loss of subsidized insurance dominates, resulting in a decline in owner-occupied housing.

Removing rebuilding grants and the foreclosure moratorium one at a time reveals that the overall effects are largely driven by the rebuilding grants. The moratorium is a relatively small-scale measure that only slightly decreases the probability of foreclosure, whereas the grants represent a far more substantial intervention. Unlike rebuilding grants, the foreclosure moratorium does not crowd out private disaster insurance. In contrast, removing the moratorium increases the insurance gap by around 1 percent, mainly driven by households in the low-risk region (see Table 3, column (2)) who hold higher liquid asset-to-income ratios. Households rely more on self-insurance through liquid assets as the downside risk of delinquency rises with a foreclosure moratorium.

Income groups in both regions are differentially affected by the removal of government aid. Across the income distribution, homeowners increase their insurance coverage, producing higher user costs of housing, especially in the high-risk region (see Table 4, column “No Aid”). The largest rise in insurance coverage is observed among middle-income households, who already held the highest insurance levels in the baseline economy. Low-income households, by contrast, increase their insurance coverage the least, as the possibility of default serves as a relatively attractive substitute for private disaster insurance. This income group is also less likely to own homes and, when they do, tends to purchase smaller properties without government aid (see Table G.7).

Government aid protects homeowners from the negative effects of natural disasters. The share of homeowners who remain in their homes after a natural disaster falls by 34 percent when government aid is eliminated (see Table 4, column “No Aid”). This effect occurs across all income groups but is largest among low-income households, whose likelihood of staying declines by 62 percent in low-risk regions and 71 percent in high-risk regions. Removing the foreclosure moratorium does not cause a rise in homeowner displacement following natural disasters. In the high-risk region, the probability of remaining in the affected home declines by only 1 percent.

Mortgage delinquencies and foreclosures respond to changes in government aid. Without the rebuilding grant, delinquency rates increase among low-income households but decline for middle- and high-income households following small disasters.²⁶ The latter increase their

²⁶Tables G.3, G.4, and G.5 document percentage-point changes in delinquencies, “involuntary” foreclo-

Table 3: Steady State Comparison - Removing existing government aid

	Baseline	Counterfactuals ($\Delta\%$)		
	(0)	(1)	(2)	(3)
		$\bar{\tau}_\delta = 0$	$M = 0$	No aid
Insurance gap				
Total	73.14	-48.90	1.32	-48.91
<i>By disaster exposure</i>				
Low-risk	71.83	-47.43	1.73	-47.43
High-risk	77.10	-53.00	0.17	-53.05
Home ownership				
Total	66.15	-2.30	-0.00	-2.30
<i>By disaster exposure</i>				
Low-risk	66.33	0.50	0.38	0.50
High-risk	65.60	-10.78	-1.18	-10.78
Owner-occupied housing stock				
Total	3.75	-2.61	-0.46	-2.61
<i>By disaster exposure</i>				
Low-risk	3.78	0.46	-0.03	0.46
High-risk	3.66	-12.14	-1.79	-12.14

Note: Column (0) reports main statics in the baseline steady state with existing government aid. Columns (1)-(3) report percent changes from the baseline steady state for the following policy counterfactuals: (1) removing the rebuilding grant while maintaining the foreclosure moratorium, (2) removing the foreclosure moratorium while maintaining the rebuilding grant, and (3) removing both the rebuilding grant and the foreclosure moratorium.

insurance coverage and, hence, reduce their default risk, whereas low-income households rely on delinquency as implicit insurance. For large disasters, delinquency rates fall across the income distribution, as households cannot afford to remain delinquent and instead enter consensual foreclosure. Removing the foreclosure moratorium generally lowers delinquency rates, as households internalize the greater downside risk of default. Nevertheless, post-disaster involuntary foreclosures increase across all income groups, since banks can now seize affected properties. For large disasters, overall foreclosures decline, driven by fewer voluntary foreclosures. This reflects lower loan-to-value ratios and smaller home sizes, which reduce rebuilding costs and exposure to natural disasters. When both policies are removed, the effect of eliminating the rebuilding grant outweighs that of removing the moratorium. To summarize, delinquency rates decline due to lower loan-to-value ratios, but foreclosure rates rise for affected households without government aid.

_____sures, and “consensual” foreclosures, respectively.

Table 4: Insurance-Independent Rebuilding Grants compared to No-Aid

	No aid		Lump-sum grant	
	Staying after disaster	Insurance gap	Staying after disaster	Insurance gap
Total	-34.3	-48.9	0.3	-30.9
<i>Low risk</i>				
Low-income	-62.0	-21.7	-0.5	-40.0
Middle-income	-28.9	-62.3	1.8	-27.8
High-income	-11.0	-53.3	-1.7	-33.5
<i>High risk</i>				
Low-income	-70.6	-12.1	-1.8	-26.4
Middle-income	-32.4	-65.7	1.0	-33.4
High-income	-34.2	-58.2	0.4	-16.5

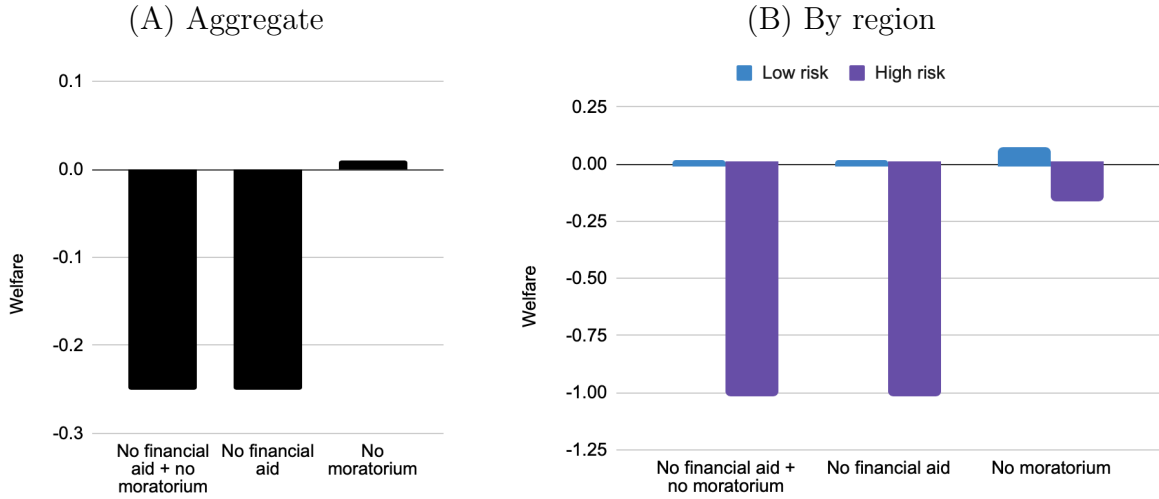
Note: The columns report percentage changes in steady-state statistics under a *lump-sum rebuilding grant* or a *no-aid scenario* relative to the baseline steady state with existing government aid.

6.1.1 Welfare Analysis

While government aid distorts insurance and housing choices, the welfare analysis suggests that abolishing it is not desirable from a utilitarian perspective. When the existing government aid is removed, aggregate welfare declines by 0.25 percent (in consumption equivalent units). Overall, aggregate welfare effects are primarily driven by the removal of the rebuilding grant. While eliminating the foreclosure moratorium alone generates small aggregate welfare effects, its impact is negligible once the rebuilding grant is removed. This suggests that the moratorium no longer provides meaningful protection in the absence of direct transfers (see Figure 10 Panel (A)). Aggregate welfare losses from removing government aid result from dominating welfare losses in the high-risk region (-1 percent), whereas the low-risk region is almost indifferent between both scenarios.

The relatively small aggregate effect in the low-risk region masks heterogeneity along the income distribution (see Figure 9). Low- and middle-income households in this region experience small welfare gains (0.05 percent and 0.02 percent) from removing government aid. Low-income households benefit because they are less likely to own homes and therefore value the increase in transfers more than the loss of insurance coverage. Middle-income households, who were already relatively well insured, experience small welfare gains in contrast to high-income households (-0.13 percent), who now face higher insurance expenses. A different pattern emerges in the high-risk region. Welfare losses are spread across the income distribution, with the largest declines observed among low-income households (-1.18 percent). As described above, these households are more likely to enter foreclosure without

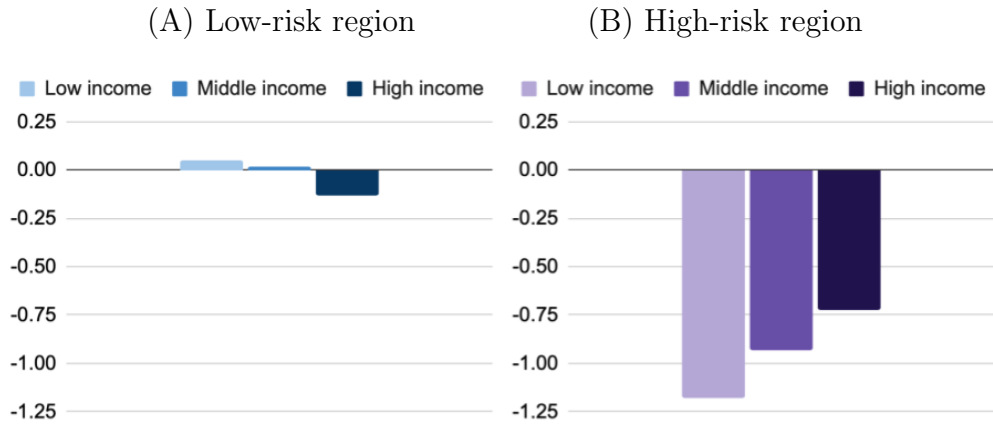
Figure 9: Welfare changes from removing existing government aid



Note: Reported welfare changes are consumption equivalence variation from baseline steady state (in %) for the following counterfactuals: (1) Removing both, the rebuilding grant and the foreclosure moratorium (2) removing the rebuilding grant while maintaining foreclosure moratorium, and (3) removing foreclosure moratorium while remaining the rebuilding grant.

government aid.

Figure 10: Welfare changes from removing government aid - by income and region



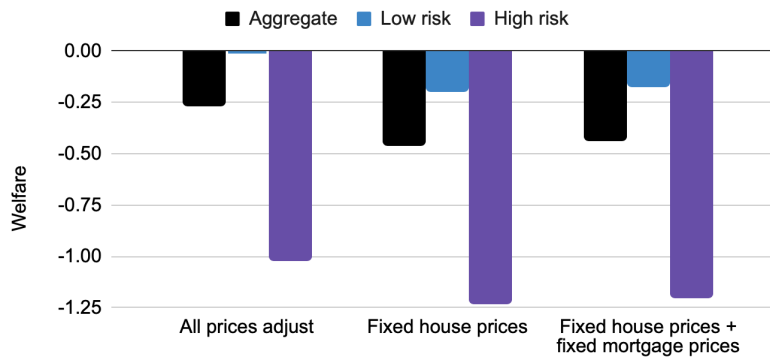
Note: Reported welfare changes are consumption equivalence variation from baseline steady state (in %) by region under the policy counterfactual of removing both, rebuilding grants and the foreclosure moratorium.

Government disaster aid generates welfare gains mainly by preventing costly mortgage default after disasters. As shown above, aid enables affected homeowners to remain in their homes rather than default. This direct effect is quantitatively important. However, additional mechanisms operating through general equilibrium prices as well as modeling

assumptions affect aggregate welfare. To understand the main drivers of welfare gains from government aid, I run several decomposition exercises.

General equilibrium price adjustments dampen the welfare losses from removing government aid. Government aid acts as a commitment device that improves mortgage financing conditions and increases welfare, but it also raises equilibrium house prices, which could offset these gains. To quantify these channels, I conduct a decomposition in which aid is removed under two alternative scenarios: (i) house prices are held fixed while mortgage prices adjust, and (ii) both house and mortgage prices are held fixed. These channels work in opposite directions. The results show that the house price channel dominates the mortgage pricing channel (Figure 11). In the baseline, removing aid reduces aggregate welfare by 0.25 percent. This loss increases to 0.45 percent when house prices are fixed, and only mortgage prices adjust. When both prices are fixed, the welfare loss declines slightly to 0.42 percent because mortgage prices no longer price higher default risk.

Figure 11: Welfare changes from removing existing government aid - Decomposition



Note: Reported welfare changes are consumption equivalence variation from baseline steady state (in %) for the counterfactual of removing both, the rebuilding grant and the foreclosure moratorium. Along the x-axis, I plot the aggregate and region-specific welfare changes, allowing for (i) the baseline with all general equilibrium effects, (ii) only adjustments of mortgage prices holding house prices fixed, and (iii) holding house prices and mortgage prices fixed.

The efficiency advantage of government aid relative to private insurance is not the main driver of welfare gains. I assume that the government is not subject to the intermediation wedge faced by private insurers and can pool and redistribute resources at low cost.²⁷ To assess the importance of this assumption, I impose the same insurance wedge on government aid. Welfare losses from removing aid decline only slightly, indicating that this channel explains only part of the gains (see Figure G.3).

²⁷This efficiency advantage of the government is consistent with evidence from Spain, where mandatory state disaster insurance operates with lower administrative and commission costs than private insurance (Von Ungern-Sternberg, 2003).

Regional redistribution generates opposing welfare forces, but is of minor quantitative importance. Government aid reallocates resources across regions and increases ex-ante expected welfare through risk sharing. I evaluate the quantitative relevance of this channel by shutting down cross-regional transfers and requiring each region to finance its own disaster aid. I find that, first, welfare losses from removing government aid still remain meaningful (see Figure G.2). Second, without regional transfers, distortions in the insurance and housing markets decline (see Table G.6).

The welfare measure compares long-run steady states and therefore abstracts from transition dynamics. The two steady states differ in house prices, the size of the owner-occupied housing stock, and the composition of homeowners. Along the transition, current homeowners would face an immediate negative wealth effect as house prices decline in response to the removal of aid. In addition, households that find homeownership no longer viable without government aid would be pushed out of ownership during the transition. Low-income owners who cannot sell quickly enough may be forced into delinquency or foreclosure even though they would not have been homeowners in the new steady state to begin with. These welfare effects are likely to operate in the same direction as the long-run welfare losses, such that the long-run welfare losses from removing government aid may be a lower bound on the total welfare costs.

6.1.2 The Role of Default: Insurance versus Commitment

A central motivation of this paper is the role of mortgage default. On the one hand, it provides households with implicit insurance against large disaster losses which reduces the value of government aid. On the other hand, it creates a commitment problem, which creates scope for government intervention. To assess which channel dominates, I eliminate default option by setting the default utility cost to infinity. Figure G.4 summarizes welfare changes under both environments, with and without a default option.

First of all, eliminating mortgage defaults has large effects on the housing market even when government aid stays unchanged. The aggregate owner-occupied housing stock falls by 27 percent, average house size declines by 25 percent, homeownership becomes more concentrated among higher-income households, and both loan-to-value ratios and the mortgage participation rate decline. The welfare effects of removing government aid change sharply. Without default, the aggregate welfare loss from eliminating disaster aid rises from 0.25 percent to 4.8 percent in consumption equivalent variation. The regional distribution of losses also changes. In the baseline, low-risk regions benefit slightly from removing aid while high-risk regions bear large losses. Without default, the losses become similar across regions and

increasingly concentrated among higher-income households, which follows from the stronger concentration of homeownership in that group.

These results suggest that the insurance channel of default dominates the commitment channel: default substitutes for government aid by providing implicit insurance, hence reducing the welfare value of publicly provided government aid.

6.2 Alternative Policy Designs

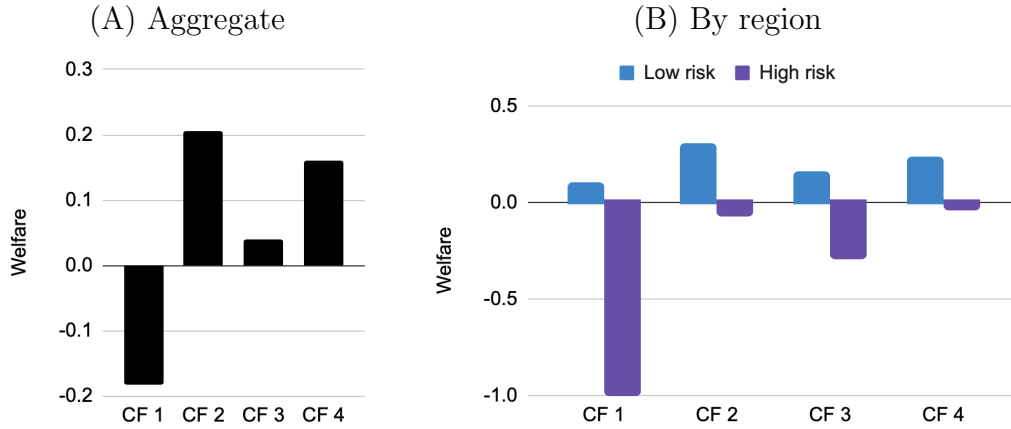
In the previous section, I showed that the current government aid policy generates welfare gains but also crowds out private insurance and leads to an overaccumulation of housing in the risky region. This section asks whether alternative, revenue-neutral policy designs can improve welfare by directly correcting these distortions. To do so, I compare steady-state outcomes under the baseline aid policy with several counterfactual policy regimes.

First, I consider a revenue-neutral policy in which the government subsidizes insurance premiums *ex ante* rather than providing rebuilding grants *ex post*. This lowers the cost of private disaster insurance for all households. Second, I analyze a design in which rebuilding grants are distributed independently of a household's insurance coverage. Both policy counterfactuals are designed to increase the uptake of private disaster insurance. Third, I study a policy that targets government aid exclusively to low-income households. To maintain revenue neutrality, the maximum grant level increases as the number of recipients declines. Finally, I examine a scenario in which the existing government aid is left unchanged but is financed through a housing tax to mitigate distortions in the housing market. Table G.7 reports percentage changes in the insurance gap, homeownership rates, and aggregate housing across counterfactuals. Figure 12 summarizes the associated welfare effects.

All policy designs reduce the targeted distortions (see Table G.8). As a result, the steady-state allocation of government aid shifts from high- to low-risk regions, either directly through the policy change itself or indirectly through the new equilibrium allocations it generates (see Table 5). Therefore, for all counterfactuals, the high-risk region faces welfare losses from the new policy, whereas the low-risk region benefits. Aggregate welfare effects are determined by which effect dominates quantitatively. Among the policy counterfactuals, the largest welfare gains (0.21 percent) are achieved under insurance-independent rebuilding grants to all households. Especially, the low-risk region benefits from this policy design.

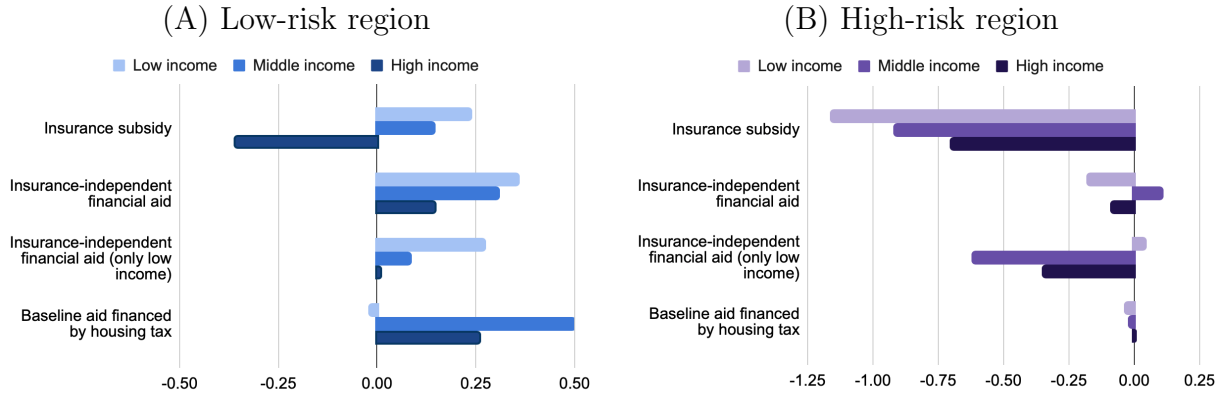
Insurance subsidy Introducing an insurance subsidy while eliminating financial government aid generates the largest aggregate welfare losses among all policy experiments, reducing total welfare by 0.18 percent (Figure 12, Panel A). Losses are particularly severe in the

Figure 12: Welfare changes under alternative policy designs



Note: Reported welfare changes are consumption equivalence variation from baseline steady state (in %) for the following revenue neutral counterfactuals: (CF 1) providing only an insurance subsidy, (CF 2) making rebuilding grants independent of insurance coverage, and (CF 3) providing insurance-independent rebuilding grants to low-income homeowners only. As the last counterfactual (CF 4), government aid is financed through a tax on homeowners' housing capital.

Figure 13: Welfare changes under alternative policy designs across the income distribution



Note: Reported welfare changes are consumption equivalence variation from baseline steady state (in %) by region for the following revenue neutral counterfactuals: (CF 1) providing only an insurance subsidy, (CF 2) making rebuilding grants independent of insurance coverage, and (CF 3) providing insurance-independent rebuilding grants to low-income homeowners only. As the last counterfactual (CF 4), government aid is financed through a tax on homeowners' housing capital.

high-risk region, where all income groups experience welfare declines exceeding 0.70 percent, with low-income households affected most (Figure 13, Panel A). Low-income households in these areas increase private disaster insurance coverage by less than other groups and instead rely more heavily on default as an informal insurance mechanism in the event of a disaster—indeed, “consensual” foreclosures rise following large events. Even in the low-risk

region, welfare effects are uneven: high-income households face welfare losses of 0.36 percent, whereas low- and middle-income households experience small gains of 0.23 and 0.14 percent, respectively (Figure 13, Panel B). Although the policy is revenue neutral, it alters the distribution of government transfers across regions, since the subsidy is not conditional on being affected by a disaster. Whereas the high-risk region previously received the majority of aid, under the insurance subsidy, its allocation falls by 65 percent (see Table 5). Low- and middle-income households in low-risk regions benefit most from the subsidy, as they already held relatively high insurance coverage in the baseline.

The primary objective of the insurance subsidy is to reduce underinsurance and correct distortions in the insurance market. However, because the policy is targeted to the whole population (not only affected households), the same budget as in the baseline allows only a 0.06 percent subsidy rate on insurance premiums. The insurance gap therefore narrows only marginally more than under the no-aid scenario (see Table G.7, column 4). Under this policy counterfactual, house prices decline in both regions. In the low-risk region, low- and middle-income households increase their per capita housing holdings by 0.13 percent and 0.45 percent, respectively. Lower house prices also encourage higher homeownership rates in the low-risk region, whereas homeownership becomes less likely in the high-risk region across all income groups.

Insurance-independent rebuilding grants Providing government aid independently of insurance generates the largest aggregate welfare gains, increasing aggregate consumption-equivalent welfare by 0.2 percent (CF 2 in Figure 12, Panel A). Welfare effects differ across regions: the low-risk region benefits (+0.3 percent), whereas the high-risk region loses (-0.06 percent). Since the policy is revenue neutral, the maximum grant available under this scenario is lower than in the baseline (-38.8 percent), which partly explains the observed regional

Table 5: Allocation of government aid across regions

	Baseline Aid	$\Delta\%$			
		CF 1	CF 2	CF 3	CF 4
Low-risk region	0.0002	140.74	4.45	-50.07	1.40
High-risk region	0.0014	-67.46	-1.81	-56.77	-0.56

Note: This table plots the change in allocation of government aid across regions under the following revenue-neutral counterfactuals with moratoria in place: (CF 1) providing only an insurance subsidy, and (CF 2) making rebuilding grants independent of insurance coverage. Under (CF 3) the government provides insurance-independent rebuilding grants to low-income homeowners only. As last counterfactual (CF 4), government aid is financed through a tax on homeowners' housing capital.

welfare losses. This reduction in the maximum grant disproportionately decreases expected transfers in the high-risk region, where disasters occur more frequently. Furthermore, since insurance coverage is higher in the low-risk region, the reform effectively reallocates government funds from high- to low-risk areas, as eligibility for government aid is no longer reduced by insurance coverage.

In the low-risk region, all income groups benefit, with the largest gains accruing to low-income households (0.35 percent). Lower maximum grants reduce house prices, which particularly benefits these households. In contrast, in the high-risk region, welfare gains are concentrated among middle-income households, who already held relatively high insurance coverage and are no longer penalized for being insured. Low- and high-income households in this region experience welfare losses from the lower maximum grant provided since aid within the region is shifted from low- and high-income households to middle-income households.

Under this policy design, eligibility for government financial aid is no longer tied to insurance coverage. This mitigates the direct crowding-out effect. However, the mere expectation of rebuilding grants continues to dampen the insurance demand (see Table G.7, column 5). The insurance gap narrows across all income groups and regions. The response is largest for low-income households in the low-risk region (-40 percent) and least for high-income households in the high-risk region (-17 percent).

Comparing the insurance-independent rebuilding grant with both the existing policy and the no-aid scenario shows two main insights (see Table 4). First, making rebuilding grants independent of insurance coverage has almost no effect on the share of households that remain in their homes after a disaster. The policy therefore preserves aid's effectiveness in preventing displacement and default. Second, the insurance gap declines under insurance-independent grants (-30.9%), though less than in the no-aid scenario (-48.9%). This difference is driven by middle- and high-income households, which reduce their insurance gap by 28 and 34 percent, respectively, compared to 62 and 53 percent in the absence of aid. For low-income households, however, the opposite pattern emerges. In this group, providing rebuilding grants crowds in private insurance. This result corresponds to the mechanism highlighted in the simple framework at the beginning of the paper. For low-income households, rebuilding grants make default relatively less attractive and increase the value of maintaining private disaster insurance. As a result, low-income households hold more private disaster insurance under insurance-independent grants than in the no-aid scenario.

Insurance-independent rebuilding grants for low-income homeowners only The policy is designed to allocate government funds more efficiently by targeting low-income households most in need. Aggregate welfare gains depend on whether the benefits to these

households outweigh the welfare losses of other income groups. Overall, this policy yields aggregate welfare gains of 0.04 percent (see Figure 12). Although designed to be revenue-neutral, total government aid declines relative to the steady state: even with full insurance for low-income homeowners, it falls by about 55 percent. Welfare gains are concentrated among low-income households in the low-risk region (+0.27 percent) and are smaller in the high-risk region (+0.04 percent), as these households directly benefit from the expansion of public insurance against disaster shocks (see Figure 13).

Welfare effects for middle- and high-income households differ markedly across regions and income groups. In the low-risk region, these groups experience welfare gains, whereas in the high-risk region, they face losses. The stronger welfare gains in low-risk areas primarily reflect stronger declines in house price, which improve housing affordability and offset the losses from removing aid for higher-income households. Consequently, homeownership rates increase across all income groups in the low-risk region. In contrast, house price declines in the high-risk region are smaller; therefore, the welfare losses from removing government aid dominate for middle- and high-income households in these areas.

Insurance choices also adjust. Low-income households remain uninsured as the government provides full insurance, while middle- and high-income households expand their coverage. This generates a 35 percent decline in the aggregate insurance gap. Finally, the likelihood of remaining in one's home after a natural disaster rises for low-income households (+12 percent in both regions) but falls for middle- and high-income groups, with the largest decline among middle-income households in high-risk areas (−33 percent).

Baseline aid financed through housing tax Replacing the lump-sum transfer adjustment with a federal housing tax as the financing source for government aid increases aggregate welfare by 0.16 percent. Welfare gains are concentrated among middle- and high-income households in the low-risk region (+0.50 and +0.26 percent, respectively), while high-income households in the high-risk region experience the largest welfare losses. Although the aggregate welfare effects are similar to those under Counterfactual 2, the distribution of gains and losses differs markedly across income groups and regions.

The policy operates through two main channels. First, by taxing housing, it counteracts the distortionary effect of government aid, which otherwise encourages excessive accumulation of housing capital. Second, it shifts the financial burden of government aid: while it is shared between homeowners and renters in the baseline, under the housing tax scenario, it falls exclusively on homeowners.

In principle, one might expect low-income households to benefit from this policy. In practice, however, higher housing user costs reduce affordability for this group, leading to

lower homeownership rates and smaller average house sizes (averaged across the entire low-income population), and ultimately to welfare losses. Because the housing tax raises user costs, many marginal low-income owners switch to renting; their move into smaller rental units lowers the unconditional average even though the conditional average for the remaining owners, reported in Table G.6, rises (+1.18 percent in the low-risk region). Per capita housing demand increases slightly in the low-risk region (+0.2 percent) but declines in the high-risk region (−0.25 percent). The contrasting regional responses stems from differences in underlying risk: in high-risk areas, the same increase in user costs exerts a stronger disincentive on homeownership due to greater exposure to potential disaster losses.

Welfare gains for middle- and high-income households in the low-risk region are generated by aid redistribution: with fewer low-income households and a smaller housing stock in high-risk regions, a larger share of government transfers now accrues to middle- and high-income households in safer areas.

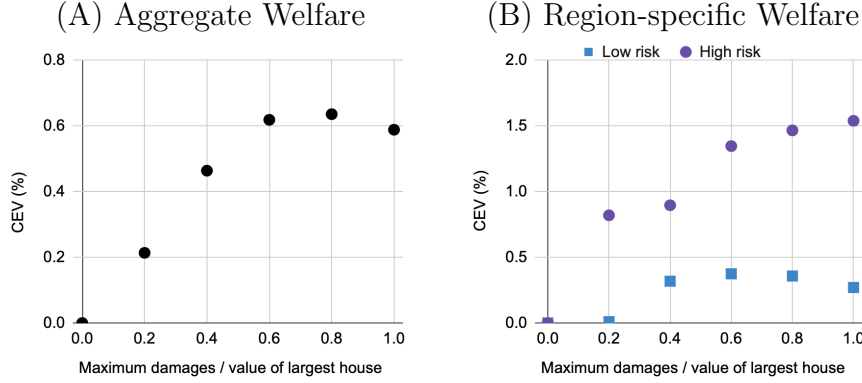
The policy has only a limited impact on insurance markets. The insurance gap rises marginally by 1.9 percent in the low-risk region and 0.3 percent in the high-risk region. In the housing market, however, the effects are more pronounced. The owner-occupied housing stock declines across all income groups in high-risk regions, with the largest reductions among low-income households with lower homeownership rates and smaller homes. In the low-risk region, only low- and middle-income households are less likely to own homes; this decline in demand is offset by higher demand among high-income households, maintaining market equilibrium. Since the reform solely changes the financing source of government aid, the share of homeowners remaining in their homes after a natural disaster remains virtually unchanged.

6.3 Different Levels of Maximum Rebuilding Grants

In this section, I assess whether welfare can be improved by increasing the maximum amount of rebuilding grants. To this end, I solve for the steady state under different values of the maximum grant, $\bar{\tau}_\delta$, while maintaining the baseline foreclosure moratorium. Figure 14 reports the resulting welfare changes, where the grant size is expressed as a share of the maximum potential damages, namely the value of the largest house in the economy based on baseline steady-state prices.

The highest welfare gains are not achieved under full government insurance. Welfare rises as the maximum rebuilding grant increases from zero percent of damages and peaks around 80 percent. It then declines until full insurance is provided. The optimal grant level,

Figure 14: Welfare under different levels of maximum rebuilding grants



Note: The figure reports aggregate and region-specific welfare changes across various steady states that only differ in the level of the maximum grants provided to households. Welfare changes are expressed as consumption equivalence variation relative to a steady state without any rebuilding grants. The grant size is expressed as a share of the maximum damages for the largest house in the economy.

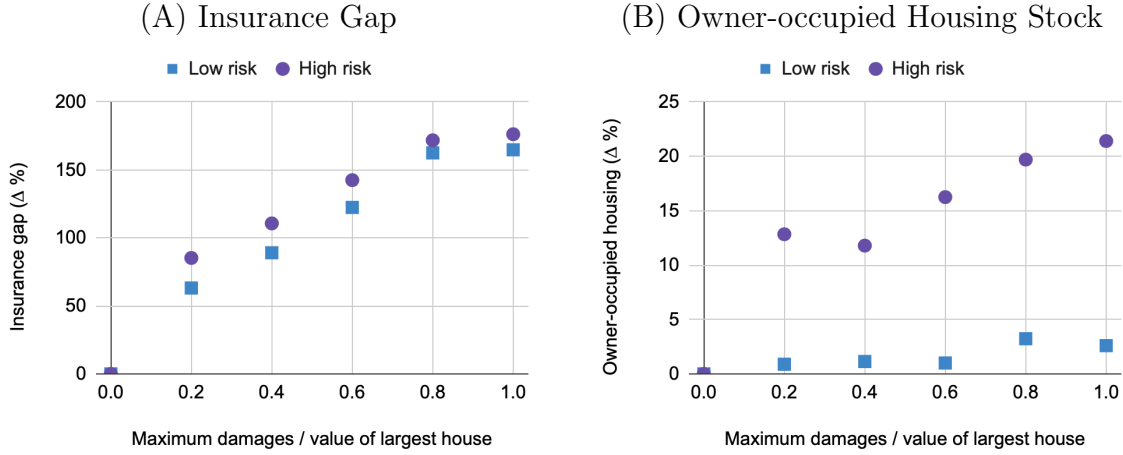
however, differs across regions. In the high-risk region, welfare increases monotonically with the grant level, whereas in the low-risk region, welfare is maximized at a grant strictly below full coverage. This divergence stems from cross-subsidization from low- to high-risk regions through government aid.

Increasing the generosity of government aid crowds out private disaster insurance similarly across regions; however, the response of the owner-occupied housing stock differs markedly between them. In both regions, the insurance gap widens as maximum grants increase, showing a decline in private disaster insurance coverage (Panel (A), Figure 15). The owner-occupied housing stock also responds to the grant size, stronger in high-risk areas (Panel (B), Figure 15). In the low-risk region, the housing stock rises modestly, by up to 3.2 percent at an 80-percent maximum grant, but larger grants lead to a contraction in aggregate housing. In contrast, the high-risk region exhibits a strictly increasing response, with the owner-occupied stock expanding by up to 21 percent as the maximum grant approaches full coverage. As the owner-occupied housing stock expands in the high-risk region, higher government expenditures dampen the response in the low-risk region.

6.4 Role of Recourse Regimes

In this section, I assess how the strictness of the recourse regime affects welfare results. I compare the counterfactual of removing all government aid (both rebuilding grants and the foreclosure moratorium) under two environments: the baseline lenient recourse regime and

Figure 15: Insurance and housing under different levels of maximum rebuilding grants



Note: The figure reports region-specific changes in the insurance gap and the owner-occupied housing stock across various steady states that only differ in the level of the maximum grants provided to households. Changes are expressed in percent deviation from a steady state without the rebuilding grant. The grant size is expressed as a share of the maximum damages for the largest house in the economy.

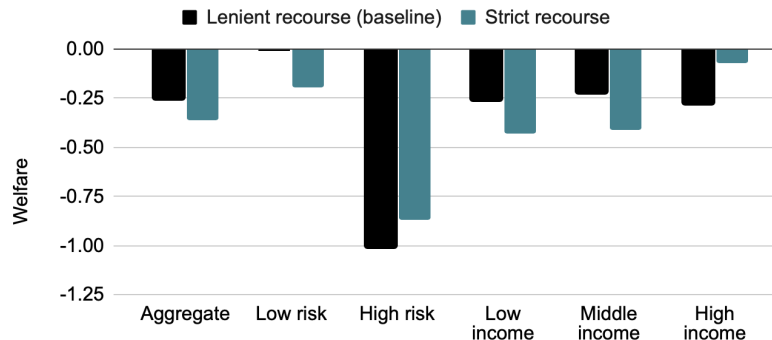
a strict recourse regime in which foreclosed households are fully liable for their outstanding mortgage balance ($\pi_R = 1$).²⁸ From the perspective of the simple model, strict recourse reduces the attractiveness of default, and mortgage prices should reflect the ability of banks to recover most losses. In this setting, households are expected to insure more ex ante, permitting little space for welfare gains from government intervention. In the full quantitative model, however, the presence of an insurance wedge, uninsurable income risk, borrowing constraints, and maximum wage garnishments reintroduces a role for welfare-improving government policies even with a strict recourse regime.

As shown in Figure 16, removing government aid is more detrimental under a strict recourse regime than under a lenient one. Welfare losses increase from 0.25 percent in the lenient recourse case to 0.36 percent under strict recourse. This is in line with previous results that showed that the implicit insurance channel dominates the commitment channel. Moreover, welfare losses are no longer concentrated solely in the high-risk region: welfare declines by 0.19 percent in the low-risk region and by 0.87 percent in the high-risk region. In this setting, welfare losses are largest among low- and middle-income households. As discussed above, without rebuilding grants, these households are more likely to enter foreclosure following a natural disaster. However, under strict recourse, the insurance role of foreclosure is reduced, thereby amplifying the policy change's welfare impact. From the

²⁸Because of limits on wage garnishment and asset exemptions, some households may still fail to fully repay their debt after foreclosure.

government's budget constraint, it is clear that eliminating disaster aid has a direct positive effect on unconditional transfer payments to all households. But since the housing market contracts, total government transfers ultimately decline, as lower housing demand reduces revenues from land permit sales.

Figure 16: Welfare changes from removing government aid by recourse regime



Note: Reported welfare changes are consumption equivalence variation from the baseline steady state (in %). In both scenarios, rebuilding grants and the foreclosure moratorium are removed. The economies only differ in their recourse probability: a lenient regime ($\pi_R = 0.1$) and a strict regime ($\pi_R = 1$).

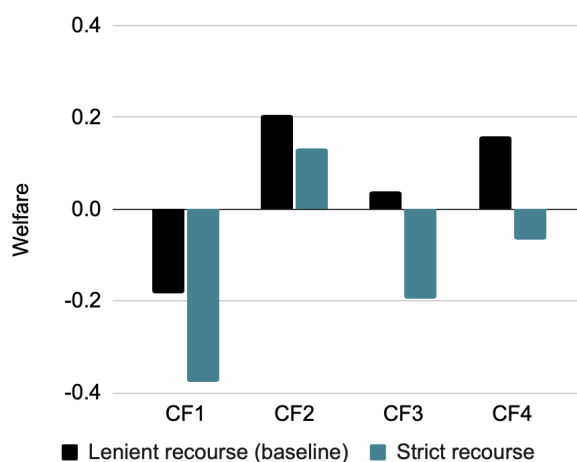
Appendix G.2 examines how varying the maximum rebuilding grant affects outcomes under a strict recourse regime. Compared to the baseline with lenient recourse, welfare gains peak at lower aid levels (between a maximum grant size of 0.6 and 0.8) and decline more sharply thereafter (see Figure G.5). Under strict recourse, regional differences in housing stocks are less pronounced. Therefore, the welfare gains from aid are smaller in high-risk regions and larger in low-risk regions compared to the lenient recourse environment. Under strict recourse, households hold smaller homes, and upon receiving small rebuilding grants, households in safer areas adjust their housing demand more strongly than under lenient recourse (see Figure G.6). Responses in the insurance gap are similar across recourse regimes as strict recourse does not close the insurance gap: rather than increasing insurance coverage, households accumulate more liquid assets and choose lower loan-to-value ratios to self-insure against shocks. This higher liquidity serves as a buffer against all reasons that push them into default (i.e., natural disaster shocks and taste shocks) and allows them to smooth consumption when subject to wage garnishment.

When comparing alternative policy counterfactuals, the main qualitative results remain unchanged under a strict recourse regime: the largest welfare gains are achieved by providing an insurance-independent grant (see Figure 17). This policy closes the insurance gap by 35 percent in low-risk regions and 26 percent in high-risk regions, but it also expands the

housing stock at risk by 2.2 percent and 1.8 percent, respectively. In contrast to the lenient recourse environment, all other alternative policy designs generate welfare losses compared to a steady state with the existing government aid in place.

For the remaining counterfactuals, the distributional patterns of welfare effects differ from the case with lenient recourse (see Figure G.8). Under a strict recourse regime, providing only an insurance subsidy (CF1) yields the largest welfare losses for low- and middle-income households, as these groups can no longer rely on default as an alternative form of insurance. By contrast, financing government aid via a housing tax (CF4) leads to a stronger contraction in housing demand and ownership rates than under lenient recourse, with welfare losses shifting toward low-risk regions.

Figure 17: Welfare changes under alternative policy designs - Role of recourse



Note: Reported welfare changes are consumption equivalence variation from baseline steady state (in %) by recourse regime for the following revenue neutral counterfactuals: (CF 1) providing only an insurance subsidy, (CF 2) making rebuilding grants independent of insurance coverage, and (CF 3) providing insurance-independent rebuilding grants to low-income homeowners only. As last counterfactual (CF 4), government aid is financed through a tax on homeowners' housing capital.

6.5 Changing disaster risk

In this section, I explore how climate change could affect government spending and household welfare in the context of altered disaster risk. Projections of aggregate natural disaster risk for the United States are relatively uncertain, as existing studies focus on individual hazards and provide wide confidence ranges. The IPCC (2023) reports high confidence in the intensification of several climate-related hazards, including extreme heat, heavy precipitation, and tropical storms, but emphasizes that the magnitude and spatial distribution of these

changes depend strongly on future greenhouse gas concentrations. In particular, tropical cyclones affecting the Gulf of Mexico and the U.S. Atlantic coast are projected to become more intense, with greater rainfall and stronger winds. Even though the precise aggregate change in disaster risk cannot be quantified with confidence, the evidence consistently points to an increase in the frequency of extreme events. Since large shares of damage in the U.S. are caused by tropical storms, I consult studies on the projected changes in the risk of this specific hazard. In the Atlantic Ocean basin, for example, category 4 and 5 hurricanes are largely expected to increase in frequency, while less intense storms are believed to become less frequent (Bloemendaal et al., 2022). To approximate this scenario, I simulate a steady state in which the frequency of large damages (δ_L) is 10% higher and the frequency of small damages (δ_S) is correspondingly lower, keeping the overall share of affected households constant. This exercise does not aim to provide a precise quantitative estimate of the costs of climate change, but rather to illustrate how the economy might adjust to a shift in disaster risk.

As large events become more frequent, households anticipate greater potential losses. This is likely to increase insurance demand, given that extreme losses are only partially covered by government aid. At the same time, homeowners may adjust their portfolios, opting for smaller houses and holding more liquid assets to buffer against shocks.

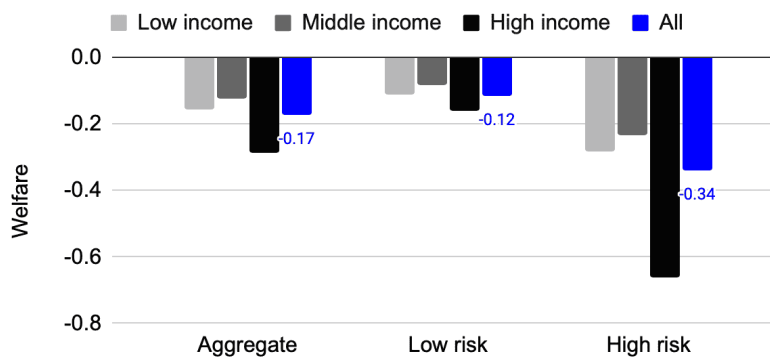
I find that the insurance gap declines only slightly in the low-risk region (−0.5 percent) but rises in the high-risk region (+0.9 percent). As the probability of large losses increases in this counterfactual, the marginal premium for coverage above the small-damage threshold rises (see eq. 22). Higher premiums lead households to substitute toward larger liquid-asset buffers (+1.9 percent in the low-risk region and +3.3 percent in the high-risk region), while some reduce high-layer insurance coverage. At the same time, households choose smaller houses. These adjustments together produce a small decline (increase) in the insurance gap in low- (high-) risk regions. In the high-risk region, higher insurance prices dominate the effect, as disasters are both more costly to insure against through private disaster insurance. The housing market adjusts accordingly: average house size falls by 0.5 percent and 1.6 percent, while homeownership rates decline by 0.9 percent in the low-risk region and 3.0 percent in the high-risk region. Together, these changes reduce the owner-occupied housing stock by 1.5 percent in the low-risk region and 4.6 percent in the high-risk region. As a result, aggregate government aid rises only modestly in the low-risk region (+1.4 percent) and even declines in the high-risk region (−0.6 percent).

Overall, aggregate welfare declines by 0.17 percent in consumption-equivalent terms, with losses of 0.12 percent in the low-risk region and 0.34 percent in the high-risk region. High-income households experience the largest welfare losses, as they tend to self-insure

through liquid assets while relying on government support for smaller disasters, making them particularly exposed when large, uninsured losses become more frequent.

Thus, in this specific scenario of more frequent, severe natural disasters, keeping the current level of disaster aid results in only small welfare losses, due to long-run adjustments in the housing market.

Figure 18: Welfare changes under changed natural disaster risk



Note: Reported welfare changes are consumption equivalence variation from the baseline steady state (in %). In this steady state, the government provides baseline government aid, but the risk of natural disasters changes: the total number of events remains unchanged, while the probability of large damage rises by 10 percent.

7 Conclusion

I develop a structural general equilibrium model to investigate the interaction between government aid and mortgage default. Within an incomplete market model, I assess households' housing and insurance choices in the presence of natural disaster shocks, and how government aid can raise welfare when homeowner have access to mortgage default.

I first present empirical evidence that homeowners use temporary non-payments of mortgages following natural disasters in the U.S. over the past twenty years. Delinquency rates rise after disasters, while foreclosure rates remain unchanged. I therefore include a delinquency option, a period of non-payment, in the quantitative framework which allows mortgage owners to become performing again.

The calibrated model predicts that government aid affects private insurance and housing allocation. While it reduces private insurance coverage by nearly half, it increases the housing stock in disaster-prone areas. Nevertheless, removing the existing government aid leads to aggregate welfare losses (0.25% CEV), concentrated in high-risk regions throughout the

whole income distribution. Among various revenue-neutral policy counterfactuals, aggregate welfare is maximized when rebuilding grants are provided independently of households' insurance coverage, mitigating the direct crowding out of private coverage. The welfare effects depend on both the institutional framework and the size of aid: recourse rules shape who gains and loses from removing aid, while raising the maximum grant improves welfare only up to a point before the gains reverse.

An interesting extension is to analyze transition dynamics. Even though the aggregate welfare along the transition should work in the same direction as long-run gains, different income groups might be differentially affected. This has political relevance for many economies, where many homes were built before natural disaster risks were widely recognized. Understanding how the government should respond to existing housing stocks in disaster-prone regions and examining welfare effects across income groups and risk levels during the transition may yield important policy insights.

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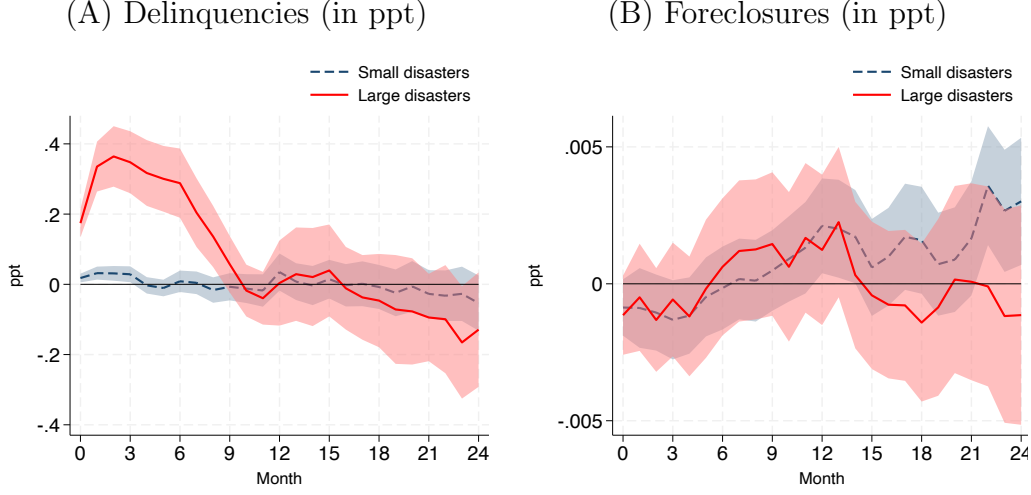
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A Empirical Appendix

Figure A.1: Mortgage Default after Natural Disasters (incl. Controls)



Note: Shaded areas are 90 percent confidence bands. Standard errors are clustered on MSA-level. Regression includes time and MSA fixed effects. Small (large) disasters are defined as events causing damages below (above) the 75th percentile of realized damages. The estimation includes regional controls such as personal income per capita, the employment rate, the median debt-to-income ratio as well as the median loan-to-value ratio at origination.

B Simple Model

B.1 Insurance choices and disaster aid without default option

Proposition 1: *Without default, agents choose insurance coverage to maximize (2).*

- (i) *Without government intervention, agents buy full insurance the agent buys full insurance $\iota = 1$ for actuarially fair insurance prices ($p_\iota = \pi_\delta$). If there exists a positive insurance wedge ($p_\iota > \pi_\delta$), agents underinsure $\iota < 1$.*
- (ii) *Under actuarially fair insurance ($p_\iota = \pi_\delta$), government aid crowds out private insurance one-to-one, $\iota = (1 - \tau_\delta)$, and welfare remains unchanged.*

Proof: Suppose the government provides disaster aid $\tau_\delta p_\delta h$, funded by income tax τ . The homeowner anticipates the disaster aid and now maximizes:

$$\begin{aligned} \max_{\iota} (1 - \pi_\delta) \log(c^B) + \pi_\delta \log(c^{ND}) \quad \text{s.t.} \quad & c^B = (1 - \tau)y - p_\iota \iota p_h \delta h \\ & c^{ND} = (1 - \tau)y + (1 - p_\iota) \iota p_h \delta h - p_h \delta h + \tau_\delta p_h \delta h \end{aligned}$$

From the first order conditions, optimal insurance coverage is defined as

$$\iota = \frac{1 - \pi_\delta}{1 - p_\iota}(1 - \tau_\delta) - \frac{p_\iota - \pi_\delta}{(1 - p_\iota)p_\iota} \frac{(1 - \tau)y}{p_h \delta h}.$$

Without government intervention, i.e. $\tau_\delta = 0$ and hence $\tau = 0$, the optimal insurance is defined as follows

$$\iota = \frac{1 - \pi_\delta}{1 - p_\iota} - \frac{p_\iota - \pi_\delta}{(1 - p_\iota)p_\iota} \frac{y}{p_h \delta h}.$$

If insurance prices are actuarially fair, $p_\iota = \pi_\delta$, and the optimal insurance equals the disaster damages $\iota = 1$. In the presence of an insurance wedge, $p_\iota > \pi_\delta$ and people buy less insurance

$$\iota = \underbrace{\frac{1 - \pi_\delta}{1 - p_\iota}}_{<1} - \underbrace{\frac{p_\iota - \pi_\delta}{(1 - p_\iota)p_\iota}}_{>0} \frac{y}{p_h \delta h} < 1.$$

In the following, I assume that insurance prices are actuarially fair ($p_\iota = \pi_\delta$) to ensure that room for government intervention does not arise mechanically via the imposed insurance wedge. Then, the optimal private insurance coverage in the presence of government intervention is $\iota^* = (1 - \tau_\delta)p_h \delta h$. This reflects the one-to-one crowding out of private insurance via government disaster aid.

The government can choose τ_δ to maximize welfare given a balanced government budget

$$\tau y = \pi_\delta \tau_\delta p_\delta h.$$

Using the optimal insurance choice of agents and the government budget, the maximization problem reduces as follows:

$$\begin{aligned} \max_{\tau_\delta} \quad & \pi_\delta [\log((1 - \tau)y - \mu m - ph(\epsilon + \delta) - p_\iota \iota p_\delta h + \iota p_\delta h + \tau_\delta p_\delta h)] \\ & + (1 - \pi_\delta) [\log((1 - \tau)y - \mu m - ph\epsilon - p_\iota \iota)] \\ \text{s.t.} \quad & \iota = (1 - \tau_\delta), \quad \tau = \frac{\pi_\delta \tau_\delta p_\delta h}{y}, \quad p_\iota = \pi_\delta \\ \iff \max_{\tau_\delta} \quad & \log(y - \mu m - ph\epsilon - \pi_\delta p_\delta h) \end{aligned}$$

Hence, welfare is independent of the choice of τ_δ as the provision of government aid crowds out private insurance one-for-one. ■

B.2 Insurance choice and disaster aid with default option

Proposition 2: *With default, agents choose insurance coverage to maximize (3).*

- (i) *Conditional on default costs κ and without government intervention $\tau_\delta = 0$, agents choose corner solutions of insurance coverage and mortgage prices respond accordingly*

$$\iota = \begin{cases} 0 & \text{if } \kappa < \bar{\kappa}(0) \\ 1 & \text{else} \end{cases} \quad \text{and} \quad q = \begin{cases} 1 - \pi_\delta & \text{if } \kappa < \bar{\kappa}(0) \\ 1 & \text{else} \end{cases}$$

(ii) Providing government aid of size τ_δ can improve welfare if $\kappa \in (\max\{\underline{\kappa}, \bar{\kappa}(\tau_\delta)\}, \bar{\kappa}(0))$.

Proof: In the following, I assume that insurance prices are actuarially fair ($p_\iota = \pi_\delta$) to focus on the default option solely. Suppose agents have access to a default option, but never choose to default, conditional on being fully insured. Hence, the utility of staying in the home, rebuilding, and repaying the mortgage must be greater than the utility of defaulting. This imposes the following restriction on the utility costs of default: utility costs of default $\log(\kappa)$ must be larger than a threshold value κ_0 .

$$\begin{aligned} \log(y - (1 - q)m - \pi_\delta p_h \delta h - p_h \xi h) &> \log(y - p_h h + qm - p_r h_r - \pi_\delta p_h \delta h) - \log(\kappa) \\ \iff \log(\kappa) &> \log(y - p_h h + qm - p_r h_r - \pi_\delta p_h \delta h) - \log(y - (1 - q)m - \pi_\delta p_h \delta h - p_h \xi h) \\ &\equiv \log(\kappa_0) \end{aligned}$$

First, assume that agents anticipate ex ante that they will default if they are hit by a natural disaster. Then, their maximization problem reduces to

$$\begin{aligned} \max_{\iota} \quad & (1 - \pi_\delta) \log(c^B) + \pi_\delta [\log(c^D) - \log(\kappa)] \\ \text{s.t.} \quad & c^B = (1 - \tau)y - (1 - q)m - \pi_\delta \iota p_h \delta h - p_h \xi h \\ & c^D = (1 - \tau)y - p_h h + qm - p_r h_r - \pi_\delta \iota p_h \delta h. \end{aligned}$$

Consequently, there is no benefit to holding any private disaster insurance where the payout is conditional on rebuilding. Hence, the optimal insurance coverage equals $\iota = 0$.

Second, assume that agents will never default even if hit by a natural disaster. Then, the optimization problem reduces to the simple case without a default option, and the households choose insurance coverage $\iota = 1 - \tau_\delta$.

Which of the two cases manifests can be expressed in a condition on the utility costs of default. If default costs are sufficiently small, agents prefer ex ante to default in case of a natural disaster and to buy no insurance at all instead of buying insurance $\iota = (1 - \tau_\delta)$. The default threshold depends on the government aid provided.²⁹ A household anticipates default and buys no insurance, if

$$\begin{aligned} & (1 - \pi_\delta) \log((1 - \tau)y - (1 - q)m - p_h \xi h) \\ & + \pi_\delta [\log((1 - \tau)y - p_h h + qm - p_r h_r) - \log(\kappa)] \\ & > \log((1 - \tau)y - (1 - q)m - \pi_\delta (1 - \tau_\delta) p_h \delta h - p_h \xi h) \\ \stackrel{\tau = \frac{\pi_\delta \tau_\delta \delta p h}{y}}{\iff} \log(\kappa) & < \frac{1 - \pi_\delta}{\pi_\delta} [\log(y - (1 - q)m - \tau_\delta \pi_\delta p_h \delta h - p_h \xi h) \\ & - \log(y - (1 - q)m - \pi_\delta p_h \delta h - p_h \xi h)] \\ & + \log(y - p_h h + qm - p_r h_r - \tau_\delta \pi_\delta p_h \delta h) \\ & - \log(y - (1 - q)m - \pi_\delta p_h \delta h - p_h \xi h) \equiv \log(\bar{\kappa}(\tau_\delta)) \end{aligned}$$

²⁹Note that in this simple model, default is only attractive if the insurance costs are high, i.e., expected damages are high through large destruction δ and high disaster probability π , and if home equity is low. A sufficient condition for $\bar{\kappa}(0) > 0$ is $\pi\delta > 1 - \lambda$, where λ is the loan-to-value ratio ($m = \lambda p h$).

This default threshold is decreasing in the size of government aid provided, as $\frac{\partial \bar{\kappa}(\tau_\delta)}{\partial \tau_\delta} < 0$. Intuitively, a higher conditional transfer by the government reduces the incentive to default as lower default costs are required to make default attractive. By defaulting, the household loses access to the government aid to which it would otherwise have contributed independently of the default. For utility costs below this threshold, government aid is too small to shift households' default incentives.

Hence, for every value of utility costs of default $\log(\kappa)$, the government can choose the size of government aid such that households would never default. If $\kappa < \bar{\kappa}(\tau_\delta)$, households will never default and mortgage prices q reflect these choices, i.e., mortgages are risk-free with $q = 1$.

First, note that if utility costs are too high, agents never default independent of aid and there is no room for government intervention (Prop. 1). Hence, I assume in the following that $\kappa < \bar{\kappa}(0)$. Government aid is welfare-improving if the expected utility under government intervention is greater than the expected utility under laissez-faire.

$$\begin{aligned} & \log((1 - \tau)y - p_h \xi h) \\ & > (1 - \pi_\delta) \log(y - (1 - q)m - p_h \xi h) + \pi_\delta [\log(y - p_h h + qm - p_r h_r) - \log(\kappa)] \\ \iff & \log(\kappa) > \frac{1 - \pi_\delta}{\pi_\delta} \left(\log(y - (1 - q)m - p_h \xi h) - \log(y - \pi_\delta p_h \delta h - p_h \xi h) \right) \\ & + \log(y - p_h h + qm - p_r h_r) - \log(y - \pi_\delta p_h \delta h - p_h \xi h) \equiv \log(\underline{\kappa}) \end{aligned}$$

Conditional on a degree of public insurance τ_δ and $\kappa < \bar{\kappa}(\tau_\delta)$, government aid is welfare improving for sufficiently large default costs $\kappa > \underline{\kappa}$. Given the one-to-one crowding out, the size of government aid τ_δ only matters for removing the default option from the household choice set, but does not affect the consumption under the staying in the house post-natural disaster scenario. Therefore, $\underline{\kappa}$ is independent of τ_δ .

It is left to show that the set $(\underline{\kappa}, \bar{\kappa}(0))$ is non-empty. It is equivalent to show that $\log(\bar{\kappa}(0)) - \log(\underline{\kappa}) > 0$.

$$\begin{aligned} \log(\bar{\kappa}(0)) - \log(\underline{\kappa}) &= \frac{1 - \pi_\delta}{\pi_\delta} \left[\log(y - (1 - q)m - p_h \xi h) - \log(y - (1 - q)m - \pi_\delta p_h \delta h - p_h \xi h) \right] \\ &+ \log(y - p_h h + qm - p_r h_r) - \log(y - (1 - q)m - \pi_\delta p_h \delta h - p_h \xi h) \\ &- \left[\frac{1 - \pi_\delta}{\pi_\delta} \left(\log(y - (1 - q)m - p_h \xi h) - \log(y - \pi_\delta p_h \delta h - p_h \xi h) \right) \right] \\ &+ \log(y - p_h h + qm - p_r h_r) - \log(y - \pi_\delta p_h \delta h - p_h \xi h) \Big] \\ &= \frac{1 - \pi_\delta}{\pi_\delta} \underbrace{\left[\log(y - \pi_\delta p_h \delta h - p_h \xi h) - \log(y - (1 - q)m - \pi_\delta p_h \delta h - p_h \xi h) \right]}_{>0} \\ &+ \underbrace{\log(y - \pi_\delta p_h \delta h - p_h \xi h) - \log(y - (1 - q)m - \pi_\delta p_h \delta h - p_h \xi h)}_{>0} > 0 \end{aligned}$$

For completeness, I show that the initial assumption of $\kappa > \kappa_0$ does not limit the result. For this, I show that $\kappa_0 < \bar{\kappa}(0)$, or equivalently $\log(\bar{\kappa}(0)) - \log(\kappa_0) > 0$.

$$\begin{aligned}
\log(\bar{\kappa}(0)) - \log(\kappa_0) &= \frac{1 - \pi_\delta}{\pi_\delta} \left[\log(y - (1 - q)m - p_h \xi h) - \log(y - (1 - q)m - \pi_\delta p_h \delta h - p_h \xi h) \right] \\
&\quad + \log(y - p_h h + qm - p_r h_r) - \log(y - (1 - q)m - \pi_\delta p_h \delta h - p_h \xi h) \\
&\quad - \left[\log(y - p_h h + qm - p_r h_r - \pi_\delta p_h \delta h) \right. \\
&\quad \left. - \log(y - (1 - q)m - \pi_\delta p_h \delta h - p_h \xi h) \right] \\
&= \frac{1 - \pi_\delta}{\pi_\delta} \underbrace{\left[\log(y - (1 - q)m - p_h \xi h) - \log(y - (1 - q)m - \pi_\delta p_h \delta h - p_h \xi h) \right]}_{>0} \\
&\quad + \underbrace{\left[\log(y - p_h h + qm - p_r h_r) - \log(y - p_h h + qm - p_r h_r - \pi_\delta p_h \delta h) \right]}_{>0} > 0
\end{aligned}$$

■

C Quantitative Model

C.1 Full definition of household decision problem

Consider the decision problems faced by agents after the labor productivity shock is realized, the insurance coverage decision, and the natural disaster is realized. I abstract from the insurance coverage choice as a state variable as this choice only affects liquid assets. Hence, liquid assets $b(\iota, \delta)$ can be interpreted as liquid assets after having paid insurance premiums and potentially having received insurance claims and government aid. For simplicity, I write $b \equiv b(\iota, \delta)$.

A homeowner who decides to stay performing solves the following problem

$$\begin{aligned}
W_{perf}^{own}(b, h, m, z, \delta) &= \max_{b'} u(c, \psi_h h) + \beta \pi_S \mathbb{E} V^{own}(b', h, m', z', \delta') \\
\text{s.t. } c &= (1 - \tau)wz + (1 + r)b - b' - (\delta + \zeta)p_h h - \mu m + \Gamma \\
b' &\geq b_{min} \\
m' &= (1 + r_m - \mu)m
\end{aligned}$$

where τ is a labor income tax and Γ are governmental transfer payments. A delinquent homeowner faces the same choices as a performing homeowner, but does not make any

mortgage payments and faces a disutility κ :

$$\begin{aligned} W_{del}^{own}(b, h, m, z, \delta) &= \max_{b'} u(c, \psi_h h) - \kappa + \beta \pi_S \mathbb{E} V^{own}(b', h, m', z', \delta') \\ \text{s.t. } c &= (1 - \tau)wz + (1 + r)b - b' - (\delta + \zeta)p_h h + \Gamma \\ b' &\geq b_{min} \\ m' &= (1 + r_m)m \end{aligned}$$

A household that decides to buy a new house chooses the optimal house size h from the discrete set of houses $\mathcal{H}$, a corresponding mortgage m subject to a loan-to-value limit λ , and savings in liquid bonds b' :

$$W_{perf}^{buy}(b, z) = \max_{h \in \mathcal{H}_O} \left\{ W_{perf}^{buy, h_O^1}(b, z), \dots, W_{perf}^{buy, h_O^{N_O}}(b, z) \right\}$$

with

$$\begin{aligned} W^{buy, h}(b, z) &= \max_{m, b'} u(c, \psi_h h) + \beta \pi_S \mathbb{E} V^{own}(b', h, m', z', \delta', k) \\ \text{s.t. } c &= (1 - \tau)wz + (1 + r)b - b' + q(b', h, m, z)m + \Gamma - p_h(1 + \zeta)h \\ b' &\geq b_{min} \\ m &\leq \lambda p_h h \end{aligned}$$

A renter who stays a renter chooses liquid savings b' and the optimal size of the rental unit $h_R \in \mathcal{H}_R$:

$$W_{new}^{rent}(b, z, k) = \max_{h_R \in \mathcal{H}_R} \{ W_{perf}^{rent}(b, h_{R1}, z, k), W_{perf}^{rent}(b, h_{R2}, z, k), \dots \}$$

with

$$\begin{aligned} W_{perf}^{rent, h_R}(b, z) &= \max_{b'} u(c, h_R) + \beta \pi_S \mathbb{E} V_{perf}^{rent}(b', z') \\ \text{s.t. } c &= (1 - \tau)wz + (1 + r)b - b' - p_r h_R + \Gamma \\ b' &\geq b_{min} \end{aligned}$$

A renter with a bad credit history chooses liquid savings b' and the size of the rental unit h_R :

$$W_{for}^{rent}(b, \omega, z) = \max_{h_R \in \mathcal{H}_R} \{ W_{for}^{rent, h_R^1}(b, \omega, z), \dots, W_{for}^{rent, h_R^{N_R}}(b, \omega, z) \}$$

with

$$\begin{aligned} W_{for}^{rent, h_R}(b, \omega, z) &= \max_{b'} u(c, h_R) - \kappa + \beta \pi_S \mathbb{E} V_{for}^{rent}(b', \omega, z') \\ \text{s.t. } c &= \max\{\underline{y}, (1 - \tau)(1 - \omega)wz\} + (1 + r)b - b' - p_r h_R + \Gamma \\ b' &\geq b_{min} \end{aligned}$$

C.2 Equilibrium Definition

To ease notation, denote the vector of individual states for homeowners and renters as $\mathbf{x}^h := (b, h, m, z, \delta, k) \in \mathbb{X}^h$ and $\mathbf{x}^r := (b, \omega, z, k) \in \mathbb{X}^r$. Let Ω be the distribution of agents over the state space. Given a risk-free interest rate r , wages w and government policies $\mathcal{P} = (\tau, \bar{\tau}_\delta, \pi_R, \mathbf{M})$, a stationary equilibrium consists of value functions $v = \{V^{own}(\mathbf{x}^h), V_{perf}^{rent}(\mathbf{x}^r), V_{for}^{rent}(\mathbf{x}^r)\}$, policy functions $f^* = \{b^*(\mathbf{x}^h), c^*(\mathbf{x}^h), \iota^*(\mathbf{x}^h), S^*(\mathbf{x}^h), D^*(\mathbf{x}^h), R^*(\mathbf{x}^h), b^*(\mathbf{x}^r), c^*(\mathbf{x}^r), h^*(\mathbf{x}^r), m^*(\mathbf{x}^r), R^*(\mathbf{x}^r)\}$, an invariant distribution Ω , mortgage pricing functions $q(\mathbf{x}^h), q_{del}(\mathbf{x}^h)$, and house pricing functions $p_h(\Omega), p_r(p_h)$ such that for all regions k

- **Households Maximization:** Given prices, pricing functions, and policies, the value functions solve the household problem and f^* are associated policy functions.
- **Zero Profit Mortgages:** Given f^* and $\mathcal{P}$, q and q_{del} solve (13) and (14) for any contract traded in equilibrium.
- **Zero Profit Insurance Contracts:** The insurance pricing equation 22 holds for any insurance contract traded in equilibrium.
- **Profit maximization:** Firms in the construction sector maximize profits (16) with associated labor demand $N_H(k)$ and housing construction $H^{new}(k)$.
- **Labor market clearing:** The labor market clears at wage $w = \Theta_C$, and labor demand in the final good sector is determined residually $N_C(k) = 1 - N_H(k)$.
- **Rental market clearing:** Given the rental price p_r determined by (20), the rental market clears

$$\begin{aligned}
H'_R(k) = & \pi_S \left[\int [R^*(\mathbf{x}_i^r) + (1 - R^*(\mathbf{x}_i^r))(1 - \pi_H)] h_i^*(\mathbf{x}_i^r) di \right. \\
& + \pi_H \int S^*(\mathbf{x}_i^h) [R^*(\mathbf{x}_i^h) + (1 - R^*(\mathbf{x}_i^h))(1 - \pi_H)] h_i^*(\mathbf{x}_i^h) \\
& + (1 - \pi_D(\mathbf{x}_i^h, \mathbf{M})) \int (1 - S^*(\mathbf{x}_i^h)) D^*(\mathbf{x}_i^h) h_i^*(\mathbf{x}_i^h) di \left. \right] \\
& + (1 - \pi_S) \int R^*(\mathbf{x}_i^r) h_i^*(\mathbf{x}_i^r) di
\end{aligned} \tag{26}$$

where the left-hand side represents the total supply of rental units, and the right-hand side represents the total demand from previous renters, households that successfully sell their homes to become renters, foreclosed homeowners who are forced to become renters, and newborn agents who stay renters.

- **Housing market clearing:** Prices $p_h(\delta)$ clear the regional housing markets such that after all decisions are made, the following equality holds

$$\begin{aligned}
& H^{sold}(k) + H^{foreclosed}(k) + (1 - \pi_S) H_O(k) + H^{new}(k) \\
& = H^{buy}(k) + [H'_R(k) - (1 - \sum_{i \in S, L} \pi_i \delta_i) H_R(k)] + \zeta H'_R(k) + \zeta H_O(k)
\end{aligned} \tag{27}$$

The left-hand side equals total inflows into the housing market: undamaged houses sold by previous homeowners (28), undamaged foreclosed homes (29), homes of deceased agents, and newly constructed housing units. The right-hand side represents total outflows from the housing market: housing units purchased by new buyers (30) and by the rental agency, as well as owners' and the rental agency's investment to offset housing depreciation. These terms are defined as follows

$$H^{sold}(k) = \pi_S \pi_H \int S^*(\mathbf{x}_i^h) (1 - \delta_i) h_i^*(\mathbf{x}_i^h) di \quad (28)$$

$$H^{foreclosed}(k) = \pi_S \int [S^*(\mathbf{x}_i^h) (1 - \pi_H) + (1 - S^*(\mathbf{x}_i^h))] \cdot D^*(\mathbf{x}_i^h) (1 - \pi_D(\mathbf{x}_i^h, \mathbf{M})) (1 - \delta_i) h_i^*(\mathbf{x}_i^h) di \quad (29)$$

$$H^{buy}(k) = \pi_S \pi_H \left(\pi_H \int S^*(\mathbf{x}_i^h) (1 - R^*(\mathbf{x}_i^h)) h_i^*(\mathbf{x}_i^h) di + \int (1 - R^*(\mathbf{x}_i^r)) h_i^*(\mathbf{x}_i^r) di \right) + (1 - \pi_S) \pi_H \int (1 - R^*(\mathbf{x}_i^r)) h_i^*(\mathbf{x}_i^r) di \quad (30)$$

- **Final good market clearing:** The final good market clears in every region:

$$Y_C(k) = \int c_i^*(\mathbf{x}_i^h) di + \int c_i^*(\mathbf{x}_i^r) di + q_R(k) H_R(k) + q_L p_L \int \iota_i^*(\mathbf{x}_i^h) di + \epsilon \pi_H^2 \int S^*(\mathbf{x}_i^h) (1 - R^*(\mathbf{x}_i^h)) p_h^B(\Omega) h_i^*(\mathbf{x}_i^h) di + \epsilon \pi_H \int (1 - R^*(\mathbf{x}^r)) p_h^B(\Omega) h_i^*(\mathbf{x}_i^r) di + \epsilon_F \int [S^*(\mathbf{x}_i^h) (1 - \pi_H) + (1 - S^*(\mathbf{x}_i^h))] \cdot D^*(\mathbf{x}_i^h) (1 - \pi_D(\mathbf{x}_i^h, \mathbf{M})) h_i^*(\mathbf{x}_i^h) di \quad (31)$$

where the right-hand side represents non-durable consumption of owners and renters, the operation costs of the rental agency and private insurance firm, the transaction costs of new home purchases by previous owners as well as new home buyers, and the loss from foreclosure.

- **Balanced government budget:** The government budget constraint holds (23), with lump-sum transfers Γ_k adjusting to balance budget.

C.3 Welfare

To compare households' welfare across different steady states under counterfactual policy regimes, I use the welfare criterion based on ex-ante expected utility W defined as

$$W = \int V(x) d\Omega \quad (32)$$

I express changes in welfare in consumption equivalence variation. Hence, I find the constant proportional increment of benchmark consumption Δ_{CEV} for each state combination under the baseline disaster policy design that yields the same expected utility under an alternative policy scenario. Define $c^*, h^* (\tilde{c}, \tilde{h})$ optimal consumption and housing choices under the baseline policy (under a counter-factual policy design). Then, I need to find Δ_{CEV} such that the following equation holds:

$$\mathbb{E} \sum_{t=0}^{\infty} \beta^t \pi_S \frac{[(\Delta_{CEV} c)^\alpha (\psi_h (1 - \delta) h)^{1-\alpha}]^{1-\sigma}}{1 - \sigma} = \mathbb{E} \sum_{t=0}^{\infty} \beta^t \pi_S \frac{[(\tilde{c})^\alpha (\psi_h (1 - \delta) \tilde{h})^{1-\alpha}]^{1-\sigma}}{1 - \sigma} \quad (33)$$

Then, Δ_{CEV} is given by

$$\Delta_{CEV} = \left(\frac{\tilde{W}}{W^*} \right)^{\frac{1}{\alpha(1-\sigma)}} \quad (34)$$

I calculate this measure for the aggregate economy and for different income levels and region-specific welfare effects.

D Solving the Model

I follow Druedahl (2021) to solve the household problem computationally efficiently in Julia. I apply the proposed nested endogenous grid method algorithm with upper envelope (NEGM) and adjust the computation for my specific case with multiple continuous and discrete choices, where the choice set depends on current state variables.

A main computational improvement is achieved by nesting the household problem. More precisely, I separate the consumption savings choice from the other continuous and discrete choices. Therefore, I can precompute the continuation value on a grid of post-decision variables.

I first solve the consumption-savings problem using the NEGM for the owner, renter, and foreclosed owner problems. I do not solve the buyer problem separately, as this can be reduced to a two-dimensional problem where only mortgages m and housing h are chosen using the solution of the owner problem.

I solve the household problem for each region separately. Therefore, I suppress the state variable k for simplicity. The state space consists of $\mathcal{N} = (b, h, m, z, \delta, \omega, \mathcal{O}, \mathcal{C}, \mathbb{I}_F, \mathbb{I}_R, \mathbb{I}_P, \mathbb{I}_H)$ with liquid assets b , housing h , mortgage m , labor productivity z , natural disaster shock δ , housing ownership status $\mathcal{O}$, and credit status $\mathcal{C}$, foreclosure shock $\mathbb{I}_F$, recourse shock $\mathbb{I}_R$, leaving recourse state shock $\mathbb{I}_P$, finding house shock $\mathbb{I}_H$. The state-dependent choice set $\mathcal{M}$

is defined as follows:

$$\mathcal{M} = \begin{cases} b', h', m', \mathcal{O}', \mathcal{C}', \iota & \text{if } \mathcal{O} = \textit{own} \\ b', h', m', \mathcal{O}' & \text{if } \mathcal{O} = \textit{rent} \text{ and } \mathcal{C} = 1 \\ b' & \text{if } \mathcal{O} = \textit{rent} \text{ and } \mathcal{C} = 2 \end{cases} \quad (35)$$

I define the variable cash-on-hand $x = (1+r)b + (1-\tau)wz + Q(\mathcal{M}, \mathcal{N})$ that reflects post-tax labor income plus beginning-of-period liquid assets plus the additive costs/benefits of choices made before the consumption-savings decision as well as realizations of stochastic variables.

$$Q(\mathcal{M}, \mathcal{N}) = \begin{cases} p((1-\epsilon)(1-\delta)h - h') - (1+r_m)m & \text{if } \mathcal{O} = \textit{own} \text{ and } \mathcal{O}' = \textit{own} \\ + qm' + \min\{\iota, p_h\delta h\} - \iota p_\iota & \text{and } (h \neq h' \text{ or } m \neq m') \text{ and } \mathbb{I}_H = 1 \\ \\ -\mu m - p_h\delta h + \min\{\iota, p_h\delta h\} - \iota p_\iota & \text{if } \mathcal{O} = \textit{own} \text{ and } \mathcal{O}' = \textit{own} \\ + \max\{0, \min\{p_h\delta h - \iota, \bar{\tau}_\delta\}\} & \text{and } (h \neq h' \text{ or } m \neq m') \text{ and } \mathbb{I}_H = 0 \\ \\ -\mu m - p_h\delta h + \min\{\iota, p_h\delta h\} - \iota p_\iota & \text{if } \mathcal{O} = \textit{own} \text{ and } \mathcal{O}' = \textit{own} \\ + \max\{0, \min\{p_h\delta h - \iota, \bar{\tau}_\delta\}\} & \text{and } (h = h' \text{ and } m = m') \text{ and } D = 0 \\ \\ -p_h\delta h + \min\{\iota, p_h\delta h\} - \iota p_\iota & \text{if } \mathcal{O} = \textit{own} \text{ and } \mathcal{O}' = \textit{own} \\ + \max\{0, \min\{p_h\delta h - \iota, \bar{\tau}_\delta\}\} & \text{and } (h = h' \text{ and } m = m') \\ & \text{and } D = 1 \text{ and } \mathbb{I}_F = 0 \\ \\ \max\{\eta, \min\{b_{\textit{exemp}} - b, 0\}\} & \text{if } \mathcal{O} = \textit{own} \text{ and } \mathcal{O}' = \textit{rent} \\ & \text{and } D = 1 \text{ and } \mathbb{I}_F = 1 \\ \\ p(1-\epsilon)h - (1+r_m)m & \text{if } \mathcal{O} = \textit{own} \text{ and } \mathcal{O}' = \textit{rent} \\ \\ -p_h h' + qm' & \text{if } \mathcal{O} = \textit{rent} \text{ and } \mathcal{O}' = \textit{own} \text{ and } \mathbb{I}_H = 1 \\ \\ 0 & \text{else} \end{cases}$$

Further, I define a matrix of feasible transitions of size $(N_b \cdot N_h \cdot N_m \cdot N_z \cdot N_j \cdot N_\delta \cdot N_\omega \cdot N_{\mathcal{T}} \cdot N_{\mathcal{C}} \cdot 2 \cdot 2 \cdot 2 \cdot 2) \times (N_b \cdot N_h \cdot N_m \cdot N_z \cdot N_j \cdot N_\delta \cdot N_\omega \cdot N_{\mathcal{T}} \cdot N_{\mathcal{C}} \cdot 2 \cdot 2 \cdot 2 \cdot 2)$. Each entry equals one if the transition from one state combination to the other is feasible.

D.1 Consumption-Saving Choice of Homeowner

I define the following post-decision variables that are important inputs for the consumption saving decision: end-of-period liquid assets $a = x - c$, housing h' , mortgages $m' = (1+r_m)m - \mathbb{I}[D=0]\mu m$, labor productivity z , ownership status $\mathcal{O}'$. I solve the consumption

saving decision of the keeper on a grid of cash-on-hand values. Then, I interpolate the keeper value for cash-on-hand values implied by the state combinations. Define the *post-decision value function*

$$w(a, h', m', z) = \beta \mathbb{E}v(b, h, m, z, \delta, \omega, \mathcal{O}, \mathcal{C}, \mathbb{I}_F, \mathbb{I}_R, \mathbb{I}_P, \mathbb{I}_H)$$

I solve the following problem using EGM

$$\tilde{v}^{keep}(x, h', m', z) = \max_c u(c, \psi_h h') + w(a, h', m', z,) \quad s.t. \quad a = x - c \geq 0 \quad (36)$$

The Euler Equation is

$$\begin{aligned} u_c &= \alpha(\psi_h(1 - \delta)h')^{(1-\alpha)(1-\sigma)} c^{\alpha(1-\sigma)-1} \\ u_c(c, \psi_h h') &= q \iff \alpha(\psi_h(1 - \delta)h')^{(1-\alpha)(1-\sigma)} c^{\alpha(1-\sigma)-1} = q \\ c &= \left(\frac{q}{\alpha(\psi_h(1 - \delta)h')^{(1-\alpha)(1-\sigma)}} \right)^{\frac{1}{\alpha(1-\sigma)-1}} \end{aligned} \quad (37)$$

D.2 Consumption-Saving and Housing Choice of Renters

The only post-decision variables that are important for the Bellman equation are contemporaneous housing (chosen in the step prior to the consumption saving decision), end-of-period assets $a = x - c$, and labor productivity z . I define the post-decision value function

$$w(a, z) = \beta \mathbb{E}v(x', z')$$

I solve the following problem using EGM

$$\tilde{v}^{rent}(x, h, z) = \max_c u(c, h) + w(a, z) \quad s.t. \quad a = x - c \geq 0 \quad (38)$$

Given the optimal consumption-saving decision, a renter decides which house size to rent from the set of discrete houses $\mathcal{H}_R$.

$$v^{rent}(x, z) = \max_{h \in \mathcal{H}_R} \tilde{v}^{rent}(x, h, z) \quad (39)$$

D.3 Consumption-Saving and Housing Choice of a foreclosed Homeowner

The only post-decision variables that are important for the Bellman equation are contemporaneous housing (chosen in the step prior to the consumption saving decision), end-of-period assets $a = x - c$, wage garnishment ω , and labor productivity z . I define the post-decision value function

$$w(a, z, \omega) = \beta \mathbb{E}v(b', z', \omega)$$

I solve the following problem using EGM

$$\tilde{v}^{forcl}(x, h, z, \omega) = \max_c u(c, h) + w(a, z, \omega) \quad s.t. \quad a = x - c \geq 0 \quad (40)$$

Given the optimal consumption-saving decision, a renter decides which house size to rent from the set of discrete houses $\mathcal{H}_R$.

$$v^{forcl}(x, z, \omega) = \max_{h \in \mathcal{H}_R} \tilde{v}^{forcl}(x, h, z, \omega) \quad (41)$$

D.4 Consumption-Saving and Housing Choice of a Buyer

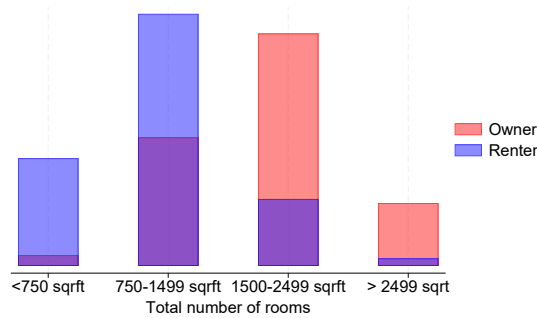
I use the value function and policy function from the owner-keeper problem. I interpolate both functions based on cash-on-hand $\tilde{x}(h', m')$ for a buyer, where I account for mortgage issuance, house purchase, and transaction costs. Then, the three-dimensional problem of finding c, h', m' reduces to a two-dimensional problem.

$$v^{buy}(x, z) = \max_{h', m'} \tilde{v}^{keep}(\tilde{x}, h', m', z) \quad s.t. \quad \tilde{x} = x - p_h(1 + \epsilon)h' + qm' \quad \text{and} \quad m' \leq \lambda p_h h' \quad (42)$$

Optimal savings / consumption is obtained by interpolating the policy function for the corresponding value of cash-on-hands $\tilde{x}(b', h')$.

E Calibration

Figure E.1: Segmentation of housing market



Note: The figure plots the distribution of four different home size groups (by square feet) for owners in red and renters in blue. Source: American Housing Survey, 2021.

E.1 Initial asset distribution

Following Kaplan and Violante (2014), I target the correlation between initial earnings and liquid wealth. For this purpose, I use the 2019 SCF and restrict the sample to households younger than 30. Although 30 does not coincide with the entry age in my model, I focus

on this broader sample because limiting the analysis to households up to age 20 would yield too few observations. I divide households into three income groups, defined by the 30th and 70th percentiles of the income distribution. Within each group, I compute (i) the share of households with zero liquid wealth and (ii) the median liquid-wealth-to-income ratio conditional on positive liquid wealth. Agents in the model are then initialized so that a fraction equal to the empirical share has zero liquid wealth, while the remaining fraction is assigned the group-specific median liquid-wealth-to-income ratio. Table E.1 reports these statistics—the share of households with zero liquid wealth and the median liquid-wealth-to-income ratio—for both the full sample and the subsample of households younger than 30.

Table E.1: Liquid Wealth by Income

	Share with zero liquid wealth		Median liquid wealth over income	
	All	< 30 years	All	< 30 years
Aggregate	0.050	0.078	0.88	0.070
<i>By Income</i>				
Low	0.132	0.148	0.060	0.082
Middle	0.026	0.075	0.058	0.044
High	0.002	0.009	0.200	0.106

Note: The table reports summary statistics on liquid assets holdings by income groups for the whole population and households below 30 years based on the Survey of Consumer Finances, 2019.

Table E.2: External Calibration of Parameters

Parameter		Value	Source/Details
Utility			
β	Discounting	0.98	6-month frequency
α	Consumption share	0.859	Mitman (2016)
σ	CRRA parameter	2	Standard assumption
π_S	Survival probability	0.99	Life expectancy of 50 years
σ_S, σ_R	Variances of taste shock	0.1	Smoothing parameter
Income process			
ρ_z	Autocorrelation	0.97	Kaplan et al. (2020)
σ_z	Standard deviation	0.2	Kaplan et al. (2020)
Financial markets			
$\underline{b}$	Budget constraint	0	No uncollateralized borrowing
π_F	Probability of foreclosure	0.015	Own estimation
ϵ_F	Inefficiency of foreclosure	0.22	Kaplan et al. (2020)
$\bar{\omega}$	Maximum garnishment	0.15	Federal Wage Garnishment Law
π_P	Leaving garnishment stage	0.1	Avg. duration of 5 yrs (Chapter 13)
r	Risk free rate	0.00885	Average Fed Funds rate (6-month freq.)
$\frac{r_m}{r} - 1$	Intermediation wedge	0.33	Mitman (2016)
λ	LTV limit	0.8	Berger et al. (2018)
b_{exemp}	Asset exemptions	0.46	U.S. wild card exemptions
Housing			
ϵ	Transaction costs	0.07	Kaplan and Violante (2014)
N^{HR}	Number of grid points	3	AHS (2021)
N^{HO}	Number of grid points	3	AHS (2021)
$\Delta_{\mathcal{H}}$	Normalized grid points	[1, 2.1, 3.7, 6.2]	AHS (2021)
ζ	Maintenance costs	0.0075	Kaplan et al. (2020)
Production			
Θ	Labor productivity	1	Normalize total output to one
ξ	Labor share of production	0.6	Kaplan et al. (2020)
Government			
τ_0	Baseline income tax	0.136	Average income tax paid in the US
$\bar{\tau}_\delta$	Maximum disaster aid	1.26	Normalized maximum grants (FEMA)
π_R	Probability of recourse	0.1	Mitman (2016)
Natural disasters			
δ	Relative destruction	[0, 0.12, 0.66]	NFIP claims transactions
π_{low}	Probability of damages	[0, 0.0006, 0.0002]	Based on the National Risk Index
π_{high}	Probability of damages	[0, 0.0033, 0.0012]	Based on the National Risk Index
Private insurance			
q_t	Administrative fees	0.33	Expense ratios of policy claims

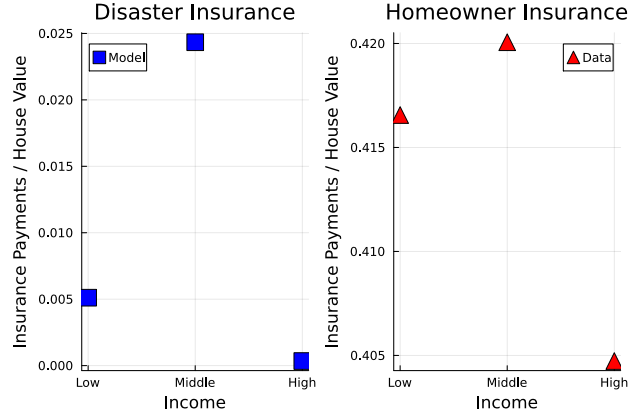
F Model Validation

Table F.1: Regional data moments

	Low-risk regions			High-risk regions			Difference
	N	Mean	SE	N	Mean	SE	
GDP (p.c.)	2,543	57.96	15.15	514	55.86	5.28	2.09
Owner costs (w/o mortgage)	682	1,154	93	142	1,813	272	659***
Number of rooms	682	5.8	0.02	142	5.3	0.03	-0.5***
Percent with mortgage	679	64.8	0.3	139	60.6	0.8	4.2***
Homeownership rate	682	67.5	0.3	142	65.6	0.7	-1.9***

Note: The table plots summary statistics based on the American Community Surveys 2010-2020 and data on GDP 2001-2020 provided by the U.S. Bureau of Economic Analysis (BEA). County-level data are aggregated to low-risk and high-risk regions based on the classification strategy explained in the main text.

Figure F.1: Insurance Payments over the Income Distribution



Note: The figure plots data moments against moments generated by the model for each income group. The left panel plots yearly insurance payments over house value in the model. The right panel plots median yearly homeowner insurance payments (covering more than only natural disaster damages) over house value. Data moments are based on the American Housing Survey 2019.

F.1 Model-Based Simulation of Impulse Response Functions

The simulation begins from the stationary distribution of performing, non-garnished homeowners—those with mortgage delinquency tenure $T = 1$ and no garnishment ($\omega = 0$)—in disaster state D at time t . At each horizon, the delinquency rate is computed as the expected mortgage-weighted default probability per unit of initial mortgage mass, using the same denominator throughout to ensure comparability across horizons.

At t , the delinquency rate equals the expected default probability $\mathbb{E}[\text{prob_default}(b, h, m, z, D)]$, weighted by leverage and house size, and read directly from the policy functions.

At $t + k$ ($k = 1, 2, 3$), states are propagated forward as follows. Households that retained their home in the previous period with probability `prob_keep` (bilinearly interpolated in liquid assets b and leverage m) transition to next-period liquid assets $b' = b^{op}(b, h, m, z, D)$ and leverage $m' = (1 + r_m - \mu)m$, where the latter reflects amortization from the stationary distribution. Income z' is drawn from the discretized AR(1) transition matrix and the disaster state D' is drawn i.i.d. from π_D . The expected default probability at (b', h, m', z', D') is obtained by bilinear interpolation of `prob_default` over the (b, m) grid. Households that voluntarily sell or are foreclosed exit the tracked population and contribute zero to delinquency in subsequent periods. The numerator at $t + k$ therefore captures the probability of defaulting exactly k periods after the initial disaster, conditional on having remained a performing homeowner in each intervening period.

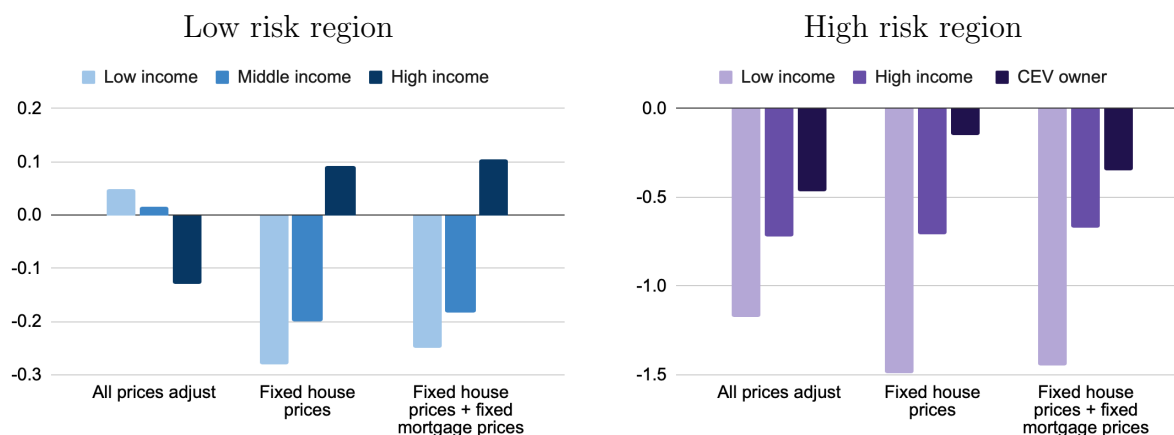
G Model Results

Table G.1: Homeowners remaining in their homes after disasters - policy comparison

	$\Delta\%$						
	$\bar{\tau}_\delta = 0$	$M = 0$	No aid	CF 1	CF 2	CF 3	CF 4
Aggregate	-34.3	-0.1	-34.4	-33.5	0.3	-16.1	0.3
<i>Low risk</i>							
All	-32.6	0.2	-32.7	-31.9	0.3	-14.6	0.4
Low income	-62.0	0.4	-62.1	-59.1	-0.5	11.6	-0.2
Middle income	-28.9	-0.2	-29.0	-28.8	1.8	-29.8	0.0
High income	-11.0	1.1	-11.1	-12.0	-1.7	-9.6	2.8
<i>High risk</i>							
All	-39.4	-1.0	-39.5	-37.8	0.2	-20.4	0.0
Low income	-70.6	0.1	-70.6	-70.1	-1.8	11.8	0.1
Middle income	-32.4	-0.2	-32.5	-32.9	1.0	-32.5	0.0
High income	-34.2	-2.9	-34.3	-29.5	0.4	-28.4	0.0

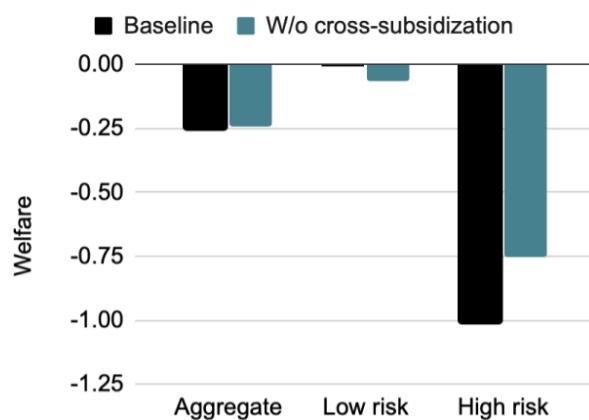
Note: This table plots the percentage change in the share of homeowners remaining in their homes after being hit by a natural disaster comparing alternative policy scenarios to the baseline steady state. Each column represents one the following counterfactuals: ($\bar{\tau}_\delta = 0$) removing rebuilding grants, ($M = 0$) removing the foreclosure moratorium, (No aid) removing both rebuilding grant and foreclosure moratorium, (CF 1) providing only an insurance subsidy, (CF 2) making rebuilding grants independent of insurance coverage, and (CF 3) providing insurance-independent rebuilding grants to low-income homeowners only. As last counterfactual (CF 4), government aid is financed through a tax on homeowners' housing capital.

Figure G.1: Welfare changes from removing existing disaster aid - Decomposition by income and region



Note: Reported welfare changes are consumption equivalence variation from baseline steady state (in %) by region for the counterfactual of removing both, financial aid and the foreclosure moratorium. Along the x-axis, I plot the income-specific welfare changes allowing for (i) the baseline with all general equilibrium effects, (ii) only adjustments of mortgage prices holding house prices fixed, and (iii) holding house prices and mortgage prices fixed.

Figure G.2: Welfare - Role of Regional Cross-subsidization



Note: Reported welfare changes are consumption equivalence variation from baseline steady state (in %) for the counterfactual of removing both, financial aid and the foreclosure moratorium. Along the x-axis, I plot the aggregate and region-specific welfare changes under (i) the baseline scenario with cross-subsidization and (ii) with region-specific aid only.

Table G.2: Delinquencies and foreclosures - policy comparison

	$\Delta\%$						
	$\bar{\tau}_\delta = 0$	$M = 0$	No aid	CF 1	CF 2	CF 3	CF 4
Delinquency rates							
Total	-0.63	-0.78	-0.66	-0.95	1.91	2.08	-1.38
<i>By risk exposure</i>							
Low-risk region	-0.35	-1.19	-0.36	-0.57	1.76	0.73	-1.66
High-risk region	-1.52	0.52	-1.59	-2.17	2.39	6.30	-0.51
Foreclosure rates (all)							
Total	12.24	-0.47	12.32	10.36	3.44	2.29	-1.49
<i>By risk exposure</i>							
Low-risk region	6.78	-1.06	6.82	5.97	2.66	0.00	-1.73
High-risk region	24.78	0.88	24.94	20.46	5.22	0.00	-0.95
Foreclosure rates (only “involuntary” foreclosures)							
Total	-0.53	-0.55	-0.43	-0.84	2.03	2.32	-1.38
<i>By risk exposure</i>							
Low-risk region	-0.31	-1.08	-0.25	-0.51	1.82	0.85	-1.66
High-risk region	-1.25	1.13	-0.99	-1.86	2.71	6.95	-0.50
Foreclosure rates (only “consensual” foreclosures)							
Total	74.78	-0.07	74.75	65.21	10.32	-80.45	-2.03
<i>By risk exposure</i>							
Low-risk region	74.20	-0.79	74.17	67.64	10.69	-86.33	-2.39
High-risk region	75.15	0.39	75.12	63.65	10.08	-76.68	-1.80

Note: This table plots the percentage change in the delinquency rates as well as foreclosure rates comparing alternative policy scenarios to the baseline steady state. Each column represents one the following counterfactuals: ($\bar{\tau}_\delta = 0$) removing rebuilding grants, ($M = 0$) removing the foreclosure moratorium, (No aid) removing both rebuilding grant and foreclosure moratorium, (CF 1) providing only an insurance subsidy, (CF 2) making rebuilding grants independent of insurance coverage, and (CF 3) providing insurance-independent rebuilding grants to low-income homeowners only. As last counterfactual (CF 4), government aid is financed through a tax on homeowners' housing capital. The “involuntary” foreclosures refer to foreclosed homeowners who stopped making mortgage payments hoping to stay delinquent until the subsequent period. “Consensual” foreclosures refers to homeowners who cannot afford to stay delinquent as the rebuilding expenditures are higher than their disposable income.

Table G.3: Delinquencies by income and region - policy comparison

	$\bar{\tau}_\delta = 0$	$M = 0$	No aid	CF 1	CF 2	CF 3	CF 4
Low-risk region							
<i>Low income</i>							
No damage	0.02	-0.08	0.02	0.04	0.02	-0.02	-0.13
Small damage	5.85	-1.28	5.26	4.34	-0.36	-0.07	-0.20
Large damage	-38.17	-0.82	-38.22	-38.28	-36.40	-33.45	0.53
<i>Middle income</i>							
No damage	0.00	-0.02	0.00	0.00	-0.01	0.00	-0.02
Small damage	-0.11	-0.44	-0.50	-0.49	-0.06	-0.12	-0.03
Large damage	-1.79	-0.47	-1.93	-1.78	0.19	-1.62	0.06
<i>High income</i>							
No damage	-0.01	0.01	-0.01	-0.02	0.02	0.01	0.03
Small damage	-0.12	-0.16	-0.27	-0.26	0.02	-0.10	0.03
Large damage	-0.67	-0.24	-0.78	-0.79	-0.39	-0.67	-0.08
High-risk region							
<i>Low income</i>							
No damage	0.16	0.04	0.16	0.22	0.36	0.08	0.00
Small damage	5.40	-1.12	4.80	5.06	0.15	0.07	0.01
Large damage	-40.18	0.37	-40.24	-40.22	-37.52	-35.41	0.13
<i>Middle income</i>							
No damage	0.02	0.00	0.02	0.03	0.03	0.04	0.00
Small damage	-0.13	-0.41	-0.50	-0.49	-0.03	-0.10	0.00
Large damage	-1.97	-0.45	-2.09	-2.00	-0.20	-1.81	0.00
<i>High income</i>							
No damage	-0.25	-0.02	-0.25	-0.20	0.04	-0.19	-0.01
Small damage	-0.36	-0.23	-0.50	-0.45	0.05	-0.29	-0.01
Large damage	-0.79	-0.21	-0.89	-0.86	-0.28	-0.75	0.03

Note: This table documents the percentage point changes in the delinquency rates comparing alternative policy scenarios to the baseline steady state by region and income. Each column represents one the following counterfactuals: ($\bar{\tau}_\delta = 0$) removing rebuilding grants, ($M = 0$) removing the foreclosure moratorium, (No aid) removing both rebuilding grant and foreclosure moratorium, (CF 1) providing only an insurance subsidy, (CF 2) making rebuilding grants independent of insurance coverage, and (CF 3) providing insurance-independent rebuilding grants to low-income homeowners only. As last counterfactual (CF 4), government aid is financed through a tax on homeowners' housing capital.

Table G.4: “Involuntary” foreclosures by income and region - policy comparison

	$\bar{\tau}_\delta = 0$	$M = 0$	No aid	CF 1	CF 2	CF 3	CF 4
Low-risk region							
<i>Low income</i>							
No damage	0.0003	-0.0012	0.0003	0.0006	0.0003	-0.0003	-0.0020
Small damage	0.0442	0.0163	0.1159	0.0328	-0.0027	0.0348	-0.0015
Large damage	-0.2885	0.2847	-0.2849	-0.2892	-0.2751	-0.2122	0.0040
<i>Middle income</i>							
No damage	0.0000	-0.0003	0.0000	0.0000	-0.0002	0.0000	-0.0004
Small damage	-0.0009	0.0077	0.0067	-0.0037	-0.0004	0.0125	-0.0002
Large damage	-0.0136	0.0133	-0.0090	-0.0135	0.0014	-0.0041	0.0005
<i>High income</i>							
No damage	-0.0002	0.0002	-0.0002	-0.0002	0.0003	0.0001	0.0004
Small damage	-0.0009	0.0044	0.0028	-0.0020	0.0001	0.0054	0.0002
Large damage	-0.0051	0.0063	-0.0020	-0.0060	-0.0029	-0.0002	-0.0006
High-risk region							
<i>Low income</i>							
No damage	0.0025	0.0005	0.0025	0.0033	0.0055	0.0012	0.0000
Small damage	0.0408	0.0183	0.1085	0.0382	0.0012	0.0364	0.0000
Large damage	-0.3036	0.3185	-0.2998	-0.3039	-0.2835	-0.2263	0.0010
<i>Middle income</i>							
No damage	0.0003	0.0000	0.0003	0.0004	0.0004	0.0006	0.0000
Small damage	-0.0009	0.0081	0.0067	-0.0037	-0.0002	0.0127	0.0000
Large damage	-0.0149	0.0148	-0.0103	-0.0151	-0.0015	-0.0059	0.0000
<i>High income</i>							
No damage	-0.0038	-0.0003	-0.0038	-0.0031	0.0006	-0.0028	-0.0001
Small damage	-0.0027	0.0047	0.0007	-0.0034	0.0004	0.0038	0.0000
Large damage	-0.0060	0.0068	-0.0034	-0.0065	-0.0021	-0.0013	0.0002

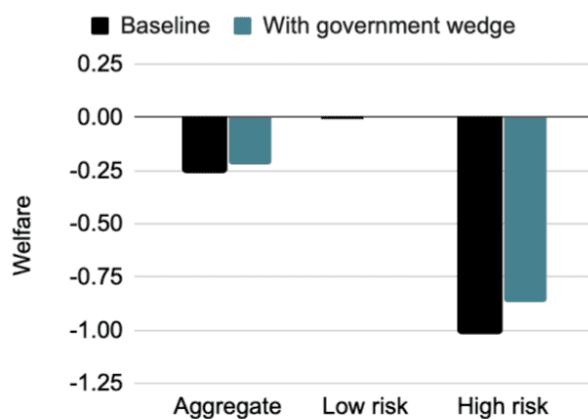
Note: This table documents the percentage point changes in the foreclosure rates comparing alternative policy scenarios to the baseline steady state by region and income. Each column represents one the following counterfactuals: ($\bar{\tau}_\delta = 0$) removing rebuilding grants, ($M = 0$) removing the foreclosure moratorium, (No aid) removing both rebuilding grant and foreclosure moratorium, (CF 1) providing only an insurance subsidy, (CF 2) making rebuilding grants independent of insurance coverage, and (CF 3) providing insurance-independent rebuilding grants to low-income homeowners only. As last counterfactual (CF 4), government aid is financed through a tax on homeowners’ housing capital. The “involuntary” foreclosures refer to foreclosed homeowners who stopped making mortgage payments hoping to stay delinquent until the subsequent period.

Table G.5: “Consensual” foreclosures by income and region - policy comparison

	$\bar{\tau}_\delta = 0$	$M = 0$	No aid	CF 1	CF 2	CF 3	CF 4
Low-risk region							
<i>Low income</i>							
No damage	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Small damage	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Large damage	34.5876	-1.1477	34.5836	36.0742	1.0983	-47.1141	-1.8789
<i>Middle income</i>							
No damage	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Small damage	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Large damage	2.1732	-0.0668	2.1744	0.6697	0.9897	0.7856	-0.1159
<i>High income</i>							
No damage	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Small damage	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Large damage	0.1921	0.0000	0.1921	0.2305	0.2907	0.2351	0.0000
High-risk region							
<i>Low income</i>							
No damage	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Small damage	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Large damage	37.9758	-0.1016	37.9735	36.7610	7.9146	-41.9458	-0.3109
<i>Middle income</i>							
No damage	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Small damage	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Large damage	1.5007	-0.0443	1.5013	1.3369	0.5557	1.2082	0.0084
<i>High income</i>							
No damage	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Small damage	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Large damage	0.3232	0.0000	0.3232	0.3050	0.1927	0.3672	0.0000

Note: This table documents the percentage point changes in the foreclosure rates comparing alternative policy scenarios to the baseline steady state by region and income. Each column represents one the following counterfactuals: ($\bar{\tau}_\delta = 0$) removing rebuilding grants, ($M = 0$) removing the foreclosure moratorium, (No aid) removing both rebuilding grant and foreclosure moratorium, (CF 1) providing only an insurance subsidy, (CF 2) making rebuilding grants independent of insurance coverage, and (CF 3) providing insurance-independent rebuilding grants to low-income homeowners only. As last counterfactual (CF 4), government aid is financed through a tax on homeowners’ housing capital. “Consensual” foreclosures refers to homeowners who cannot afford to stay delinquent as the rebuilding expenditures are higher than their disposable income.

Figure G.3: Welfare - Role of Insurance Wedge



Note: The figure plots welfare changes in CEV % from removing government aid under (i) the baseline assumption that the government does not face any intermediation wedge and (ii) the assumption that the government faces the same intermediation wedge as the insurance firm.

Table G.6: Housing and insurance choices - Role of Cross-Subsidization

	$\Delta\%$		
	Insurance gap	Homeownership rate	Owner-occupied housing stock
Low risk	-0.15	0.62	0.83
High risk	0.83	-1.42	-2.14

Note: The table plots percentage deviations of steady state statistics for a scenario with baseline government aid financed within one region compared to the baseline steady state.

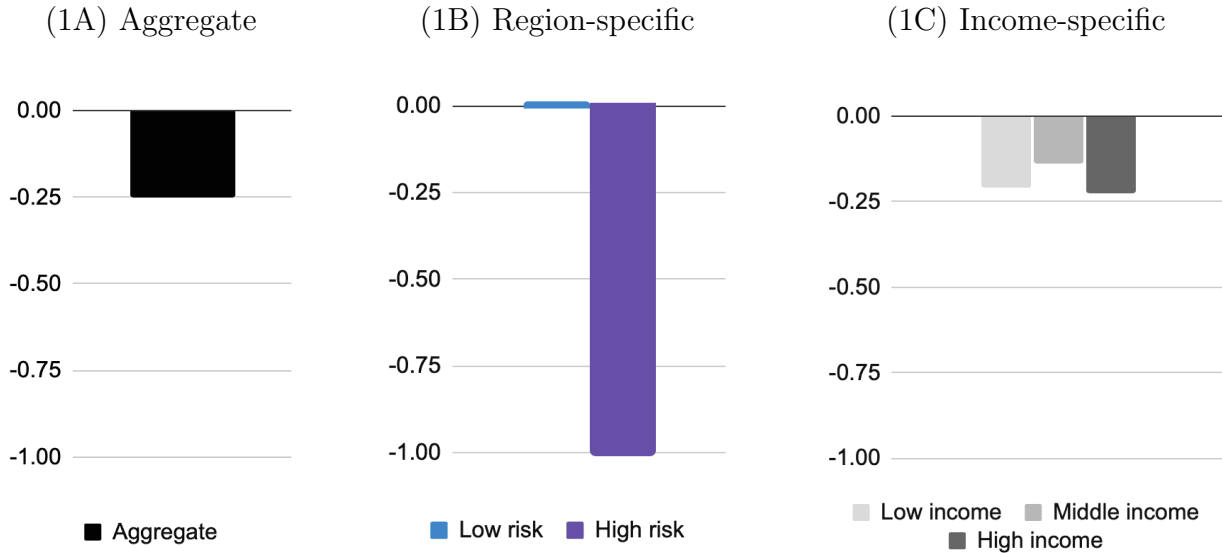
Table G.7: Steady State Comparison by Income - Removing existing disaster aid

	Counterfactuals ($\Delta\%$)							
	(0) Base	(1) $\tau_\delta = 0$	(2) M = 0	(3) No aid	(4) CF 1	(5) CF 2	(6) CF 3	(7) CF 4
Insurance gap								
Total	73.14	-48.90	1.32	-48.91	-50.69	-30.87	-35.17	1.47
<i>Low risk</i>								
Low income	85.52	-21.73	0.05	-21.73	-28.77	-39.99	16.93	0.50
Middle income	47.45	-62.32	4.23	-62.32	-64.66	-27.81	-61.31	3.87
High income	99.00	-53.32	0.33	-53.32	-53.94	-33.53	-49.47	0.20
<i>High risk</i>								
Low income	80.86	-11.90	-0.35	-12.11	-13.12	-26.36	23.67	-0.03
Middle income	58.48	-65.66	1.22	-65.66	-64.77	-33.41	-66.26	0.65
High income	98.75	-58.22	-0.00	-58.21	-53.25	-16.54	-52.25	0.24
Home ownership								
Total	66.15	-2.30	-0.00	-2.30	-3.35	0.63	1.44	0.20
<i>Low risk</i>								
Low income	0.51	0.18	1.52	0.17	-2.11	3.12	6.77	-1.13
Middle income	0.77	0.33	-0.61	0.33	-0.12	0.73	0.85	-0.67
High income	0.67	1.00	1.06	1.01	-0.28	2.2	1.14	3.72
<i>High risk</i>								
Low income	0.40	-12.71	-0.68	-12.73	-19.54	-12.97	28.21	-2.21
Middle income	0.75	-3.50	-0.52	-3.50	-4.58	-2.25	-1.15	-0.46
High income	0.79	-19.00	-2.28	-19.00	-16.52	2.01	-16.33	-0.29
Owner-occupied housing stock								
Total	3.75	-2.61	-0.46	-2.61	-3.73	2.49	1.44	0.28
<i>Low risk</i>								
Low income	0.81	-0.20	1.43	-0.21	-2.64	5.39	7.59	0.53
Middle income	1.91	0.78	-1.19	0.78	0.14	1.71	1.58	-1.41
High income	1.05	0.40	0.94	0.41	-0.77	3.49	0.96	4.57
<i>High risk</i>								
Low income	0.64	-14.70	-1.22	-14.72	-21.31	-8.07	24.7	-2.32
Middle income	1.75	-2.52	-0.94	-2.52	-4.05	2.69	0.98	-0.75
High income	1.27	-24.16	-3.24	-24.15	-21.4	2.98	-20.84	-0.60
Per-capita housing (owner)								
Total	5.66	-0.40	-0.46	-0.40	-0.47	1.86	-0.02	0.07
<i>Low risk</i>								
Low income	5.33	-0.37	-0.08	-0.38	-0.54	2.21	0.76	1.18
Middle income	6.16	0.45	-0.58	0.45	0.26	0.98	0.72	-0.63
High income	5.25	-0.60	-0.12	-0.60	-0.50	1.27	-0.18	1.16
<i>High risk</i>								
Low income	5.26	-2.30	-0.55	-2.30	-2.2	5.63	-2.74	-0.12
Middle income	5.86	1.02	-0.42	1.02	0.56	5.05	2.16	-0.29
High income	5.37	-6.36	-0.99	-6.35	-5.85	0.94	-5.40	-0.30

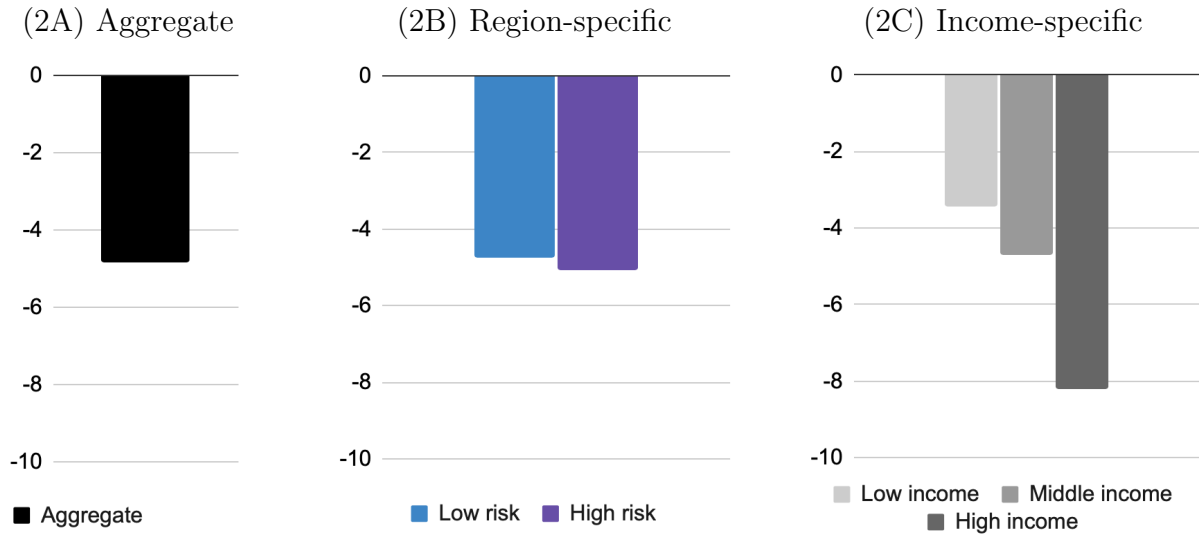
Note: Column (0) reports main statics in the baseline steady state with existing disaster aid in a lenient recourse regime. Columns (1)-(3) report percent changes from the baseline steady state for the following policy counterfactuals: (1) Removing rebuilding grants, (2) removing foreclosure moratorium, and (3) removing both, rebuilding grants and the foreclosure moratorium. In addition, the table plots results of the following revenue neutral policies: (4) providing only an insurance subsidy, (5) making financial aid independent of insurance coverage, and (6) providing insurance-independent financial aid to low-income and middle-income homeowners only. Lastly, under (7) disaster aid is financed through a tax on homeowners' housing capital.

Figure G.4: Welfare change from removing disaster aid - Role of the default option

(1) Including a default option



(2) Excluding the default option



Note: The figure plots welfare change from removing disaster aid from different baseline steady states, (1) a steady state with a default option and (2) as steady state without a default option. Welfare changes expressed in consumption equivalence variation in percent and reported for (A) the aggregate economy, (B) by regions, and (C) for all income groups.

G.1 Alternative Policy Designs

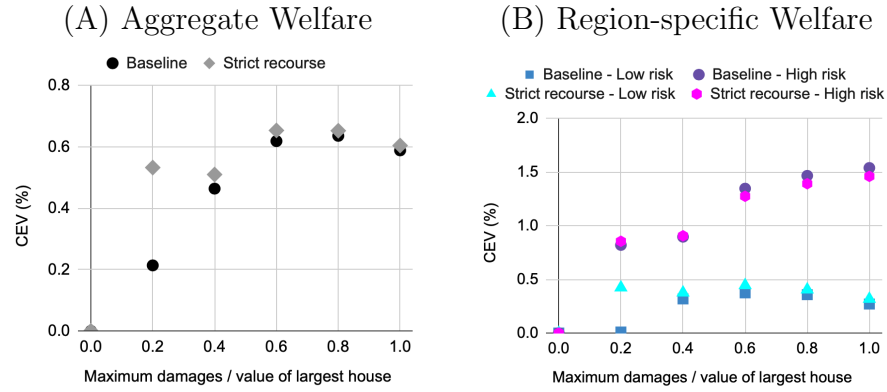
Table G.8: Steady State Comparison by Region - Alternative Policy Designs

$\Delta\%$	Insurance subsidy	Lump-sum grant	Low-income only	Housing tax
Insurance gap				
Low-risk region	-50.51	-33.40	-33.92	1.88
High-risk region	-51.19	-23.82	-38.65	0.33
Homeownership rate				
Low-risk region	-0.62	1.72	2.30	0.51
High-risk region	-11.64	-2.69	-1.19	-0.72
Owner-occupied housing stock				
Low-risk region	-0.72	3.00	2.70	0.68
High-risk region	-13.07	0.92	-2.46	-0.97

Columns report percent changes from the steady state with existing aid for policy counterfactuals.

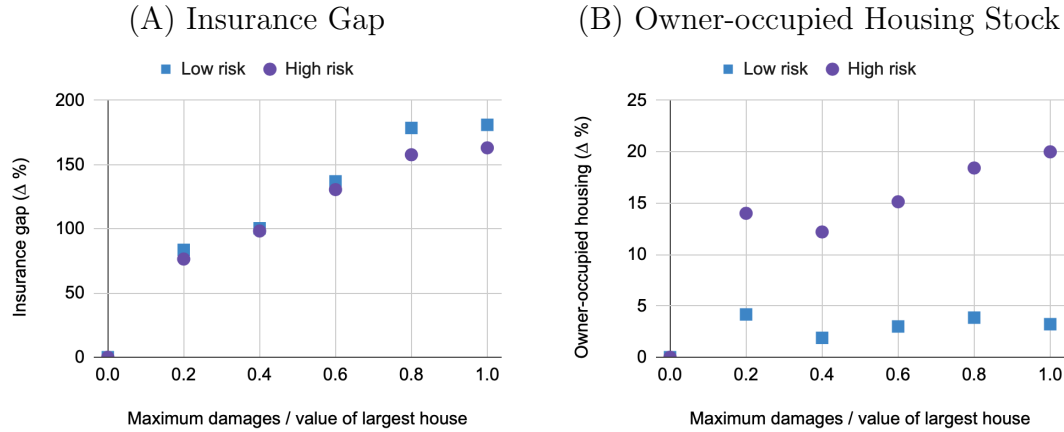
G.2 Role of recourse regime

Figure G.5: Welfare under different levels of financial aid - Role of Recourse



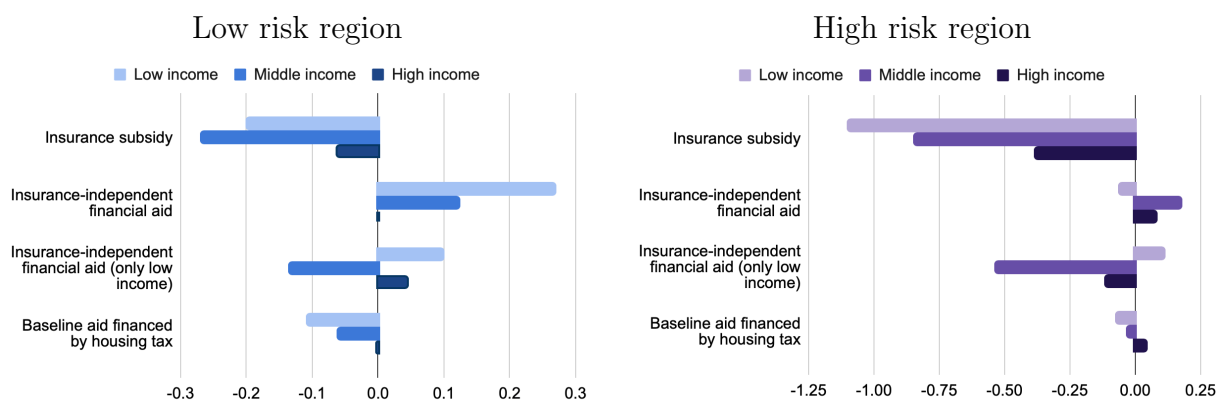
Note: The figure reports aggregate and region-specific welfare changes across various steady states that differ in the level of the maximum grants provided to households as well as the recourse regime. Welfare changes are expressed in consumption equivalence variation from a steady state without any financial aid. The grant size is expressed as a share of the value of maximum damages to the largest house in the economy.

Figure G.6: Insurance and housing under different levels of financial aid - Strict recourse



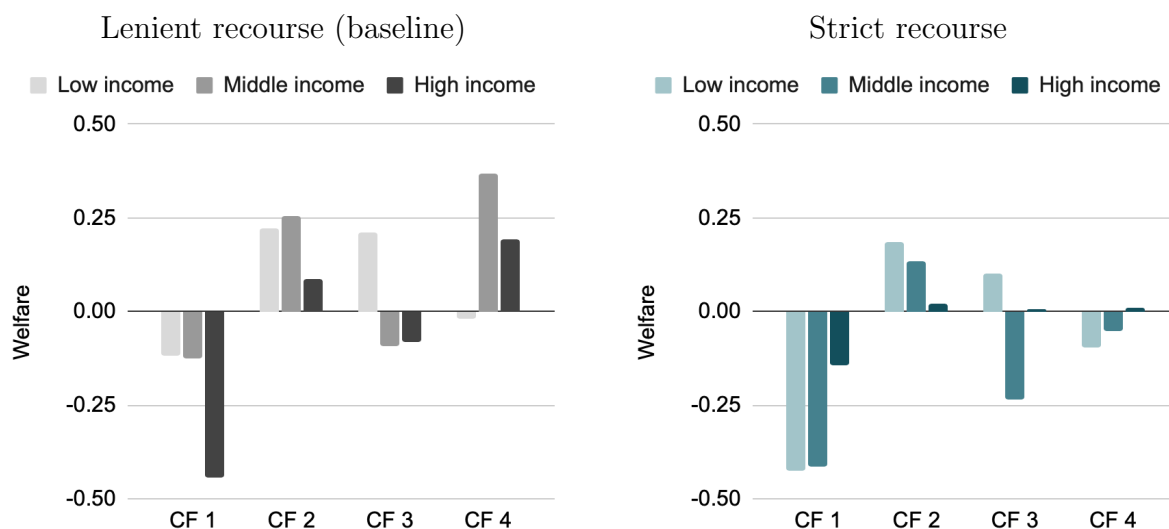
Note: The figure reports region-specific changes in the insurance gap and the owner-occupied housing stock across various steady states that only differ in the level of the maximum grants provided to households. Changes are expressed in percent deviation from a steady state without any financial aid. The grant size is expressed as a share of the value of maximum damages to the largest house in the economy.

Figure G.7: Welfare changes under alternative policy designs across the income distribution
- Strict recourse regime



Note: Reported welfare changes are consumption equivalence variation from baseline steady state (in %) by region for the following revenue neutral counterfactuals: (CF 1) providing only an insurance subsidy, (CF 2) making financial aid independent of insurance coverage, and (CF 3) providing insurance-independent financial aid to low-income homeowners only. As last counterfactual (CF 4), disaster aid is financed through a tax on homeowners' housing capital.

Figure G.8: Welfare changes under alternative policy designs across the income distribution
by recourse regime



Note: Reported welfare changes are consumption equivalence variation from baseline steady state (in %) by recourse regime for the following revenue neutral counterfactuals: (CF 1) providing only an insurance subsidy, (CF 2) making financial aid independent of insurance coverage, and (CF 3) providing insurance-independent financial aid to low-income homeowners only. As last counterfactual (CF 4), disaster aid is financed through a tax on homeowners' housing capital.