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, which alone lowers private insurance demand and creates scope for government intervention. 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 featuring two degrees of mortgage default: delinquency and foreclosure. Calibrated to the U.S. economy over 2000-2020, the model yields three main results. First, existing government aid increases the share of uninsured losses by 36pp and expands owner-occupied housing in disaster-prone areas by 14% relative to a no-aid scenario. Second, government aid generates aggregate welfare gains of 0.25% in consumption-equivalent terms, concentrated among households in high-risk regions. Third, for the same fiscal cost, the largest welfare gains arise when rebuilding transfers are provided independently of insurance coverage, as this reduces 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 about \$2.27 trillion, while the federal government has provided around \$347 billion in government aid through the Disaster Relief Fund (Smith, 2023; CBO, 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 only roughly 43 percent of economic losses are covered by private disaster insurance (Swiss RE, 2024). As climate change increases 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., 2018a). Yet, eliminating aid altogether would leave many households financially exposed (Gallagher and Hartley, 2017; Kousky et al., 2020). Beyond private disaster insurance, government aid, and self-insurance through savings, mortgage default can function as an implicit form of partial insurance. Periods of temporary nonpayment (delinquency) can buffer short-term expenditure shocks. When lenders face limited recourse, meaning that foreclosed homeowners are not liable for outstanding mortgage debt, foreclosure shields borrowers from large property losses. This implicit insurance may reduce the value of private disaster insurance contracts, generating room for government intervention and shaping the welfare effects of government aid. Government aid in terms of foreclosure moratoria, which temporarily restrict banks' ability to foreclose on nonperforming loans, reinforce this implicit insurance channel.

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: (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 aid to be welfare improving, 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 traditional insurance market imperfections. 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, increasing the ex ante incentive to insure and improving financing conditions for homeowners through reduced default risk. In addition, I provide novel empirical evidence on U.S. mortgage performance following natural disasters over the past two decades. The results align with the proposed insurance mechanisms, showing sharp increases in delinquencies not accompanied by rises in foreclosures in counties hit by natural disasters. This pattern reflects the government aid provided and the quasi-insurance role of temporary delinquency, as many loans 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 service and incur reconstruction costs, with the latter being a substantial 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 premia 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 accordance with the existing aid programs in the U.S., I model government aid as foreclosure moratoria and rebuilding grants proportional to the 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 the absence of government aid.

I calibrate the quantitative model to the U.S. economy and the incidence of natural disasters over the past 20 years, 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

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[1] Empirical 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).

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. Second, I assess whether welfare can be improved by raising the maximum grant level currently provided by the government. One main finding is that existing government aid improves welfare relative to a scenario with no 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%. Despite these distortions, government aid increases aggregate welfare by 0.25% in consumption-equivalent units (CEU), with the largest gains accruing to low-income households in high-risk regions. This result is somewhat surprising, as 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 substantially reduces the likelihood of displacement after a natural disaster and thus lowers default risk. 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. 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—namely, the crowding out of private disaster insurance, over-accumulation of housing in risky areas, and regressive cross-subsidization. Relative to the current government aid, the largest welfare gains (+0.21% CEU) occur when rebuilding grants are provided independently of private disaster insurance coverage, thereby reducing direct crowding out. In contrast, eliminating government aid and reallocating the same funds to subsidize private disaster insurance reduces aggregate welfare (–0.18% CEU), 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 rebuilding grants exclusively to low-income households yields modest aggregate gains (+0.04% CEU), as gains for low-income households are offset by substantial 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% CEU, as it discourages over-investment 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. Whether foreclosed homeowners remain liable for outstanding mortgage debt shapes welfare outcomes. The recourse regulation plays a central role in determining the winners and losers of 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 is substantially 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. To evaluate policy performance, 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 modestly increases expenditures (by 0.1%) and lowers aggregate welfare by 0.2% CEU.

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 important implicit insurance mechanism and therefore relevant to include when assessing the effects of natural disasters on homeowners. The only paper combing 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 contrast, this paper develops an aggregate 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. It further explicitly models household delinquencies and private insurance choices—two key mechanisms absent from her work—that jointly determine effective insurance in the economy. Allowing for recurrent disasters and anticipation of aid, the analysis moves beyond partial-equilibrium welfare comparisons to evaluate how the design of government aid shapes private disaster insurance coverage, housing-market outcomes, and aggregate welfare. Empirical studies document that government aid can influence private insurance and housing market behavior (Raschky et al., 2013; Kousky et al., 2018b; Ostriker and Russo, 2024).[2] Hence, accounting for these interactions is essential when quantifying welfare effects. Other studies, apart from Aron-Dine (2025), have not included mortgage default and government aid jointly in frameworks with natural disasters. Abstracting from

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[2] Related work quantifies frictions in insurance uptake and welfare effects of proposed reforms in natural disaster insurance markets (Wagner, 2022).

default, recent work examines government aid in post-disaster rebuilding (Gregory, 2017; Fu and Gregory, 2019) 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. The model demonstrates that the welfare benefits of aid exceed the efficiency losses from crowding out private insurance.

Second, the paper relates to empirical research on the immediate impact of natural disasters on mortgage performance and household finance (Paxson and Rouse (2008), Gallagher and Hartley (2017), Du et al. (2020), Issler et al. (2020), Calabrese et al. (2021), Biswas et al. (2023)). While most studies find modest or transitory effects, these average estimates mask significant heterogeneity: vulnerable households, those with low pre-disaster credit scores or incomes, are disproportionately affected (Roth Tran (2020), 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)). 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), Hannon (2023), 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 through changes in 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.

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[3] More broadly related are papers on adaptation to climate change (Bilal and Känzig, 2024; Bilal and Rossi-Hansberg, 2023) as well as government regulation and hazard-exposure of housing (Ospital, 2025). 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).

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 are 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 modelling of a delinquency period and emphasize the implicit insurance through mortgage default.

I use the *Spatial Hazard Events and Losses Database for the US* (SHELDUS) that provides estimated monthly county-level USD 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 of the Metropolitan Statistical Area (MSA) of the properties' location. The final sample is a month-MSA-state panel ranging from 2000 to 2020 including around 100,000 observations and 409 different MSAs. To construct a delinquency measure $Delinquency_{mst}$ and a foreclosure measure $Foreclosure_{mst}$, I aggregate the monthly loan-level data to the MSA-state level.

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

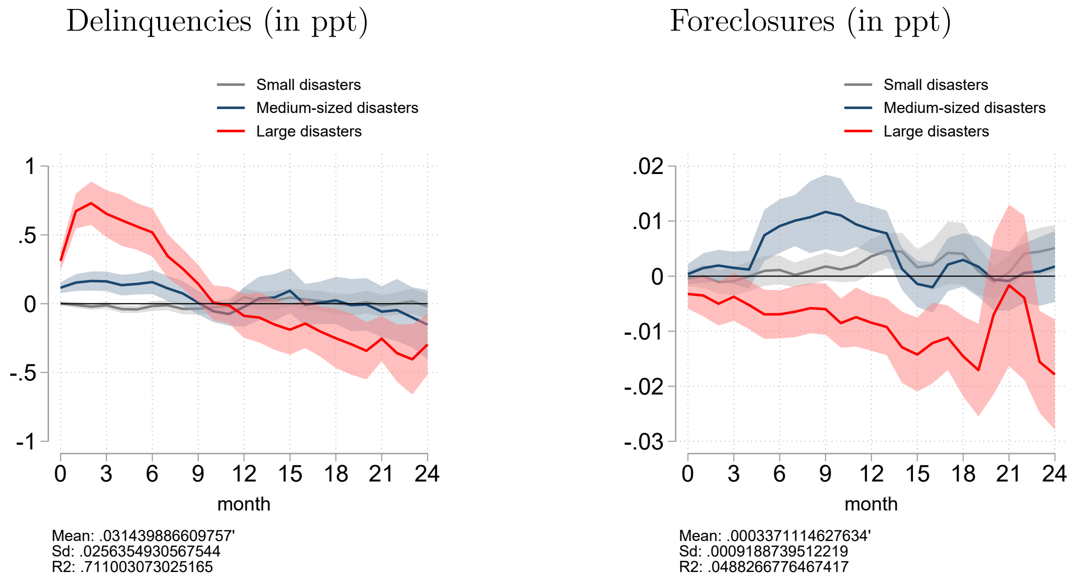
$$Foreclosure_{mst+h} = \frac{\text{value of properties foreclosed in } m \text{ and state } s \text{ at time } t+h}{\text{total value of mortgages in } m \text{ and state } s \text{ at time } t-1}$$

To examine size-dependent responses, I group natural disasters based on the realized USD damages, defining disasters as small (S)/medium-sized (M) if damages are within the 95th and 99th percentiles and large (L) if above the 99th percentile. I define the dummy variable $D^i_{ms,t}$ that equal one if in MSA m and state s at time t a disaster of size $i \in \{S, M, L\}$ occured. Then, I estimate impulse response functions by running local projections as proposed by Jordà (2005):

$$\Delta_h Y_{ms,t+h} = \beta^S_h D^S_{ms,t} + \beta^M_h D^M_{ms,t} + \beta^L_h D^L_{ms,t} + \alpha^h_{ms} + \alpha^h_t + \epsilon_{m,t+h} \tag{1}$$

with $\Delta_h Y_{mst+h} = Y_{mst+h} - Y_{mst-1}$ and $Y_{mst+h} \in \{Delinquency_{mst+h}, Foreclosure_{mst+h}\}$. Conditional on the location, the actual realization of natural disasters can be seen as an exogenous variation. Therefore, I include region fixed effects (α_m) to account for region-specific exposure to natural disasters as well as 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 increase in delinquencies during the great financial crisis.

Figure 1: Impulse Response Functions



Note: Shaded areas are 90 percent confidence bands. Standard errors are clustered on MSA-level.

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 medium-scale and large disasters upon impact. However, this effect is transient. For large disasters, there is even a negative impact on delinquencies after one year. In contrast, foreclosure rates display a delayed response, increasing within the first 15 months following a medium-sized disaster, but fewer homes face foreclosure after large disasters. Hence, for large-scale natural disasters, the rise in delinquencies is not matched with a proportional rise in foreclosures.

Given that large disasters often trigger a federal disaster declaration and free up extensive financial assistance[4], I incorporate an additional specification including a dummy variable indicating federally declared disasters (see Figure A.1).[5] Interestingly, the impulse response functions of delinquency rates remain unchanged. However, the response of foreclosure rates

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[4] In the U.S., disaster assistance from the Federal Emergency Management Agency (FEMA) supports homeowners through grants from the Individuals and Households Program (IHP) and Small Business Administration (SBA) loans, supplemented by aid from the National Flood Insurance Program (NFIP).

[5] This provides only a simplified measure of disaster aid, as not all assistance is distributed at the federal level. I nevertheless use this approach to offer suggestive, motivational evidence.

to large disasters no longer exhibits a significant negative trend, suggesting that government assistance prompted by federal disaster declarations may alleviate foreclosure rates. Furthermore, 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 decision. 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 conditional 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 risk of default. The government can intervene by imposing an income tax τ to finance government aid covering a fraction τ_δ of 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:

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

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 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: 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

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

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

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

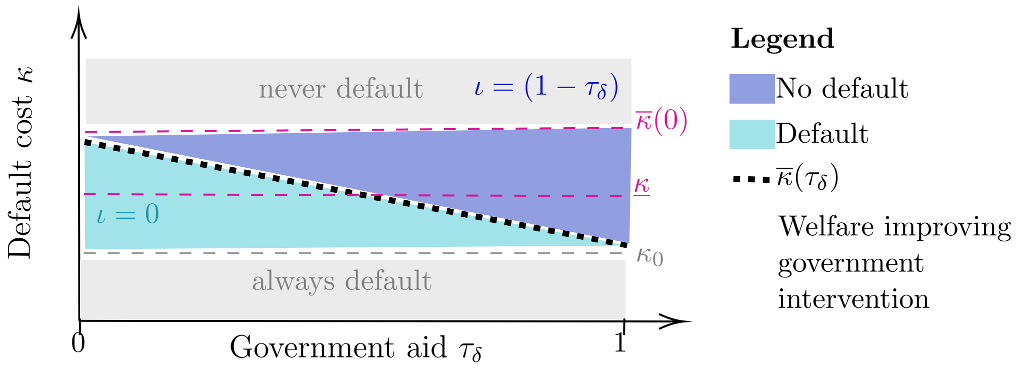
(ii) Providing government aid of size τ_δ *can improve welfare if* $\kappa \in (\max\{\underline{\kappa}, \bar{\kappa}(\tau_\delta)\}, \bar{\kappa}(0))$.

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 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.

Figure 2: Default costs and government aid



Note: The figure shows default regions as a function of default costs κ, government aid τ_δ, and insurance coverage ι. Along the x-axis, government aid shifts the default threshold: $\forall \tau_\delta$, $\exists \bar{\kappa}(\tau_\delta)$ such that agents are indifferent between default and no default. For very high (low) costs $\bar{\kappa}(0)$ (κ_0), default is unaffected by aid. The hatched area marks the parameter space of κ and τ_δ where aid can be welfare-improving.

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 looses access to the government aid to which he has to contribute independently of the default choice. For utility costs below this threshold, government aid is too small to shift default incentives for households.

The welfare effects of government aid depend depend jointly on default costs and the size of the intervention. When default costs are very low ($\kappa < \kappa_0$), default is unavoidable and aid is ineffective. When costs are very high ($\kappa > \bar{\kappa}(0)$), households insure fully without default, so aid simply crowds out private coverage. In the intermediate range $\kappa \in (\underline{\kappa}, \bar{\kappa}(0))$, aid can improve welfare—but only if large enough to shift incentives above $\bar{\kappa}(\tau_\delta)$. Given the one-to-one crowding out, the size of government aid τ_δ only matters for making the default option dominated by rebuilding but does not affect the consumption under the staying in the house post natural disaster scenario.

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 by income and wealth. 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 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.[6] 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.[7] The government balances its budget across regions, financing disaster 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 utility flows from housing services. Second, I include regional heterogeneity in disaster exposure to analyze cross-region redistribution through disaster 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 disaster 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.

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[6] In 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. Using local projections at the MSA level, I find no significant effect of natural disasters on employment after controlling for presidential disaster declarations. Only small negative effects emerge after four years, well after the timing of the expenditure shock that primarily drives household distress following disasters (see Figure A.2).

[7] As the whole U.S. is partitioned into two regions, those regions are sufficiently large to make this assumption less strict. 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) find 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 disaster 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.[8] 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

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

where β is the discount factor and π_S the survival probability. Agents period utility function is defined as follows

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

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 wage rate w per efficiency unit of supplied labor. Newborn agents draw initial liquid wealth from a income-specific distribution of initial assets $\mathcal{B}_{initial}$,

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[8] The 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 ($\mathcal{O} = rent$) or own ($\mathcal{O} = own$) a house, and choose a house size from the corresponding discrete set of rental houses $\mathcal{H}_R = \{h_R^1, ..., h_R^{N_R}\}$ or owner-occupied houses $\mathcal{H}_O = \{h_O^1, ..., h_O^{N_O}\}$. 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 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.[9] 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:

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

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 housing services for homeowners. Renters do not suffer a reduced utility flow from housing services after natural disasters.[10] 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 amount exceeds the remaining value of the house. 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.

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

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[9] I 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.

[10] Agents 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 assume that renters face no utility loss from disasters, while a constant share of rental units is destroyed by the natural disaster.

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 $m' = (1 + r_m - \mu)m$.[11] 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 $e = p_h(1 - \delta)h - (1 + r_m)m$.[12] Despite the loan-to-value limit, mortgage holders can end up with negative home equity because of a natural disaster shock.

Delinquency and foreclosure A homeowner with 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 and indicating whether a foreclosure moratorium is imposed. This moratorium limits the bank's ability to foreclose households affected by natural disasters, thereby increases the probability of staying delinquent. Details on this moratorium are provided in Section 4.6. 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 $\tilde{e}(h, m, \delta) = (1 - \epsilon_F)p(1 - \delta)h - (1 + r_m)m$. 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.[13] Figure 3 summarizes the different within period outcomes after having missed a mortgage payment.

Under recourse, the bank can seize liquid assets above the exemption limit b_{exemp} and

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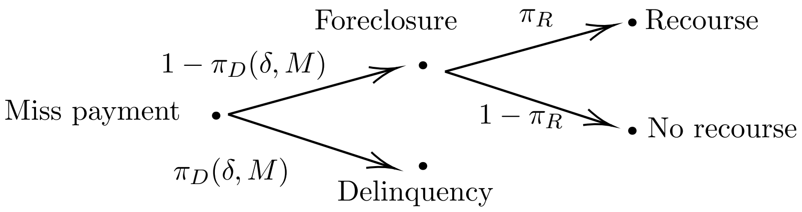
[11] The assumption, similar to that in Chatterjee and Eyigungor (2009), Herkenhoff and Ohanian (2019), and Luzzetti and Neumuller (2014), preserves tractability by ensuring that mortgage maturity does not enter the state space.

[12] In 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 $PV = \mu m \sum_{t=0}^{\infty} \left(\frac{1+r_m-\mu}{1+r_m}\right)^t = (1 + r_m)m$.

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

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.

garnish a share $\omega(b, \tilde{e}(h, m, \delta), z)$ of the households' labor income to recover the outstanding mortgage amount in expectation.[14] 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:

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

It is important to note that 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.

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

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

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 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

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

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 realization of the natural disaster shock, the homeowner decides whether to sell ($S = 1$) or to keep ($S = 0$) the house.

$$\begin{aligned} \mathbf{E}V^{own}(b,h,m,z,\delta) = \max_{S\in\{0,1\}} \Big\{ &(1-S)\big[\mathbf{E}V^{keep}(b,h,m,z,\delta) + \sigma_S\varepsilon_S(0)\big] \\ &+ S\big[\mathbf{E}V^{sell}(b_S(h,m,\delta),h,m,z,\delta) + \sigma_S\varepsilon_S(1)\big]\Big\}, \end{aligned} \tag{8}$$

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.[15] They smooth choice probabilities for computational tractability and capture unobserved relocation motives such as changes in family circumstances or job opportunities.

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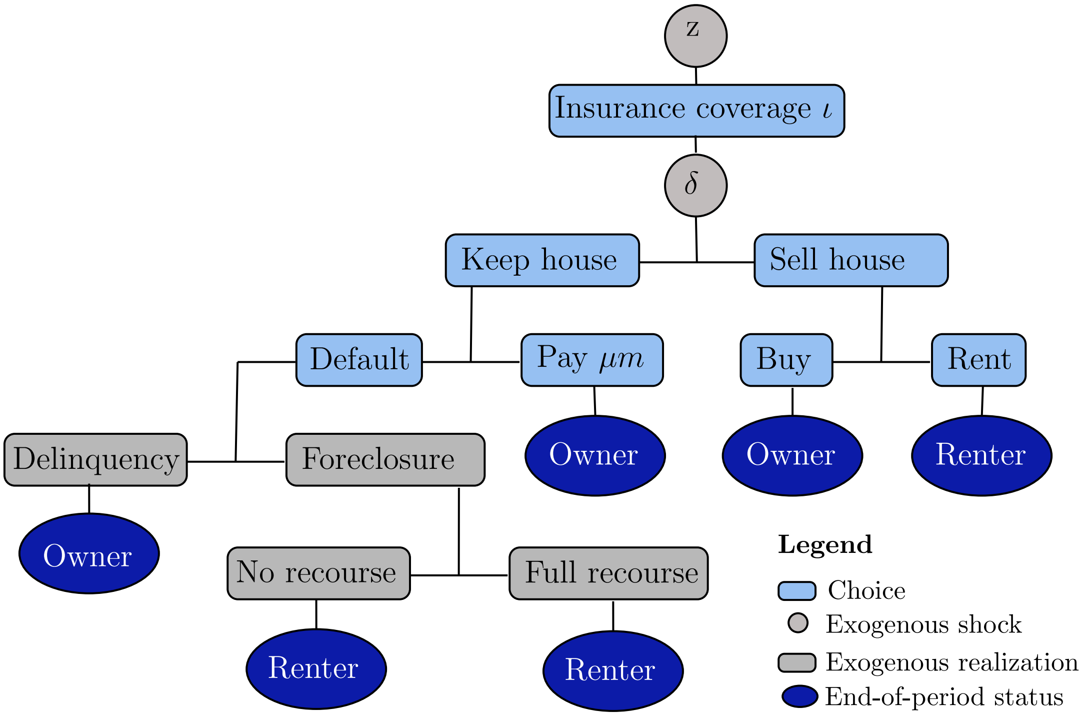
[15] Liquid assets after selling a house are defined as $b_S(h,m,\delta) = b + \frac{1}{1+r}\left[p_h(1-\epsilon)(1-\delta)h - (1+r_m)m\right]$.

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 realize. μm represent the per period mortgage payments conditional on having a mortgage of size m. For simplicity, I abstract from probability of being actually 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 ($D = 1$).

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

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.[16] Since $\mathbf{E}V^{keep}(b(\iota,\delta),h,m,z,\delta)$ 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.[17] 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 ($R = 1$).[18] If the agent is unsuccessful in finding a suitable buyer, she faces the same decision problem as in equation (9).

$$\begin{aligned}\mathbf{E}V^{sell}(b,h,m,z,\delta) =&(1-\pi_H)\mathbf{E}V^{keep}(b,h,m,z,\delta)\\ &+\pi_H \max_{R\in\{0,1\}}\Big\{R\big[W^{rent}_{perf}(b_S(h,m,\delta),z)+\sigma_R\varepsilon_R(1)\big]\\ &(1-R)\big[W^{buy}(b_S(h,m,\delta),z)+\sigma_R\varepsilon_R(0)\big]\Big\},\end{aligned} \tag{10}$$

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 $W^{buy}, W^{rent}_{perf}, W^{rent}_{for}, W^{own}_{perf}$, and W^{own}_{del}, 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

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[16] Only 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 shock 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.

[17] If 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.

[18] The option to buy the same house size with a different mortgage amount implicitly allows for re-financing of mortgages in the model.

with (h,m,δ)π_H. The expected value function can be summarized as

$$V^{rent}_{perf}(b,z) = \max_{R\in\{0,1\}} \Big\{ R\big[W^{rent}_{perf}(b,z) + \sigma_R\varepsilon_R(1)\big]$$
$$+ (1-R)\big[\pi_H W^{buy}(b,z) + (1-\pi_H)W^{rent}_{perf}(b,z) + \sigma_R\varepsilon_R(0)\big]\Big\},$$

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

$$\mathbf{E}\left[V^{rent}_{for}(b,\omega,z)\right] = \pi_P W^{rent}_{perf}(b,z) + (1-\pi_P)W^{rent}_{for}(b,\omega,z)$$

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 $W^{own}_{perf}, W^{own}_{del}, W^{rent}_{for}, W^{buy}_{perf}, W^{rent}_{perf}$, 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 through their impact on 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 than can be seized and the wages that can be garnished under recourse:

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

where the share of garnished income is defined as follows

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

with a maximum wage garnishment $\bar{\omega}$.[19] The intermediary prices mortgages by discounting the expected stream of repayments at the rate r_m, resulting in the following pricing function:

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

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.[20]

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

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

[20] The present value of a delinquent mortgage is defined as follows

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

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

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

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

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

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:

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

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

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

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 out to households at rental price p_r. The rental agency faces per-period operating costs q_R per unit rented out 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:

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

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

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

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

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

4.5 Private insurance firm

A perfectly competitive private insurance company offers one-period contracts to households at 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 $\pi_{L,k}$:

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

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

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

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:

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

with

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

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 ($M = 1$):

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

where π_M reflects the length of the foreclosure moratorium. An additional policy tools 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 2000-2020, 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 Individual discount future utility flows by $\beta = 0.98$. I assume constant relative risk aversion with an intertemporal elasticity of 1/2 ($\alpha = 2$). Following Mitman (2016), I set the Cobb-Douglas parameter $\gamma = 0.859$ 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 in 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 market value of homes. 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. $\underline{b} = 0$. The annual risk-free rate r is set to match at 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 based on the Expected Annual Loss Rate (EALR) as defined in the National Risk Index Database.[21] 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 that was destroyed by natural disasters. I sort regions by their EALR and define the cut off loss rate such that the low-risk regions constitute

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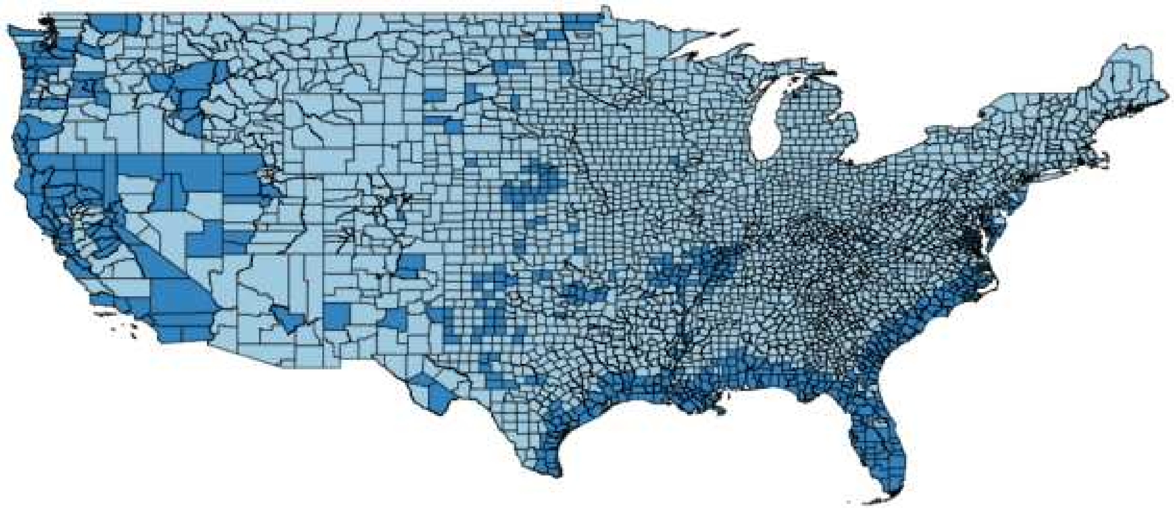
[21] The National Risk Index, developed by the Federal Emergency Management Agency (FEMA), combines risk for 18 natural hazards to an index on county-level. The key component *Expected Annual Loss* for each county c is constructed as $EAL_c = \sum_{h=1}^{18} EAL_{c,h}$ with $EAL_{c,h} = Exposure_{c,h} \cdot AnnualizedFrequency_{c,h} \cdot HistoricLossRatio_{c,h}$ where h represents a hazard-type. The index is based on various data sources. The historical loss rate based on SHELDUS and building exposure values are based on values recorded in Hazus 6.0. The annualized frequency 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).

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 damages as well as the actual cash value of affected properties. After trimming the bottom and top one percent of observations, I compute the average share of property damages 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 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 for a single disaster under the individual housing assistance by FEMA is USD43,600. Normalizing this by the median household income gives an upper bound on ex-post financial aid of $\bar{\tau}_\delta = 1.28$. 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 of 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 (CBO, 2017). These numbers are in line with expense ratios 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 $(h_{min}, \psi_h, FC, \bar{L}, q_R, \sigma_D, \sigma_S)$ 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 FC and the variance of the taste shock on default σ_D. I use loan-level data 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 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

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) Untarged 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%
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.

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, where 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 as well as 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 feature a rebuilding decision, this outcome corresponds to the share of homeowners who do not relocate to a differently sized house after a disaster. The median income ratio of owners to renters is 1.3 in the model, 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 (based on Swiss RE (2024)). However, estimates of insurance coverage should be interpreted with caution due to data limitations in the U.S.

Regional differences As documented in Table F.1, low-risk and high-risk regions exhibit significant 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 despite people living in smaller homes. Homeownership rates are lower in high-risk regions, and homeowners are less likely to carry mortgages.[22]

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 in income.

Given the limited availability of data on insurance coverage against natural disasters by

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[22] Although 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.

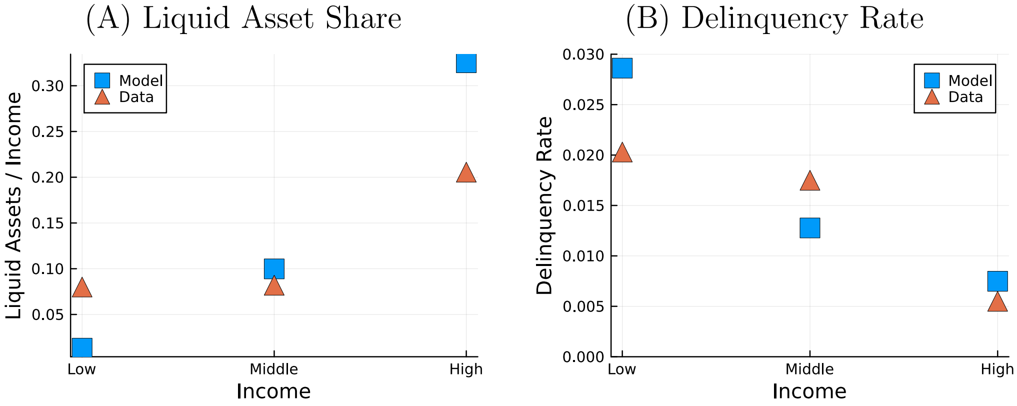
Table 2: Model Fit - Regional Differences

	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 number of rooms in the data. Owner costs without mortgage payments in the model are defined as per-period maintenance costs and rebuilding expenditures.

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.

Figure 7: Liquid Asset and Delinquency over the Income Distribution


(A) Liquid Asset Share

(B) Delinquency Rate

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 being behind on their mortgage against the delinquency rate in the model. Data moments are based on the Survey of Consumer Finances 2019 and American Housing Survey 2019.

6 Results

The results are presented in five parts. First, I analyze 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 changes under a strict recourse environment to the baseline case with a very lenient regime. Lastly, I simulate a climate change scenario and assess the welfare effects of an altered disaster risk. To compare welfare across 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).

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. In particular, I assess whether households in the low-risk region and low-income households benefit from the elimination of government aid. To isolate the effects of both types of government aid, Table 3 reports all statistics of how the insurance gap 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 generates distortions in both housing and insurance markets. In its absence, the insurance protection gap–the share of disaster losses not covered by private insurance–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 reflects 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.

Table 3: Steady Sate 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
By disaster exposure				
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
By disaster exposure				
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
By disaster exposure				
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 in a lenient recourse regime. Columns (1)-(3) report percent changes from the baseline steady state for the following policy counterfactuals: (1) Removing the rebuilding grant while maintaining foreclosure moratorium, (2) removing foreclosure moratorium while remaining the rebuilding grant, and (3) removing both, the rebuilding grant and the 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, leading to higher user costs of housing especially in the high-risk region. 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, tend to purchase smaller properties without government aid. Even though removing government aid reduces market distortions–such as lowering the housing stock in risky areas and increasing insurance uptake–households still not choose full private disaster insurance.

Government aid effectively shields homeowners against 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 G.1). This effect occurs across all income groups but is most pronounced among low-income households, whose likelihood of staying declines by 62 percent in low-risk regions and 71 percent in high-risk regions.

When removing rebuilding grants and the foreclosure moratorium separately, it becomes evident that the aggregate effects are primarily driven by the rebuilding grants. This result is not surprising, as the moratorium represents a relatively small intervention that merely reduces foreclosure probabilities compared to the rebuilding grants provided. 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, primarily driven by households in the low-risk region (see Table 3, column (2)) who hold higher liquid asset-to-income ratios. This pattern reflects increased reliance on self-insurance through liquid assets: as delinquency-based insurance becomes riskier, savings provide a more attractive form of protection. Since the moratorium releases only small amounts of liquidity through missed mortgage payments, households favor liquid asset holdings over private disaster insurance, owing to the intermediation wedge. In the low-risk region, per capita owner-occupied housing declines slightly, but the likelihood of ownership rises. Because government aid is capped, the larger number of (albeit smaller) homes implies that more aid is allocated to homeowners in low-risk areas. Despite the relatively stable aggregate housing stock, the broader distribution of ownership increases the total aid directed to this region. By contrast, in high-risk regions, the removal of the moratorium reduces homeownership, and the aggregate owner-occupied housing stock falls by nearly 2 percent. Consequently, the low-risk region contributes less to government aid targeted toward high-risk areas, while its share of total aid rises (see Table 4). Removing the foreclosure moratorium does not lead to substantial displacement of homeowners following natural disasters. In the high-risk region, the probability of remaining in the affected home declines by only 1 percent (see Table G.1).

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.[23] The latter expand their insurance coverage, reducing exposure to default risk, whereas low-income households rely on

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[23] Tables G.3, G.4, and G.5 document percentage-point changes in delinquencies, “involuntary” foreclosures, and “consensual” foreclosures, respectively.

Table 4: Allocation of government aid across regions

		Δ%				
	Baseline Aid	$M = 0$	CF 1	CF 2	CF 3	CF 4
Low-risk region	0.0002	1.42	140.74	4.45	-50.07	1.40
High-risk region	0.0014	-2.42	-67.46	-1.81	-56.77	-0.56

Note: This table plots the change in allocation of government aid across regions under the baseline rebuilding grants but no moratorium ($M = 0$) and 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.

delinquency as a form of informal 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 repossess affected properties. For large disasters, overall foreclosures decline, driven by fewer voluntary foreclosures, reflecting lower loan-to-value ratios and smaller home sizes that reduce rebuilding costs. When both policies are removed, the effect of eliminating the rebuilding grant outweighs that of removing the moratorium when their impacts diverge. In summary, without government aid, baseline delinquency declines due to lower loan-to-value ratios, but foreclosure rates rise in the absence of support for affected households.

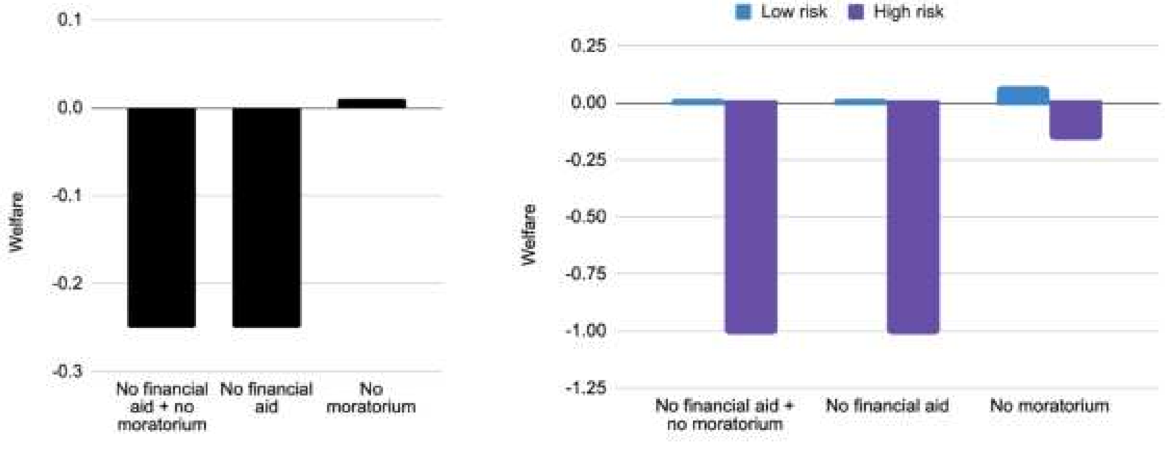
6.1.1 Welfare Analysis

Despite its distortional effects on insurance and housing choices, abolishing government aid would be undesirable. Removing existing government aid altogether does not yield welfare gains; instead, 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 modest welfare effects, its impact becomes negligible once the rebuilding grant is removed, as the moratorium no longer provides meaningful protection in the absence of direct transfers (see Figure 9 Panel (A)). Aggregate welfare losses from removing government aid are driven by substantial welfare losses in the high-risk region (-1 percent), whereas the low-risk region is almost indifferent between an economy with and without government aid (<0.01 percent).

However, the relatively small aggregate effect in the low-risk region masks considerable heterogeneity along the income distribution (see Figure 8). Low- and middle-income households in this region actually 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 widespread 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 under the new policy environment.

Welfare effects of removing the foreclosure moratorium are modest, amounting to +0.01 percent in consumption-equivalent terms. Households in high-risk regions experience welfare losses as they lose an important insurance mechanism, while those in low-risk regions gain through the reallocation of aid and higher net transfers—benefiting low- and middle-income households the most. In contrast, high-income households in low-risk regions face welfare losses. These households have the lowest insurance coverage and typically rely on liquid assets to recover from disasters; without the moratorium, they lose access to delinquency as a key consumption-smoothing channel. This effect is particularly pronounced after large disasters, where the rebuilding grant is insufficient to cover losses: in such cases, the probability that high-income homeowners enter delinquency declines by 19 percent.

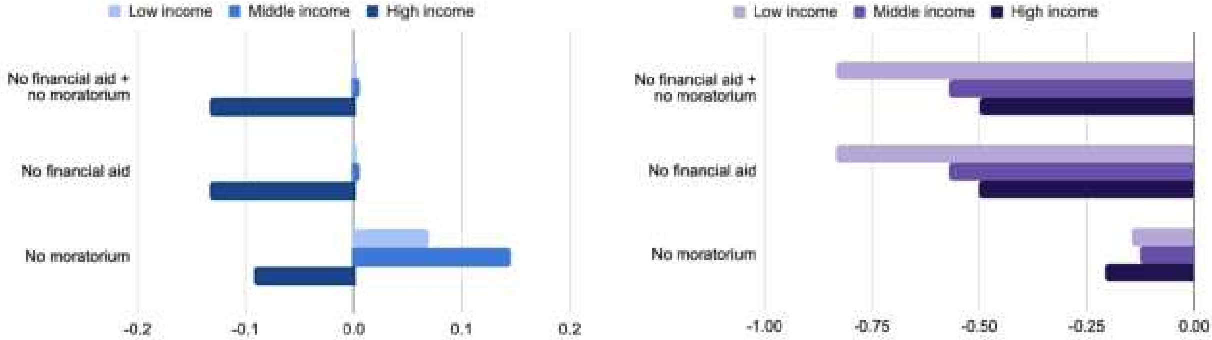
Figure 8: Welfare changes from removing existing government aid


(A) Aggregate (B) By region

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 disaster aid generates welfare gains mainly by preventing costly mortgage

Figure 9: Welfare changes from removing existing government aid across the income distribution



(A) Low-risk region

(B) High-risk region

Note: Reported welfare changes are consumption equivalence variation from baseline steady state (in %) by region 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.

default after disasters. As shown above, aid allows affected homeowners to remain in their homes instead of entering 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 10). 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 reflect higher default risk.

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.[24] To

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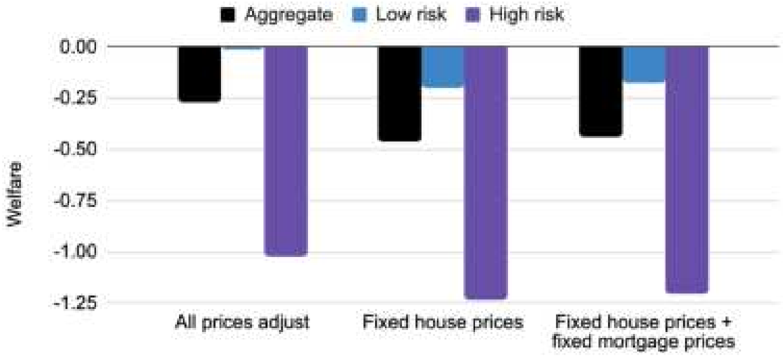
[24] This efficiency advantage of the government is consistent with evidence from Spain, where mandatory state disaster insurance operates with lower administrative and commission costs than private insurance (Von Ungern-Sternberg, 2003).

Figure 10: 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.

assess the importance of this assumption, I impose the same insurance wedge on government aid. Welfare losses from removing aid decline, but remain substantial, indicating that this channel explains only part of the gains (see Figure G.3).

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. Two interesting facts arise: first, welfare losses from removing government aid still remain substantial (see Figure G.2). Second, without regional transfers distortions in the insurance and housing markets decline (see Table G.6).

As a last decomposition, I assess the role of default in the welfare effects of removing government aid and find that eliminating default amplifies welfare losses and changes their distribution across households and regions (see Appendix G.1 for details). Hence, the insurance channel of default dominates the commitment problem introduced through the default option.

6.2 Alternative Policy Designs

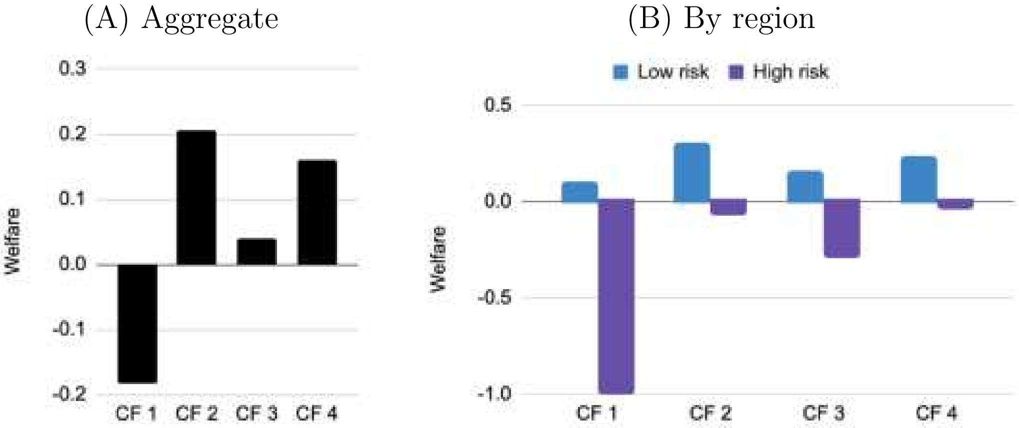
In the previous section, I showed that the current government aid policy generates welfare gains but also crowds out private insurance and leads to an overaccumulation of housing in the risky region. This section asks whether alternative, revenue-neutral policy designs can improve welfare by directly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

First, I consider a policy in which government funds are used to subsidize insurance premia ex-ante rather than providing rebuilding grants ex-post, thereby lowering 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 aid policy 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, while Figure 11 summarizes the associated welfare effects.

All policy designs reduce the targeted distortions (see Table G.8). As a result, the steady-state distribution 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 4). 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, 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 11, Panel A). Losses are particularly severe in the high-risk region, where all income groups experience welfare declines exceeding 0.70 percent, with low-income households affected most (Figure 12, 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 modest gains of 0.23 and 0.14 percent, respectively (Figure 12, Panel B). Although the policy is revenue neutral, it substantially alters the distribution of government transfers, since the subsidy is not conditional on being affected by a disaster. Whereas the high-risk region previously received the

Figure 11: Welfare changes under alternative policy designs


(A) Aggregate

(B) By region

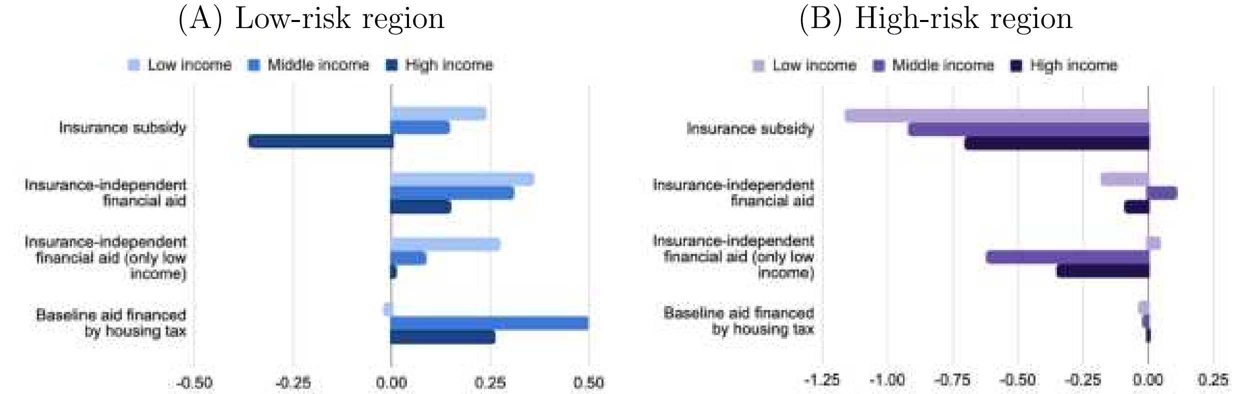
Note: Reported welfare changes are consumption equivalence variation from baseline steady state (in %) for the following revenue neutral counterfactuals: (CF 1) providing only an insurance subsidy, (CF 2) making rebuilding grants independent of insurance coverage, and (CF 3) providing insurance-independent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

majority of aid, under the insurance subsidy its allocation falls by 65 percent (see Table 4). 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 costly, the same budget as in the baseline allows only a 0.06 percent subsidy rate on insurance premiums. As a result, the insurance gap 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 11, Panel A). Welfare effects differ across regions: the low-risk region benefits (+0.3 percent) whereas the high-risk region losses (-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 local welfare losses. This reduction in the grant cap disproportionately decreases expected

Figure 12: Welfare changes under alternative policy designs across the income distribution


(A) Low-risk region

(B) High-risk region

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 last counterfactual (CF 4), government aid is financed through a tax on homeowners' housing capital.

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 constrained by insurance coverage levels.

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 - government aid within the regions is shifted from low and high to middle income households.

Under this policy design, eligibility for financial government aid is no longer tied to insurance coverage, thereby mitigating the direct crowding-out effect. However, the mere expectation of rebuilding grants continues to dampen 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, yields two main insights (see Table 5). 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 the effectiveness of aid in preventing displacement and default. Second, the insurance gap declines substantially under insurance-independent grants, though less than in the no-aid scenario. 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 mirrors 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.

Table 5: Insurance-Independent Rebuilding Grants compared to No-Aid

	Lump-sum grant		**No aid**	
	Staying after disaster	**Insurance gap**	**Staying after disaster**	**Insurance gap**
Total	0.3	-30.9	-33.4	-48.9
Low risk				
Low income	-0.5	-40.0	-62.1	-21.7
Middle income	1.8	-27.8	-29.0	-62.3
High income	-1.7	-33.5	-11.1	-53.3
High risk				
Low income	-1.8	-26.4	-70.6	-12.1
Middle income	1.0	-33.4	-32.5	-65.7
High income	0.4	-16.5	-34.3	-58.2

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.

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 11). Although designed to be revenue neutral, total government aid declines relative to the steady state: even with full insurance for low-income homeowners, government aid falls by about 55 percent. Welfare gains are concentrated among low-income households in the low-risk region (+0.27 percent) and are more modest in the high-risk region (+0.04 percent), as these households directly benefit from the expansion of public insurance against disaster shocks (see Figure 12).

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 more pronounced house price declines, which improve affordability and offset the removal of public 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 removal of government aid dominate for middle- and high-income households in high-risk areas.

Insurance patterns also adjust. Low-income households remain uninsured as the government provides full insurance, while middle- and high-income households expand their coverage, leading to a 35 percent decline in the aggregate insurance gap. Finally, the likelihood of remaining in one's home after a natural disaster rises substantially 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 this burden is shared between homeowners and renters in the baseline, under the housing tax it falls exclusively on homeowners.

In principle, one might expect low-income households to benefit from this policy. In practice, however, higher user costs of housing 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 reflect 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 the redistribution of aid: 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 modest 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—driven by both 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.

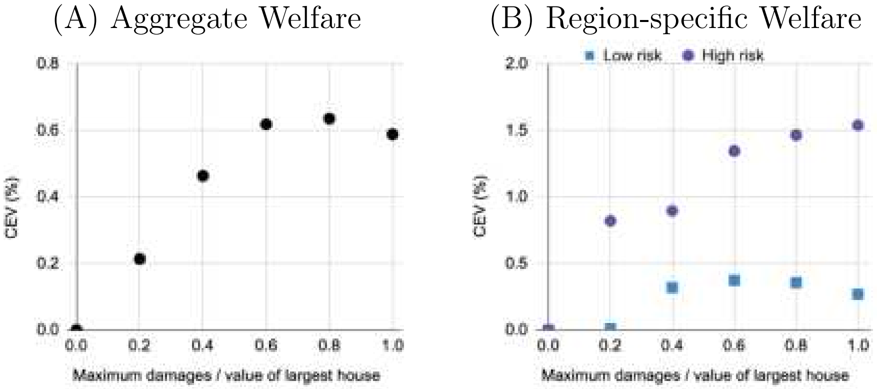
6.3 Different Levels of Maximum Rebuilding Grants

Can welfare be improved by increasing the amount of maximum rebuilding grants provided? 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 13 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. Welfare effects are measured in consumption-equivalent variation.

Highest welfare gains are not reached under full government insurance. Welfare rises as the maximum grant increases from zero percent of damages, peaks around 80 percent, and then declines once full insurance is provided. The pattern, 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 reflects the cross-subsidization from low- to high-risk regions through financial 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

Figure 13: Welfare under different levels of maximum rebuilding grants


(A) Aggregate Welfare (B) Region-specific Welfare

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 in consumption equivalence variation from a steady state without any rebuilding grants. The grant size is expressed as a share of the value of maximum damages to the largest house in the economy.

markedly between them. In both regions, the insurance gap widens as maximum grants increase, indicating a decline in private disaster insurance coverage (Panel (A), Figure 14). The owner-occupied housing stock also responds to the grant size, though the effects are more pronounced in high-risk areas (Panel (B), Figure 14). 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 response in low-risk region.

6.4 Role of Recourse Regimes

In this exercise, 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 a very strict recourse regime in which foreclosed households are fully liable for their outstanding mortgage balance ($\pi_R = 1$).[25] 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, leaving little room for welfare gains from government intervention. In the full quantitative model, however, the presence of an insurance wedge, uninsurable income

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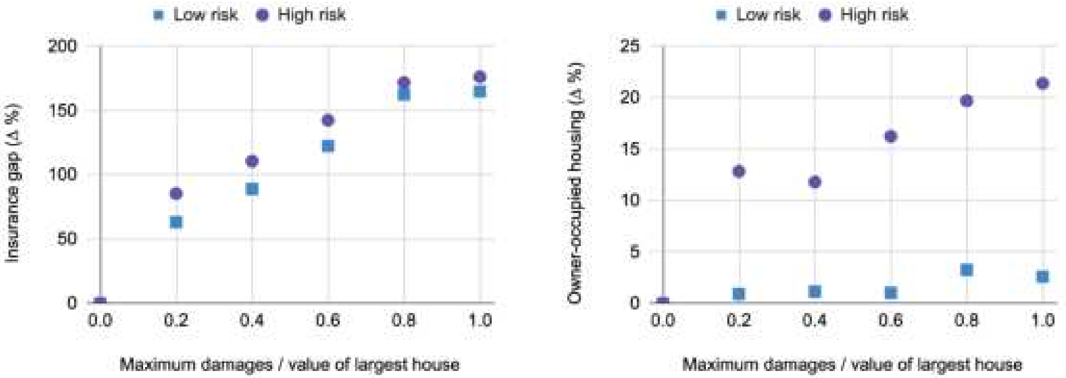
[25] Because of limits on wage garnishment and asset exemptions, some households may still fail to fully repay their debt after foreclosure.

Figure 14: Insurance and housing under different levels of maximum rebuilding grants


(A) Insurance Gap

(B) Owner-occupied Housing Stock

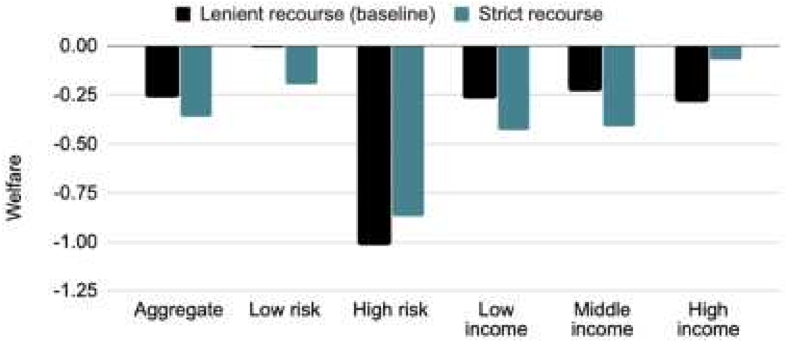
Note: The figure reports region-specific changes in the insurance gap and the owner-occupied housing stock across various steady states that only differ in the level of the maximum grants provided to households. Changes are expressed in percent deviation from a steady state without any the rebuilding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

risk, borrowing constraints, and maximum wage garnishments reintroduce a role for welfare-improving government policies even with a strict recourse regime.

As shown in Figure 15, 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. Moreover, these 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 substantially reduced, which amplifies the welfare impact of the policy change. From the government's budget constraint, it is clear that eliminating disaster aid has a direct positive effect on unconditional transfer payments to all households. However, because the housing market contracts, total government transfers ultimately decline, as lower housing demand reduces revenues from land permit sales.

Appendix G.3 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 declines 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

Figure 15: Welfare changes from removing government aid by recourse regime



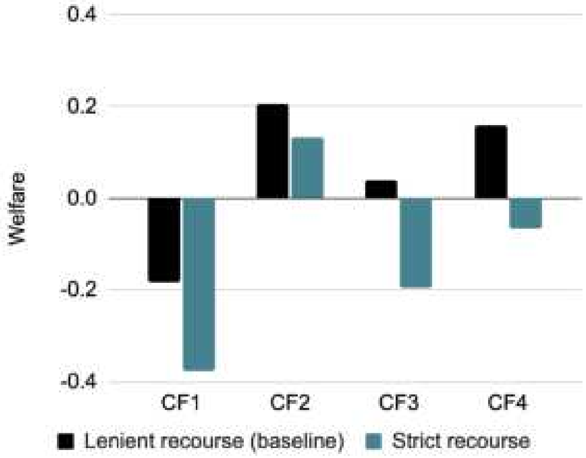
Note: Reported welfare changes are consumption equivalence variation from the baseline steady state (in %). In both scenarios, rebuilding grants and the foreclosure moratorium are removed. The economies only differ in their recourse probability: a lenient regime ($\pi_R = 0.1$) and a strict regime ($\pi_R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

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 compared to 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 severs as 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 16). 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 16: 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 under a changed disaster risk. Comprehensive projections of aggregate natural disaster risk for the United States remain highly uncertain, as existing studies focus on individual hazards and provide wide confidence ranges across regions and event types. The Intergovernmental Panel On Climate Change (IPCC) 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. Overall, while the precise aggregate change in disaster risk cannot be quantified with confidence, the evidence consistently points toward a rise in the frequency of extreme events. Since large shares of damages in the U.S. are caused by tropical storms, I consult studies on the projected change in 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, so that the overall share of affected households remains 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 under such a shift in disaster risk.

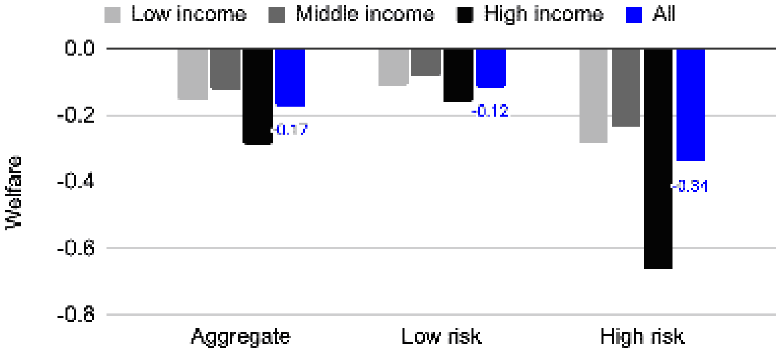
As large events become more frequent, households anticipate greater potential losses. This is likely to induce higher demand for insurance, given that such extreme losses are only partially covered by government aid. At the same time, homeowners may adjust their portfolios, opting for smaller houses 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). The underlying mechanism is straightforward: 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 modest 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, under more frequent severe natural disasters, maintaining the current level of disaster aid results in only modest welfare losses, due to long-run adjustments in the housing market.

Figure 17: 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 the baseline government aid but the risk of natural disasters changes: the total number of events stays unchanged while the probability of large damages rises by 10 percent.

7 Conclusion

To conclude, I have developed a structural general equilibrium model to investigate the interplay between government aid and mortgage default. Within an incomplete market framework, my model illustrates the dual impact of natural disaster shocks—destroying housing capital and diminishing housing service utility—and the role of delinquencies, where mortgage payments are temporarily paused without leading to foreclosures.

The analysis shows that government aid substantially affects private insurance and housing allocation: it reduces private insurance coverage by nearly half while increasing the housing stock in disaster-prone areas. Removing existing aid leads to aggregate welfare losses (0.25% CEV), concentrated in high-risk regions across the whole income spectrum. Among alternative policy designs, welfare is maximized when aid is provided independently of households' insurance status, mitigating the crowding out of private coverage. The welfare effects of government aid depend critically on both the institutional framework and the baseline generosity of aid. First, recourse regulation strongly shapes the distribution of winners and losers across households. Second, while increasing the maximum grant can improve welfare when starting from a no-aid scenario, these gains plateau and eventually reverse. In the context of climate change, keeping the current government aid design under a scenario of more extreme events (but fewer small disasters) results in only modest welfare losses (0.2 percent) and a slight increase in aggregate aid, as households adjust their housing and insurance choices.

I also provide empirical evidence on household financial behavior following natural disasters in the U.S. over the past twenty years. The data show a clear pattern: delinquency rates rise after disasters, while foreclosure rates fall. An important extension is to analyze transition dynamics, since disaster policy reforms may improve long-term welfare but could adversely affect current homeowners. This consideration is especially relevant in today's economy, 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—could provide valuable policy insights.

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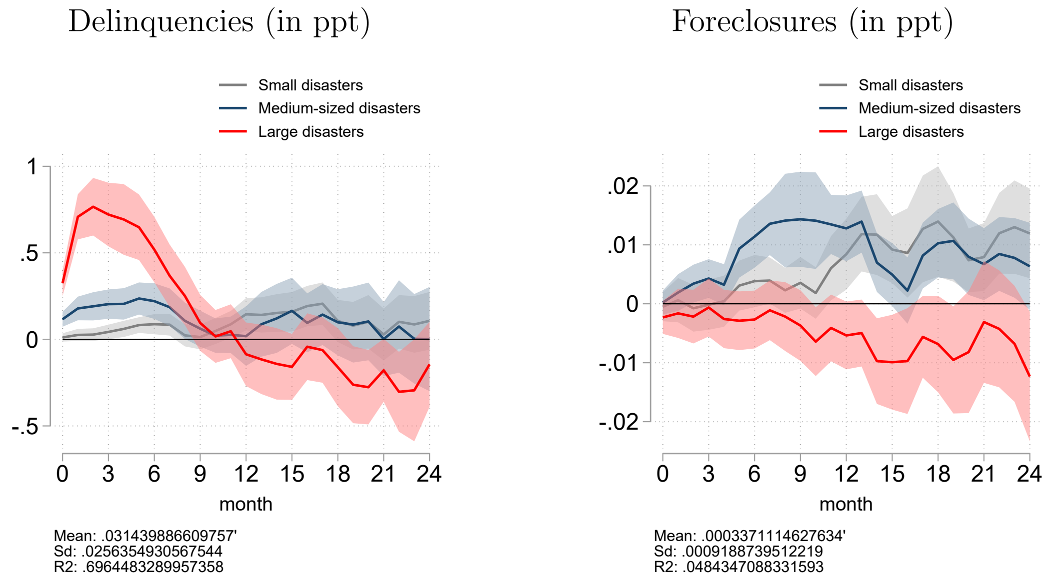
A Empirical Appendix

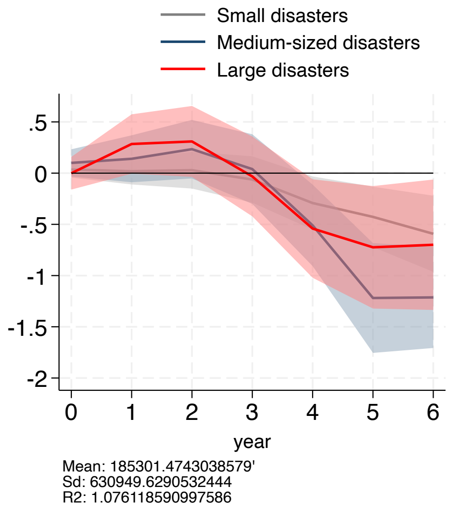
Figure A.1: Impulse response functions (including a dummy for disaster declarations)


Delinquencies (in ppt)

Foreclosures (in ppt)

Note: Shaded areas are 90 percent confidence bands. Standard errors are clustered on MSA-level.

Figure A.2: Impulse response functions of employment (including a dummy for disaster declarations)



Note: Shaded areas are 90 percent confidence bands. Standard errors are clustered on MSA-level. Yearly MSA-level employment data is based on the data from the U.S. Bureau of Economic Analysis.

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:

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

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 actuarily 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 actuarily 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:

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

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

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

(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 actuarily fair ($p_\iota = \pi_\delta$) to focus on the default option soley. Suppose agents have access to a default option, but never choose to default conditional on being fully insured. Hence, the utility from staying in the home, rebuilding and repaying the mortgage must be larger than the utility from 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 participate ex-ante that they will default conditional on being hit by a natural disaster. Then, their maximization problem reduces to

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

Consequently, there is no benefit of 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.[26] A households anticipates default and buys no insurance, if

$$\begin{aligned}
&(1-\pi_\delta)\log((1-\tau)y-(1-q)m-p_h\xi h)\\
&\quad+\pi_\delta[\log((1-\tau)y-p_hh+qm-p_rh_r)-\log(\kappa)]\\
&> \log((1-\tau)y-(1-q)m-\pi_\delta(1-\tau_\delta)p_h\delta h-p_h\xi h)\\
\overset{\tau=\frac{\pi_\delta\tau_\delta\delta ph}{y}}{\iff}\quad \log(\kappa) &< \frac{1-\pi_\delta}{\pi_\delta}\big[\log(y-(1-q)m-\tau_\delta\pi_\delta p_h\delta h-p_h\xi h)\\
&\quad-\log(y-(1-q)m-\pi_\delta p_h\delta h-p_h\xi h)\big]\\
&\quad+\log(y-p_hh+qm-p_rh_r-\tau_\delta\pi_\delta p_h\delta h)\\
&\quad-\log(y-(1-q)m-\pi_\delta p_h\delta h-p_h\xi h)\equiv\log(\bar{\kappa}(\tau_\delta))
\end{aligned}$$

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 looses access to the government aid to which he has to contribute independently of the default choice. For utility costs below this threshold, government aid is too small to shift default incentives for households.

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 larger than the expected utility under the laissez-faire case.

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

Conditional on a degree of public insurance τ_δ and $\kappa < \bar{\kappa}(\tau_\delta)$, government aid is welfare

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[26] Note that in this simple model default is only attractive if the insurance costs are large, 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 ($m = \lambda ph$).

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 $\log(\bar{\kappa}(0)) - \log(\underline{\kappa}) > 0$.

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

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

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

■

C Quantitative Model

C.1 Full definition of household decision problem

Consider the decision problem of agents after the realization of the labor productivity shock, the insurance coverage decision, and the realization of the natural disaster. I abstract from the insurance coverage choice as a state variable as this choice only affect liquid assets. Hence, liquid assets $b(\iota, \delta)$ can be interpreted as liquid assets after having paid insurance premia 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

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

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:

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

A household who 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':

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

with

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

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

$$W^{rent}_{new}(b,z,k) = \max_{h_R \in \mathcal{H}_R} \{W^{rent}_{perf}(b,h_{R_1},z,k), W^{rent}_{perf}(b,h_{R_2},z,k), ...\}$$

with

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

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

$$W^{rent}_{for}(b,\omega,z) = \max_{h_R \in \mathcal{H}_R} \{W^{rent,h^1_R}_{for}(b,\omega,z), ..., W^{rent,h^{N_R}_R}_{for}(b,\omega,z)\}$$

with

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

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 $v = \{V^{own}(\mathbf{x}^h), V^{rent}_{perf}(\mathbf{x}^r), V^{rent}_{for}(\mathbf{x}^r)\}$, 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

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

  where the left-hand-side represents total supply of rental units and the right-hand side total demand of previous renters, households who are successful in selling 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 the rental agency as well as investment of owners and the rental agency to offset housing deprecation. These terms are defined as follows

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

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

$$\begin{aligned}
H^{buy}(k) =& \pi_S\pi_H\Bigg(\pi_H\int S^*(\mathbf{x}_i^h)(1 - R^*(\mathbf{x}_i^h))h_i^*(\mathbf{x}_i^h)di \\
&+ \int(1 - R^*(\mathbf{x}_i^r))h_i^*(\mathbf{x}_i^r)di\Bigg) \\
&+ (1 - \pi_S)\pi_H\int(1 - R^*(\mathbf{x}_i^r))h_i^*(\mathbf{x}_i^r)di
\end{aligned} \tag{30}$$

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

$$\begin{aligned} Y_C(k) = &\int c_i^*(\mathbf{x}_i^h)di + \int c_i^*(\mathbf{x}_i^r)di + q_R(k)H_R(k) + q_\iota p_\iota \int \iota_i^*(\mathbf{x}_i^h)di \\ &+ \epsilon\pi_H^2 \int S^*(\mathbf{x}_i^h)(1 - R^*(\mathbf{x}_i^h))p_h^B(\Omega)h_i^*(\mathbf{x}_i^h)di \\ &+ \epsilon\pi_H \int (1 - R^*(\mathbf{x}^r))p_h^B(\Omega)h_i^*(\mathbf{x}_i^r)di \\ &+ \epsilon_F \int [S^*(\mathbf{x}_i^h)(1 - \pi_H) + (1 - S^*(\mathbf{x}_i^h))] \\ &\cdot D^*(\mathbf{x}_i^h)(1 - \pi_D(\mathbf{x}_i^h, \mathbf{M}))h_i^*(\mathbf{x}_i^h)di \end{aligned} \tag{31}$$

  where the right-hand side represent 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

$$W = \int V(x)d\Omega \tag{32}$$

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 $c^*, h^* \left(\tilde{c}, \tilde{h}\right)$ 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:

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

Then, Δ_{CEV} is given by

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

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

D Solving the Model

I following 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 to 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 am able to pre-compute the continuation value on a grid of post-decision variables.

I first solve the consumption-savings problem using the NEGM for the owner problem, the renter problem and the foreclosed owner-problem. 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 is 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:

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

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 begin of period liquid assets plus the additive costs/benefits of choices made before the consumption-savings decision as well as realizations of stochastic variables.

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

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 for 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

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

The Euler Equation is

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

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

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

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

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

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

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

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

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

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.

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

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

E Calibration

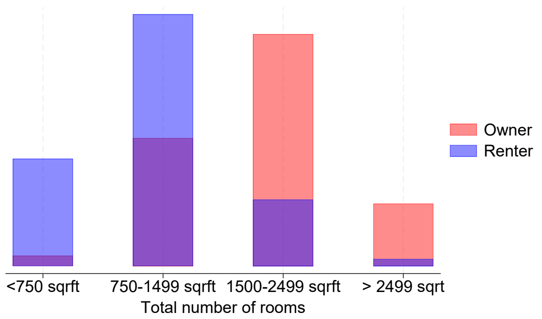


Figure E.1: Segmentation of housing market (AHS, 2021)

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.

	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
By Income				
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.1: Liquid Wealth by Income

	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_H	Variance 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^{H_R}	Number of grid points	3	AHS (2021)
N^{H_O}	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_ι	Administrative fees	0.33	Expense ratios of policy claims

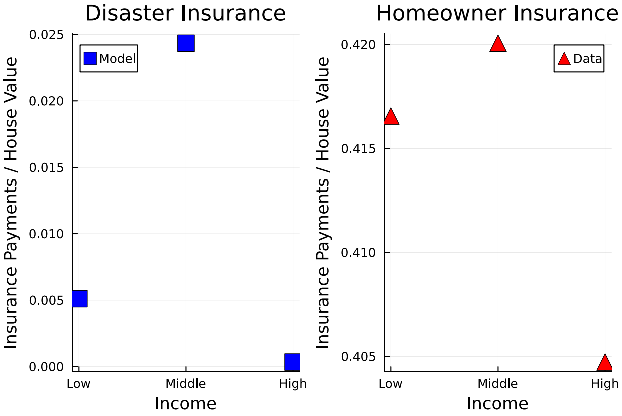
Table E.2: External Calibration of Parameters

F Model Validation

	Low-risk regions			High-risk regions			
	N	Mean	SE	N	Mean	SE	Difference
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 is aggregated to low-risk and high-risk regions based on the classification strategy explained in the main text.

Table F.1: Regional data moments



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.

Figure F.1: Insurance Payments over the Income Distribution

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**
Low risk							
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
High risk							
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

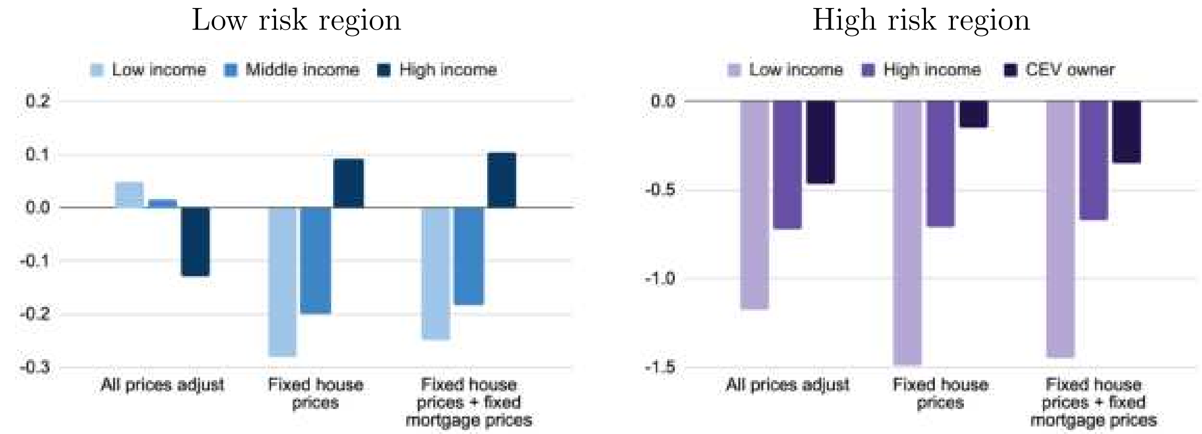
Note: This table plots the percentage change in the share of homeowners remaining in their homes after being hit by a natural disaster comparing alternative policy scenarios to the baseline steady state. Each column represents one the following counterfactuals: ($\bar{\tau}_\delta = 0$) removing rebuilding 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.

G.1 Role of default option

To understand the role of default, I recalibrate the model by setting the utility cost of default to infinity, effectively eliminating default behavior. When default is ruled out, the aggregate owner-occupied housing stock falls by 27%, and average house size decreases by 25%. Homeownership becomes more concentrated among higher-income households, while loan-to-value ratios decline by 8%, and the share of households with mortgages falls by 13%.

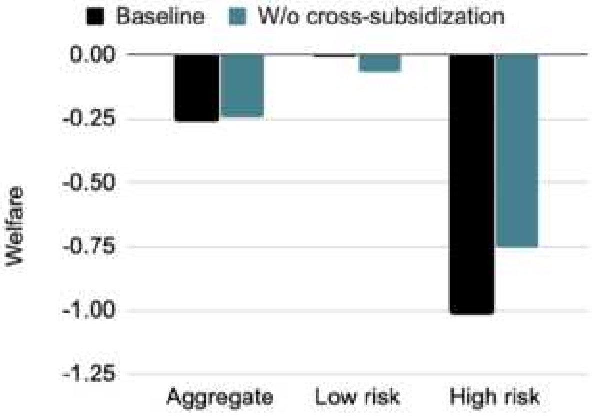
Including a default option significantly alters the effects of disaster aid and who gains or loses from its removal. Figure G.4 summarizes welfare changes under both environments, with and without a default option. Without default, the aggregate welfare loss from eliminating disaster aid rises sharply to 4.8% in equivalent variation, compared to only 0.25% in the baseline. Previously, low-risk regions benefited slightly from removing aid, while high-risk regions experienced large losses; under the no-default scenario, losses become similar across regions (–4.7% vs. –5.1%). Moreover, welfare losses become increasingly concentrated among higher-income households, reflecting the stronger concentration of homeownership in this group.

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

	Δ%						
	$\bar{\tau}_\delta = 0$	**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
By risk exposure							
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
By risk exposure							
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
By risk exposure							
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
By risk exposure							
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							
Low income							
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
Middle income							
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
High income							
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							
Low income							
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
Middle income							
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
High income							
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							
Low income							
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
Middle income							
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
High income							
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							
Low income							
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
Middle income							
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
High income							
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

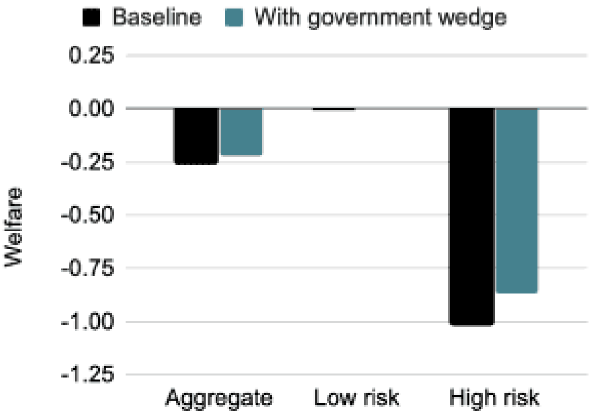
Note: This table documents the percentage point changes in the foreclosure rates comparing alternative policy scenarios to the baseline steady state by region and income. Each column represents one the following counterfactuals: ($\bar{\tau}_\delta = 0$) removing rebuilding grants, ($M = 0$) removing 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							
Low income							
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
Middle income							
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
High income							
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							
Low income							
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
Middle income							
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
High income							
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

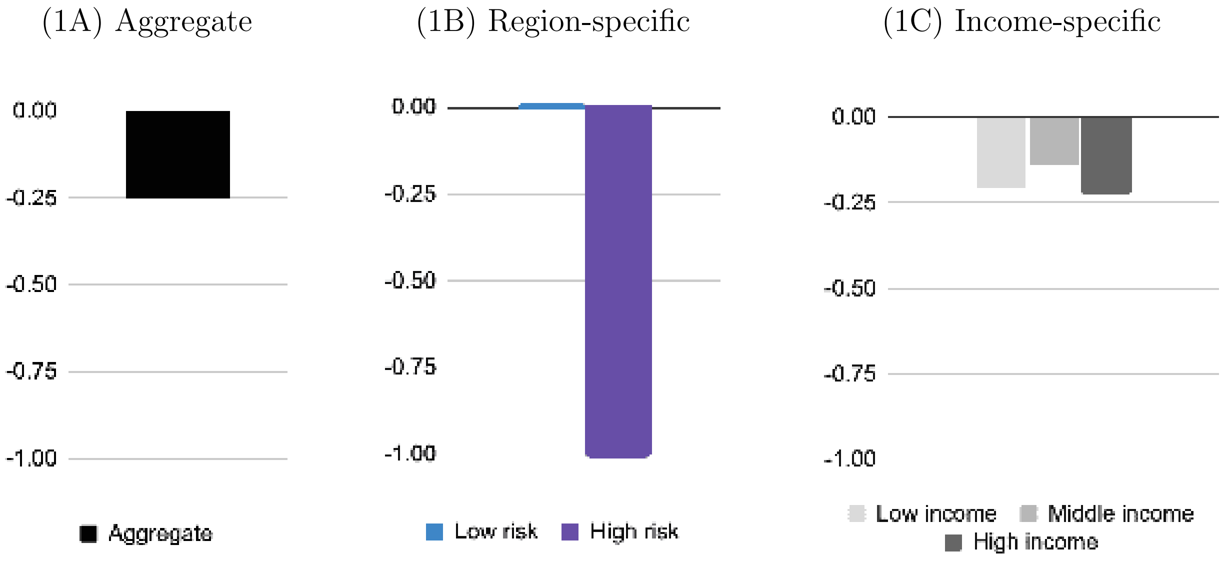
Note: The table plots percentage deviations of steady state statistics for a scenario with baseline government aid financed within one region compared to the baseline steady state.

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

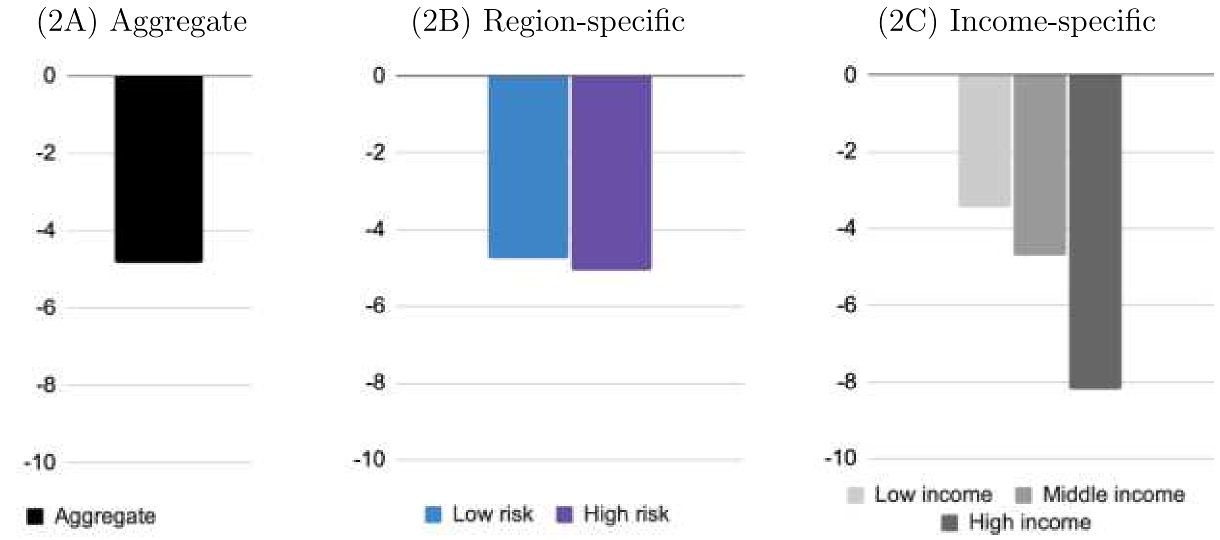
		Counterfactuals ($\Delta\%$)						
	(0) **Base**	**(1)** $\tau_\delta = 0$	**(2)** **M = 0**	**(3)** **No aid**	**(4)** **CF 1**	**(5)** **CF 2**	**(6)** **CF 3**	**(7)** **CF 4**
Insurance gap								
Total	73.14	-48.90	1.32	-48.91	-50.69	-30.87	-35.17	1.47
Low risk								
Low income	85.52	-21.73	0.05	-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
High risk								
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
Low risk								
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
High risk								
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
Low risk								
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
High risk								
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
Low risk								
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
High risk								
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.

(1) Including a default option


(1A) Aggregate (1B) Region-specific (1C) Income-specific

(2) Excluding the default option


(2A) Aggregate (2B) Region-specific (2C) Income-specific

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.

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

G.2 Alternative Policy Designs

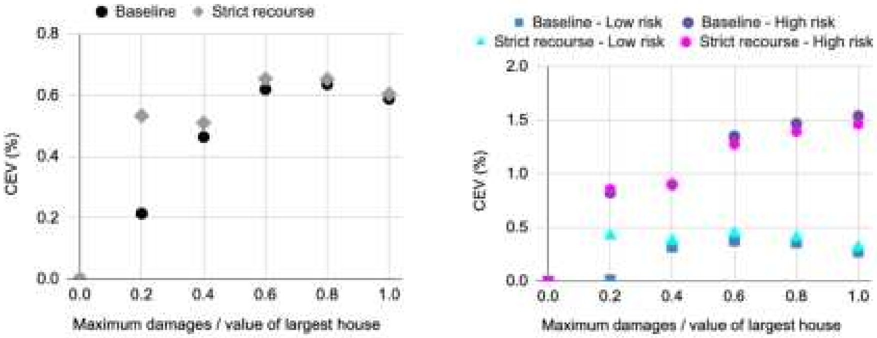
Table G.8: Steady State Comparison by Region - Alternative Policy Designs

Δ%	**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.3 Role of recourse regime

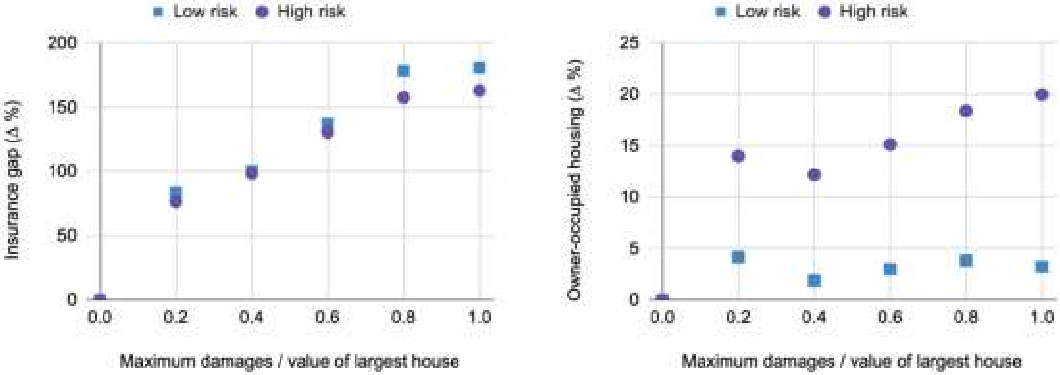
Figure G.5: Welfare under different levels of financial aid - Role of Recourse



(A) Aggregate Welfare (B) Region-specific Welfare

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 equivalance 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.

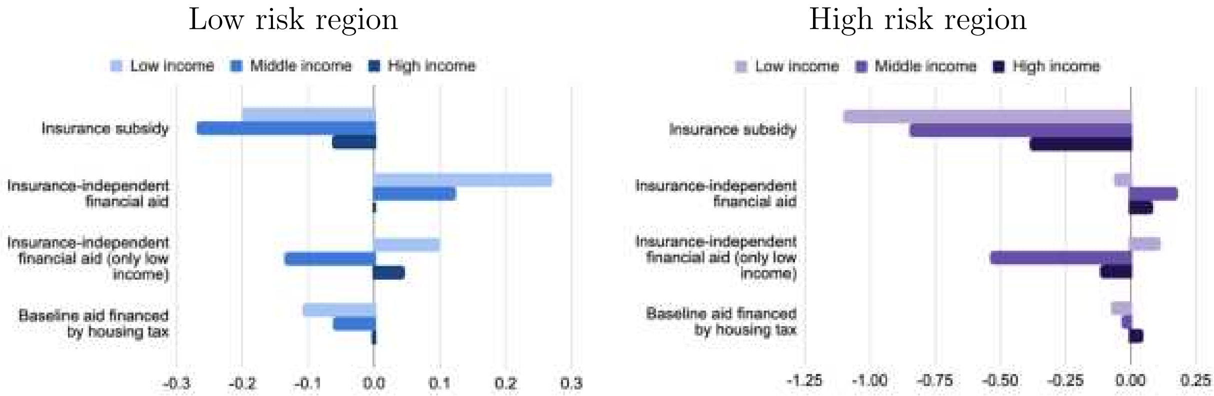
Figure G.6: Insurance and housing under different levels of financial aid - Strict recourse



(A) Insurance Gap (B) Owner-occupied Housing Stock

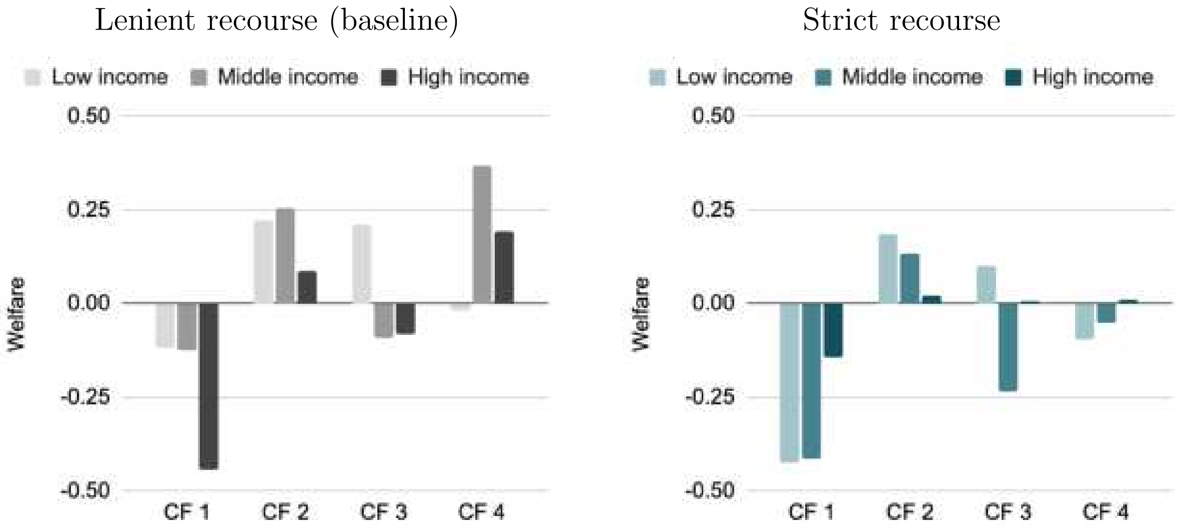
Note: The figure reports region-specific changes in the insurance gap and the owner-occupied housing stock across various steady states that only differ in the level of the maximum grants provided to households. Changes are expressed in percent deviation from a steady state without any financial aid. 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 and middle-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 and middle-income homeowners only. As last counterfactual (CF 4), disaster aid is financed through a tax on homeowners' housing capital.