Natural Disasters, Property Insurance, and Housing Markets

Michael Boutros Nuno Clara Pierre Mabille*

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Abstract

We study how local climate risk affects the entire housing market of a country and household finances through moving and property insurance channels. We develop a dynamic spatial equilibrium housing model in which households choose location, tenure, and property insurance coverage across regions with heterogeneous exposure to climate risk. Spatial mobility and insurance decisions interact to shape house prices and population distributions across regions, and hence exposure to climate risk. The model generates realistic patterns of insurance demand, including underinsurance and strong heterogeneity across wealth, age, and regions. Using counterfactual experiments, we find that higher local climate risk induces selective migration out of exposed regions, leading to lower house prices as higher climate risk and insurance costs are capitalized into home values. Our results underscore the joint importance of endogenous spatial sorting and property insurance choices to evaluate the housing market impacts of climate change.

*Boutros: University of Toronto (michael.boutros@utoronto.ca), Clara: Duke University, Fuqua School of Business (nuno.clara@duke.edu), Mabille: INSEAD (pierre.mabille@insead.edu). We thank Manuel Adelino, João Cocco, Adriano Rampini, David Zhang (discussant) and participants at the Columbia-NYU-Yale Housing Day, University of Toronto Macro Brownbag, Duke Fuqua Brownbag and the Indiana University & Chicago Fed 3rd Annual Symposium on Real Estate and Urban Policy, for helpful comments.

1 Introduction

Natural disasters have become an increasingly important component in shaping local housing markets, both through the physical destruction of housing capital and changes in expected housing costs. In the United States, natural disasters have caused $2.9 trillion in damages from 1980 to 2024, with more than half of that total coming since 2015, and most of it being concentrated in areas with wildfires, storms, and sea level rise.[1] Beyond realized destruction that impacts local housing stocks ex post, climate risk also potentially affects housing markets ex ante by altering expected housing quality, local amenities, and costs.

How does climate risk affect the *entire* housing market of a country? While there is increasing evidence that climate risk impacts exposed local areas, its effect on the housing market as a whole and on households' finances remains an open question. On the one hand, if households are able to *adapt* to climate risk by moving to less exposed areas, avoid owning exposed housing units by remaining or becoming renters, or can default on exposed mortgages, then the total effect of climate risk on housing markets and their balance sheets may be less than local estimates suggest. Similarly, if households are able to *mitigate* the damages from climate risk by purchasing property insurance, then the impact of natural disasters eventually may depend more on the financial sustainability of insurance companies than on local exposure to climate risk, and it would also be less than if households were directly exposed. Far from doomsday concerns, this would make climate risk less of a problem for policymakers and diversified stakeholders in the housing ecosystem that are mostly concerned about aggregate outcomes. On the other hand, multiple frictions to households' moving decisions, the likely increase in house prices and rents if they were to move en masse to less exposed regions, and the rise in insurance costs if households instead remain in exposed regions or if the financial sustainability of insurance companies deteriorates, suggest that adaptation and mitigation channels may fall short of dampening the impact of climate risk on the housing market.

In this paper, we develop a dynamic spatial equilibrium model of the cross section of U.S. housing markets with heterogeneous households and climate

[1] Sources: https://www.ncei.noaa.gov/access/billions/time-series/US/cost and https://www.ncei.noaa.gov/access/billions/mapping.

risk that addresses this question. The model is the first, to the best of our knowledge, to account for the substantial variation in exposure to climate risk between regions in the data. Local differences in climate risk endogenously translate into differences between local housing markets. We consider two key adaptation and mitigation channels. First, when households move across regions, these differences generate spatial reallocation and equilibrium housing price changes. Climate risk can give rise to migrations across geographies that generate spillovers impacting the entire housing market including beyond exposed areas. In that case, climate risk can have significant impact on housing prices even in periods and in areas without realized shocks. Second, when households buy property insurance against climate risk, they can partly protect themselves from local exposure at the expense of higher insurance costs that put a dent in their financial resources, affecting in turn housing prices. As a result, house prices and rents, population distributions, and property insurance coverage adjust jointly across space in equilibrium. This richness is central to understanding the aggregate effects of climate risk on the housing market.

In the model, households choose their location, tenure, and property insurance coverage in the presence of heterogeneous local climate risk. In the U.S., property insurance is effectively mandatory for most homeowners through mortgage underwriting standards, making insurance costs a large and recurring component of total housing costs. Households adapt to and mitigate local climate risk through three main channels: relocating across regions, adjusting insurance coverage, and changing tenure between owner and renter. These endogenous responses interact in equilibrium, jointly determining house prices, rents, and the spatial allocation of households in equilibrium.

In addition to endogenous moving and insurance purchase decisions, three ingredients help us estimate the equilibrium consequences of climate risk on households' balance sheets. First, we introduce heterogeneous local exposures to climate shocks. In contrast, housing market models with a single location typically abstract from such regional heterogeneity and would thus fail to accurately capture the impact of climate risk on the housing market. We solve the model at an annual frequency to capture the dynamics of migration, insurance adjustment, and housing market, which substantially increases the dimensionality of the state space. To address this challenge, we introduce a new recursive formulation of the discrete choice problem governing household location and tenure decisions. Second, households' Epstein–Zin preferences capture their preference for early resolution of uncertainty, which is a key determinant for how natural disaster risk is priced into housing markets including in the absence of realized shocks. Third, a constant elasticity of substitution utility function between non-durable consumption and housing services captures the trade-offs that climate risk creates for households, who can insure and retain the best possible housing quality at the cost of higher insurance premiums and lower non-durable consumption.

Our setting complements and extends existing empirical work based on the cross section of local housing markets, which typically identifies local average treatment effects (LATE) by comparing areas with heterogeneous exposures to climate risk. While valuable to document the local effects of climate risk, these estimates are mostly silent about its total effect on the U.S. housing market and how serious a concern it is at the aggregate level. We use the model to compute the net effect of aggregating such LATE estimates and estimate its total impact. This aggregation exercise would not be possible in the data alone due to the spillovers across local housing markets that arise when households move to other housing units, insure their existing properties, and house prices endogenously adjust in response to climate risk.

We calibrate the model by splitting the U.S. housing market between a region with high exposure to climate risk (Florida) and the rest of the country with relatively less exposure. Compared with property insurance data, the model endogenously generates realistic insurance demand across households and regions. When households are presented with a menu of insurance premiums and coverage, demand is non-monotonic and highly non-linear in household liquidity, age, and background climate risk. Under-insurance is prevalent at both tails of the wealth distribution. Liquidity constrained households cannot afford insurance and are exposed directly to climate risk, while wealthier households can partially self-insure and avoid directly buying full coverage. Increased climate risk weakens this pattern by reducing sensitivity of insurance demand to household liquidity and increasing average insurance coverage. Then, we use the model as a laboratory to study three counterfactual experiments that map out how insurance costs, physical climate risk, and insurance rate regulation shape housing markets and spatial allocation.

In our first experiment, we raise the insurer's cost-of-capital coefficient by 10 percent, increasing the cost of supplying private insurance. At fixed house prices, the shock reduces the relative attractiveness of the high-risk region. In general equilibrium, however, the population response is much smaller: Florida's population share falls by only 0.19 percentage points. The adjustment operates through rents, tenure choice, and sorting. Higher insurance costs are passed through to rental costs, while homeowners adjust coverage choices, so the shock raises demand for owner-occupied housing. House prices rise slightly in both regions, by 0.22 percent in the rest of the United States and 0.09 percent in Florida.

In our second experiment, we increase the annual probability of a climate disaster in Florida by 10 percent. At baseline house prices, the direct response is large: Florida's population share and homeownership rate fall sharply. In general equilibrium, lower Florida house prices partly capitalize the higher risk and moderate the population response. Florida's population share rises slightly, by 0.30 percentage points, but homeownership falls by 3.23 percentage points and owner-occupied housing demand declines. Florida house prices fall by 2.27 percent, average net worth falls by 12.41 percent, and average consumption falls by 10.21 percent. Thus, higher climate risk mainly reduces the value of owning in the high-risk region and shifts the composition of residents toward renters.

Our final experiment studies cross-subsidization under rate regulation. We cap Florida insurance prices at 98 percent of their baseline schedule and finance the subsidy through a small compensating markup in the rest of the United States. At fixed house prices, the subsidy generates a large movement toward Florida. In general equilibrium, most of this direct incentive is capitalized into Florida house prices, which rise by 0.46 percent. Florida's population share rises by only 0.18 percentage points, and homeownership is essentially unchanged. The experiment shows that even small insurance subsidies can create spatial incentives, but house-price capitalization absorbs much of the direct benefit.

Taken together, the three experiments underscore a key policy insight: the equilibrium effects of rising insurance costs depend critically on their source, as different drivers trigger distinct sorting responses that can amplify or partially offset the direct price effect.

The remainder of the paper is organized as follows. Section 2 presents the model. Section 3 describes the calibration. Section 4 documents insurance demand patterns in the model. Section 5 presents the three counterfactual experiments: a rise in insurance capital costs, an increase in climate risk, and the introduction of cross-subsidization through rate regulation. Section 6 concludes.

1.1 Related Literature

This paper studies how climate risk shapes the entire housing market across an economy. We analyze how natural disaster risk, which varies mostly locally, affects aggregate housing markets and households' finances, when households can adapt and mitigate its impact through moving and property insurance. We contribute to three main strands of the literature.

Natural Disasters and Housing Markets. First, our work complements the growing literature on natural disasters and housing markets, which is mostly empirical. There is increasing evidence that natural disaster risk affects financial markets in general and housing markets in particular (see, e.g., the survey by Giglio *et al.* (2021b) who document how climate risk is priced across asset classes), and that it has become a first-order consideration for investors and policymakers (Stroebel & Wurgler, 2021).

Existing work suggests that exposure varies strongly with geography as well as with housing stock and household types. For example, Bernstein *et al.* (2019) estimate price discounts for sea-level-rise exposure in coastal housing markets in a local and partial equilibrium empirical design. Baldauf *et al.* (2020) show that climate risk is capitalized into house prices only where beliefs about climate change are stronger, and Bakkensen & Lint (2022) estimate a dynamic housing market model in which heterogeneous flood risk beliefs generate sorting. This finding motivates our equilibrium approach to joint location and housing price adjustments. Keys & Mulder (2020) show changes in housing and mortgage lending in response to sea-level-rise exposure. Building on their analysis, we study the aggregate consequences of local exposure to climate risk through reallocation. The total impact depends on households' preferences for housing, frictions to migration and access to insurance, and expectations about future climate shocks, all of which potentially differs across demographic groups. Accounting for heterogeneity in households' resources is key: income, wealth, and borrowing constraints affect their ability to move, insure, and absorb losses, ultimately shaping the housing market response to climate shocks.

Macro-Finance Models with Climate Risk. Second, we build a spatial equilibrium model of housing markets with climate risk that incorporates two key margins of adjustment and mitigation for households: endogenous moves between areas with heterogeneous exposure and property insurance choices. Our model contributes to the recent literature on macroeconomic and asset pricing models of climate risk.

While regional heterogeneity in exposure to climate risk is a central feature of the data, existing macro-finance models typically abstract from it and consider its effect on a single location, implicitly removing households' option to move across regions (e.g., Giglio *et al.* (2021a) and Van der Straten (2025)). By explicitly considering spatial heterogeneity, our model allows households to adapt to local climate risk through migration, as well as to mitigate its ex post impact through endogenous property insurance choices. As such, our work relates to existing spatial models of housing and mortgage markets as in Hurst *et al.* (2016), Beraja *et al.* (2019), Guren *et al.* (2020), Mabille (2023) and Fonseca *et al.* (2025), which have focused on the consequences of financial shocks but not those of climate risk, a major feature of modern housing markets and an open question. Our focus on household finances and housing markets is also a key difference from Bilal & Rossi-Hansberg (2025), who study how local exposure to various types of climate shocks shapes capital accumulation across U.S. regions. While their work has forcefully demonstrated the impact of climate risk on firms and labor markets, considerable uncertainty remains over whether and how it impacts housing and mortgage markets at the country level, and thus households' largest assets and liabilities.

Property Insurance Choices. Third, we consider property insurance as an central mitigation channel for households. Buying insurance may be a complement or a substitute to the option of moving, and though it is likely to affect the total impact of climate risk on housing markets, there is limited evidence about its total effects on the housing market.

As such, our work adds to important recent research on the interaction between property insurance and climate risk. Keys & Mulder (2025) show that the repricing of catastrophic risk increases the pass-through of risk into premiums and reduces home values in high-exposure areas, which our model captures in equilibrium. Similarly, Jotikasthira *et al.* (2025) and Kalda *et al.* (2025) document that insurers can also transmit disaster costs to policyholders through non-price contract dimensions (e.g., claim rejections), which we also capture. In our setting, the effects of climate shocks and the constraints faced by insurance companies spill over to housing markets and also affect households' mortgages as in Sastry *et al.* (2025a), Sastry *et al.* (2025b), Ge *et al.* (2026) and Eastman *et al.* (2024). As in the data, shocks to insurers' balance sheets due, e.g., to under-capitalization or under-diversification, eventually transmit to households and housing prices through higher insurance premiums, potentially distorting households' allocation across regions and hence their exposure to climate risk.

Finally, we connect with the quantitative literature on insurance by modeling private and public property insurance suppliers who offer a menu of coverage and premium options to homeowners. We introduce an insurance pricing function building on Koijen & Yogo (2015) and Koijen & Yogo (2016), in which insurance premiums include a capital wedge arising from regulatory and financial frictions. We extend their framework to property insurance markets, where capital requirements are tied to disaster tail risk and reinsurance costs, generating nonlinear pricing in coverage. As in Oh *et al.* (forthcoming), insurance prices are determined by both risk and institutional features rather than only actuarially fair pricing. We also build on Gropper & Kuhnen (2025) and Rampini & Viswanathan (2022) to discipline households' heterogeneity in coverage and the extent to which insurance can attenuate or amplify housing market responses to climate risk. Indeed, the former document that wealthier households purchase more coverage in the context of life insurance data, and the latter show in a dynamic model with collateral constraints that insurance is generally increasing in household net worth. We show how such mechanisms are modified in our lifecycle model with housing, in which wealthy retirees drawing down on their assets may endogenously reduce coverage, thus attenuating the positive wealth-property insurance relationship at the top of the distribution, and increasing exposure to climate risk.

2 Model

This section presents a dynamic spatial housing model with climate risk and property insurance. We first describe locations and their risk exposure before detailing households' tenure and location choice problems, insurance companies, and finally housing supply. We then define the recursive competitive equilibrium that jointly determines household allocations, insurance outcomes, and house prices in each region. The economy is populated by overlapping generations of heterogeneous risk-averse households. Markets are incomplete, and house prices and rents are endogenous. Population size is stationary, and there is a continuum of measure 1 of households with a life cycle from age $t = 1$ to $t = T$. Time τ is discrete.

2.1 Locations

There are N_ℓ locations in the model indexed by $\ell \in \{1, 2, ..., N_\ell\}$. Each location has amenities for owners, $\Xi_{\ell O}$, and amenities for renters, $\Xi_{\ell R}$.

Property Damage and Climate Risk. Each period, houses experience a stochastic total damage rate δ_ℓ consisting of baseline depreciation and a climate disaster shock:

$$\delta_\ell = \delta_b + \chi_\ell \cdot \mathbb{1}_{\chi,\ell}, \qquad \delta_b \sim \text{Beta}(\alpha_b, \beta_b) \text{ on } [0, \bar{\delta}_b].$$

The baseline component δ_b captures routine depreciation events such as minor weather damage, wear-and-tear, and other property risks unrelated to major climate disasters, and is i.i.d. across properties and time. Appendix Figure A1 shows that the scaled Beta distribution captures empirical patterns of property damage fairly well.

We model climate disasters as Bernoulli events that strike with probability $p_{\chi,\ell}$ in location ℓ and cause a damage rate of χ_ℓ. Climate disaster shocks are i.i.d. over time, region-specific, and common to all properties in ℓ in a given period.

2.2 Insurance Companies

We model two types of insurance companies, private and public, that offer insurance contracts with three elements: coverage, price per unit of coverage, and rejection rate. The private insurance company may operate in multiple regions, while the public insurer is a state-funded "insurer of last resort" operating independently in each region.

2.2.1 Private Insurance Company

A representative national insurance company supplies insurance contracts in each location. The insurer offers a menu of coverage options from which households can endogenously select under- or full-coverage. Across it's entire portfolio, the insurer rejects a fraction of valid claims with probabilities $\theta_{b,\ell} \in [0,1]$ on baseline-depreciation claims and $\theta_{d,\ell} \in [0,1]$ on climate-disaster claims.

As a benchmark, the actuarially fair price $p_{A,\ell}$ equals the expected payout per unit of contracted coverage. The insurer pays $(1-\theta_{b,\ell})\delta_b$ on baseline-depreciation claims and $(1-\theta_{d,\ell})\chi_\ell \mathbb{1}_{\chi,\ell}$ on climate-disaster claims per unit of ϕ':

$$p_{A,\ell} = (1-\theta_{b,\ell})\,\mathbb{E}[\delta_b] + (1-\theta_{d,\ell})\,p_{\chi,\ell}\,\chi_\ell,$$

where $\mathbb{E}[\delta_b] = \bar{\delta}_b \cdot \alpha_b/(\alpha_b+\beta_b)$ is the expected baseline depreciation as in the data. For example, with every valid claim paid ($\theta_{b,\ell} = \theta_{d,\ell} = 0$), this reduces to $p_{A,\ell} = \mathbb{E}[\delta_b] + p_{\chi,\ell}\chi_\ell$. Even regions with no climate disaster risk ($p_{\chi,\ell} = 0$) have positive insurance costs reflecting baseline property damage.

Building on the actuarially fair price, the per-unit price of insurance in location ℓ for a household choosing coverage ϕ is:

$$p_\ell(\phi) = \frac{1+\kappa(\phi)}{1-\mu} \cdot p_{A,\ell},$$

where $\mu \geq 0$ defines a constant markup and $\kappa(\phi)$ is a coverage-dependent capital charge. The coverage-dependent capital charge is:

$$\kappa(\phi) = c \cdot \phi^\eta,$$

with $c > 0$ and $\eta > 1$. The formulation nests actuarially fair pricing as a special case with $c = 0$ and $\mu = 0$.

This reduced-form specification is motivated by the framework developed in Koijen & Yogo (2015) and Koijen & Yogo (2016), in which insurance premiums reflect actuarial losses, competitive structure, and a capital wedge arising from regulatory and financial frictions. Under NAIC risk-based capital (RBC) standards, insurers must hold capital reserves proportional to their underwritten exposure. The parameter c reflects the cost of regulatory capital that insurers must hold per unit of coverage-weighted exposure, including cost-of-capital spread, the opportunity costs of holding reserves, frictional costs such as taxes, and origination costs. These costs are passed through to policyholders as a loading above the actuarily fair price.

Primary insurers typically transfer natural disaster risk exposure through layered reinsurance structures ("reinsurance towers"), with higher layers priced at increasing rates (Froot, 2001). We capture this institutional feature in reduced form through the curvature parameter η, which governs how capital and reinsurance costs scale with coverage. As insured limits rise, insurers must obtain additional protection in higher layers and hold more capital against tail exposure. Values $\eta > 1$ allow marginal costs to rise with coverage, consistent with capital requirements, concentration penalties in regulatory and rating-agency models, and the pricing structure of layered reinsurance contracts.

In each location ℓ, the insurer's expected profit is:

$$\mathbb{E}[\pi_\ell] = p_{h,\ell}\, h_\ell \Big[p_\ell(1)\, H^{\ell R}_{t+1} + \int_{\Omega^{\ell O,\phi}_{t+1}} p_\ell(\phi'_i)\, \phi'_i\, \omega_i\, di \\ - \big(p_{A,r,\ell}\, H^{\ell R}_t + p_{A,\ell} \int_{\Omega^{\ell O,\phi}_t} \phi_i\, \omega_i\, di\big)\Big].$$

Altogether, the insurer collects premiums on current-period contracts (from homeowners and from renters' landlords) and pays the effectively-covered portion of realized depreciation on previous-period contracts. With $\Omega^{\ell h}_t$ the mass of owners or renters in location l at time t, $\Omega^{\ell O,\phi}_t \subseteq \Omega^{\ell O}_t$ is the set of homeowners on the private insurer in location ℓ at t (i.e., those who do not choose the public contract $\underline{\phi}_\ell$ described below), and these homeowners choose how much insurance coverage to purchase.

We treat renters' landlords as sophisticated and repeat players who purchase full insurance and whose claims are honored in full. The analogous actuarially fair price is $p_{A,r,\ell} = \mathbb{E}[\delta_b] + p_{\chi,\ell}\chi_\ell$ and the aggregate stock of rental units, $H^{\ell R}_t \equiv$

$\int_{\Omega_t^{\ell R}} h_{i,t}^{\tilde{R}}\, di$, depends on the population of renters' unit size decision.

2.2.2 Public Insurance Company.

In each location ℓ, a single insurer of last resort offers a fixed minimum-coverage contract $\underline{\phi}_\ell$ with rejection rates $\underline{\theta}_{b,\ell}$ and $\underline{\theta}_{d,\ell}$. The per-unit price is a discount $\underline{\lambda} \leq 1$ of the actuarily fair price, $\underline{p}_\ell = \underline{\lambda} \underline{p}_{A,\ell}$, with $\underline{p}_{A,\ell} = (1 - \underline{\theta}_{b,\ell})\, \mathbb{E}[\delta_b] + (1 - \underline{\theta}_{d,\ell})\, p_{\chi,\ell}\, \chi_\ell$. The public insurer charges homeowners a lump-sum "hurricane tax" T_ℓ to ensure that its expected budget balances in each period:

$$p_{h,\ell}\, h_\ell\, \underline{p}_\ell\, \underline{\phi}_\ell \int_{\Omega_{t+1}^{\ell O,\underline{\phi}}} \omega_i\, di + T_\ell\, \Omega_{t+1}^{\ell O} = p_{h,\ell}\, h_\ell\, \underline{p}_{A,\ell}\, \underline{\phi}_\ell \int_{\Omega_t^{\ell O,\underline{\phi}}} \omega_i\, di,$$

where $\Omega_t^{\ell O,\underline{\phi}}$ is the set of homeowners on the public contract.

2.3 Households

Households live for T periods, each corresponding to one year. They make location and tenure decisions in each period. We define generic location-specific value functions that are used by both homeowners and renters in evaluating their options of whether to move or remain in their current location and tenure status. These unconditional value functions depend generically on household wealth, income, and age, but not on their current location/tenure. In what follows, we denote the household's current location as ℓ and the collection of other location as ℓ'.

2.3.1 Preferences and Income

Households have Epstein-Zin preferences that separate risk aversion from the elasticity of intertemporal substitution and imply a preference for the early resolution of uncertainty:

$$V_t(S) = \left(u_t^{1-\rho} + \beta \left(\mathbf{E}_t \left[V_{t+1}(S')^{1-\gamma} \right] \right)^{\frac{1-\rho}{1-\gamma}} \right)^{\frac{1}{1-\rho}},$$

where γ is the coefficient of relative risk aversion, $1/\rho$ is the elasticity of intertemporal substitution β is the subjective discount factor and S_t is the state space that we describe below. The flow utility function is a CES aggregator of consumption c and effective housing services:

$$u_t(c, h, \Xi_{\ell\tau}) = ((1-\alpha)c^{\epsilon} + \alpha h^{\epsilon})^{1/\epsilon} + \Xi_{\ell\tau},$$

where α governs the preference for housing services, ϵ controls the elasticity of substitution between consumption and housing, and $\Xi_{\ell\tau}$ is an amenity shifter specific to location ℓ and tenure $\tau \in \{O, R\}$, where O stands for owner and R stands for renter. The substitutability between consumption and housing is important for the insurance channel: when a climate shock lowers housing quality, households can partially smooth utility by substituting toward consumption.

Households receive stochastic income that varies over the life cycle and is a combination of persistent and transitory components. Log income for household i of age t in location ℓ is:

$$\log Y_{i,t,\ell} = \alpha_{\ell}^{inc} + g(t) + z_{i,t,\ell},$$

where α_{ℓ}^{inc} is a location fixed effect, $g(t)$ is a deterministic age profile, and $z_{i,t,\ell}$ is a persistent stochastic component following an AR(1) process:

$$z_{i,t,\ell} = \rho_z z_{i,t-1,\ell} + \varepsilon_{i,t}, \quad \varepsilon_{i,t} \overset{iid}{\sim} \mathcal{N}(0, \sigma_{\varepsilon}^2).$$

Retired households receive a deterministic income that is a fraction of their preretirement earnings.

2.3.2 Generic Location-Specific Value Functions

Within each location, households can either be homeowners or renters. We define three location-specific value functions for households: the value from living in an owner-occupied home in the location, the value from purchasing a new home in the location, and the value from renting in the location. In the next section, these three value functions will be used to build up the rest of the household's decision tree.

Inactive Homeowner: Living in Location. For a homeowner living in location ℓ, the state variables consist of cash-on-hand X, mortgage balance M, effective housing quality ω, and the persistent component z of the (log) income process;

we collect these as $S \equiv (X, M, \omega, z)$ for use in the spatial-decision subsections below. An inactive homeowner $\tilde{O}$ in region ℓ chooses consumption c and property insurance ϕ' to maximize the value function:

$$V_t^{\ell\tilde{O}}(X, M, \omega, z) = \max_{c_t^{\ell\tilde{O}}(\cdot),\, \phi'^{\ell\tilde{O}}(\cdot)} u(c_t^{\ell\tilde{O}}(X, M, \omega, z),\, \tilde{h},\, \Xi_{\ell O}) + \beta\, EV_{t+1}^{\ell O}(X', M', \omega', z'),$$

subject to the budget constraint:

$$c_t^{\ell\tilde{O}}(X, M, \omega, z) + P^{\ell\tilde{O}}(X, M, \omega, z) + T_\ell + (1 - \lambda + r_M)M + \frac{s}{1+r} = X,$$

where T_ℓ is the uniform lump-sum tax that finances the public insurer and $P^{\ell\tilde{O}}(X, M, \omega, z)$ is the cost of insurance:

$$P^{\ell\tilde{O}}(X, M, \omega, z) \equiv p^*\left(\phi'^{\ell\tilde{O}}(X, M, \omega, z)\right) \phi'^{\ell\tilde{O}}(X, M, \omega, z)\, p_{h,\ell}\, \omega\, h_\ell,$$

with $p^*(\phi') = \underline{p}_\ell$ if $\phi' = \underline{\phi}_\ell$ (public contract) and $p^*(\phi') = p_\ell(\phi')$ otherwise (private menu). The premium is the product of the per-unit price, the chosen coverage level $\phi'^{\ell\tilde{O}}(X, M, \omega, z)$, and the effective home value $p_{h,\ell}\omega h_\ell$. As emphasized by Rampini & Viswanathan (2022), insurance is an intertemporal decision: premiums $P^{\ell\tilde{O}}$ are paid in the current period for insurance contracts $\phi'^{\ell\tilde{O}}$ that pay off in the next period.

Utility is derived from chosen consumption and effective housing quality, $\tilde{h} \equiv \omega h_\ell$, that depends on the previous period's insurance choice and the realization of damage shocks. In the current period, then, households can insure against future damages. As detailed in Section 2.2, households can purchase insurance coverage ϕ' with rejection probabilities $\theta_{b,\ell}$ on baseline-depreciation claims and $\theta_{d,\ell}$ on climate-disaster claims. The household's uninsured loss rate is the fraction of home value lost after coverage and rejection,

$$L_\ell(\phi') \equiv \left(1 - (1 - \theta_{b,\ell})\, \phi'\right) \delta_b' + \left(1 - (1 - \theta_{d,\ell})\, \phi'\right) \chi_\ell\, \mathbb{1}'_{\chi,\ell},$$

and effective housing quality evolves according to uninsured losses and the current effective quality, $\omega' = \left(1 - L_\ell(\phi')\right) \omega$.

Finally, mortgage balances decrease by the principal payment, $M' = M - (1-\lambda)M = \lambda M$, and cash-on-hand evolves according to exogenous income and savings, $X' = Y' + s$. Savings in the risk-free bond at rate $1 + r$ is cash-on-hand minus expenditures on consumption, insurance, the public-insurer tax, and mortgage payments (if there is a mortgage outstanding):

$$s = (1 + r)\left(X - c_t^{\ell\tilde{O}}(X, M, \omega, z) - P^{\ell\tilde{O}}(X, M, \omega, z) - T_\ell - (1 - \lambda + r_M)M\right).$$

Active Homeowner: Purchase New Home. We next define a generic value function, $V^{\cdot,\ell O}$, for a household O that purchases a new home in location ℓ, regardless of its current location or homeownership status (currently a renter or currently a homeowner that will sell its existing home and purchase another, whether within or across locations). The only relevant state variables are the current cash-on-hand X and the persistent component z of its income process.[2]

The generic household's choice variable is the size of the mortgage used to finance the new home cost, $p_{h,\ell}h_\ell$. The new LTV is chosen subject to an exogenous LTV limit $\theta_{LTV}^{\cdot,\ell O} \leq \bar{\theta}_{LTV}$ and a payment-to-income ratio $\bar{\theta}_{PTI}$, measured as:

$$\frac{(1-\lambda+r_M)\theta_{LTV}^{\cdot,\ell O} p_{h,\ell}h_\ell}{\tilde{Y}} \leq \bar{\theta}_{PTI},$$

with $\tilde{Y} = \exp(\alpha_i + g(t) + z)$. Combining the two constraints implies that the maximum loan size is bounded above by the tighter of the two constraints:

$$\theta_{LTV}^{\cdot,\ell O} \leq \min\left\{\bar{\theta}_{LTV}, \left(\frac{(1-\lambda+r_M)p_{h,\ell}h_\ell}{\tilde{Y}}\right)^{-1}\bar{\theta}_{PTI}\right\}.$$

For a given LTV, the required mortgage is $\theta_{LTV,t}^{\cdot,\ell O} p_{h,\ell}h_\ell$, and the required down-payment is $(1-\theta_{LTV}^{\cdot,\ell O})p_{h,\ell}h_\ell$. In addition, the household pays variable and fixed buying fees, $f_{b,\ell}$ and $F_{b,\ell}$. In total, the household's available cash-on-hand net of these fees defined as:

$$\tilde{X}^{\cdot,\ell O} = X - (1-\theta_{LTV}^{\cdot,\ell O} + f_{b,\ell})p_{h,\ell}h_\ell - F_{b,\ell}.$$

Altogether, the problem of purchasing a new home is equivalent to the problem of choosing an LTV and then remaining inactive in that home:

$$V_t^{\cdot,\ell O}(X,z) = \max_{\theta_{LTV,t}^{\cdot,\ell O}(X,z)} V_t^{\ell\tilde{O}}(\tilde{X}^{\cdot,\ell O}, \tilde{M}^{\cdot,\ell O}, 1, z),$$

with $\tilde{M}^{\cdot,\ell O} = \theta_{LTV,t}^{\cdot,\ell O}(X,z)p_{h,\ell}h_\ell$ and the effective housing quality for the new home is $\omega = 1$.

[2] The current cash-on-hand includes the proceeds of a sale of a home (net of fees and mortgage prepayment), if applicable. This will become clear later when we define $X^{\ell O,\ell' O}$.

Renter: Living in Location. The renter $\tilde{R}$ living in location ℓ has state variables cash-on-hand X and the persistent component z of the income process. The renter chooses consumption and the rental size every period to maximize the value function

$$V_t^{\ell\tilde{R}}(X,z) = \max_{c_t^{\ell\tilde{R}}(X,z),h_t^{\ell\tilde{R}}(X,z)} u(c_t^{\ell\tilde{R}}(X,z), h_t^{\ell\tilde{R}}(X,z)\cdot h_\ell, \Xi_{\ell R}) + \beta E V_{t+1}^{\ell R}(X',z'),$$

with $h_t^{\ell\tilde{R}}(X,z) \in [\underline{h}^R, \bar{h}^R]$ and subject to the budget constraint:

$$c_t^{\ell\tilde{R}}(X,z) + p_{r,\ell} h_t^{\ell\tilde{R}}(X,z) h_\ell + \frac{s}{1+r} = X.$$

The location-specific rental rate, $p_{r,\ell}$, is the user cost of capital:

$$p_{r,\ell} = (r + \omega_{r,\ell} p_\ell(1) + \phi^{R,\ell}) p_{h,\ell},$$

where $\omega_{r,\ell}$ is the pass-through from landlords to tenants on the full coverage insurance price, $p_\ell(1)$, and $\phi^{R,\ell}$ is an additional rent premium. Future cash-on-hand combines future income and net savings after the household's choices for consumption and rental housing:

$$X' = Y' + (1+r)(X - c_t^{\ell\tilde{R}}(X,z) - p_{r,\ell} h_t^{\ell\tilde{R}}(X,z)).$$

2.4 Spatial and Tenure Decisions

We now turn to the household's joint discrete choices of where to live and whether to own or rent. Using the location-specific values for ownership and renting from the last section, we model the decision of a homeowner and renter currently living in location ℓ.

2.4.1 Homeowner

Consider a household entering the period as a homeowner. This household faces a menu of choices regarding homeownership. First, it can choose to remain in the same home, meaning it is inactive in the housing market. Alternatively, it sells its home and faces two options in each location: buy a new home or rent. So with N_ℓ locations, the homeowner has $2N_\ell + 1$ options to consider.

We first consider the several options faced by a homeowner O in location ℓ. First, the homeowner may remain inactive ($\tilde{O}$), opting to live in the same home in the same location. Second, the homeowner may move to a new home, either as a renter or homeowner, in any location, including its current location. Let $\mathcal{L} = \{\ell_1, \ell_2, \ldots, \ell_{N_\ell}\}$ denote the set of all locations, including the current location $\ell \in \mathcal{L}$. The household's envelope value function is given by the maximum over all options:

$$V_t^{\ell O}(S) = \max\{V_t^{\ell \tilde{O}}(S), V_t^{\ell O,\ell_1}(S), V_t^{\ell O,\ell_2}(S), \ldots, V_t^{\ell O,\ell_{N_\ell}}(S)\}.$$

The first option is to be inactive in housing markets and remain in both the same location and house. The other options entail moving to a different home. Consider a location $\ell' \in \mathcal{L}$, which we refer to as another location but may be the same as the current location. The function $V_t^{\ell O,\ell'}$ denotes the value of moving from being a homeowner O in location ℓ to location ℓ'. Within location ℓ', the household further decides to purchase a home or become a renter:

$$V_t^{\ell O,\ell'}(S) = \max\{V_t^{\ell O,\ell' O}(S), V_t^{\ell O,\ell' R}(S)\}.$$

In both cases, the household sells its current home in ℓ for $p_{h,\ell}\omega$, subject to fixed and proportional selling fees $F_{s,\ell}$ and $f_{s,\ell}$. Net of mortgage prepayment, total proceeds from the home sale are given by $(1 - f_{s,\ell})p_{h,\ell}\omega h_\ell - F_{s,\ell} - M$, where M is the current mortgage balance. We therefore define new cash-on-hand for the household leaving homeownership in location ℓ as:

$$\tilde{X}^{\ell O,\cdot} = X + (1 - f_{s,\ell})p_{h,\ell}\omega h_\ell - F_{s,\ell} - M.$$

Stay in Current Home. The first option $V_t^{\ell \tilde{O}}(S)$ defined above is the value of the homeowner living in the current location. This is the choice to be inactive in housing markets and remain in both the same home and location.

Owner in New Home. The homeowner in location ℓ considers purchasing a new home in ℓ'. There are two types of moving costs as in the data. Moving entails a utility cost $\Psi(\ell O, \ell' O)$ and a financial cost $\psi(\ell O, \ell' O)$. This allows for the case where $\ell' = \ell$, i.e., the homeowner moves to a different house in the same location.

Using the new definition of cash-on-hand with net home proceeds and the generic home purchase value function defined above, we can write the problem of a homeowner in location ℓ purchasing a new home in location ℓ' as:

$$V^{\ell O,\ell' O}(S) = V^{\cdot,\ell' O}(\tilde{X}^{\ell O,\cdot} - \psi(\ell O,\ell' O), z) - \Psi(\ell O,\ell' O).$$

To see this, recall that cash-on-hand in the generic purchase value function for location ℓ' is defined as:

$$\tilde{X}^{\cdot,\ell' O} = X - (1 - \theta_{LTV}^{\cdot,\ell' O} + f_{b,\ell'})p_{h,\ell'}h'_{\ell} - F_{b,\ell'}.$$

Then, using the cash-on-hand net of proceeds from a home sale in location ℓ and subtracting the financial cost of moving, we can define:

$$\begin{aligned} X^{\ell O,\ell' O} &\equiv \tilde{X}^{\cdot,\ell' O}|\tilde{X}^{\ell O,\cdot} - \psi(\ell O,\ell' O) \\ &= X + (1 - f_{s,\ell})p_{h,\ell}\omega h_{\ell} - F_{s,\ell} - M - (1 - \theta_{LTV}^{\cdot,\ell' O} + f_{b,\ell'})p_{h,\ell'}h'_{\ell} - F_{b,\ell'} - \psi(\ell O,\ell' O). \end{aligned}$$

Altogether, cash-on-hand is initial cash holdings plus proceeds from the current home sale, less outlays for the new home sale and moving costs.

Become a Renter. When the homeowner in location ℓ considers becoming a renter in ℓ', moving entails a utility cost of $\Psi(\ell O,\ell' R)$ and a financial cost of $\psi(\ell O,\ell' R)$.

Using the value function of a renter living in location ℓ', the value from becoming a renter is given by:

$$V_t^{\ell O,\ell' R}(S) = V_t^{\ell' \tilde{R}}(\tilde{X}^{\ell O,\cdot} - \psi(\ell O,\ell' R), z) - \Psi(\ell O,\ell' R).$$

2.4.2 Renter

Consider instead a household entering the period as a renter. A renter will have the option to remain a renter or to buy a home. These options are present in every location, including the current location, and thus the renter has $2N_{\ell}$ options to consider.

A renter in location ℓ considers moving to a new home in every location, including the one in which they currently rent:

$$V_t^{\ell R} = \max\{V_t^{\ell R,\ell_1}, V_t^{\ell R,\ell_2}, \ldots, V_t^{\ell R,\ell_{N_\ell}}\}.$$

Unlike the homeowner, there is no explicit option to remain inactive in the current home, as the renter can simply choose to rent the same or a different unit in the same location.

As above, consider a location $\ell' \in \mathcal{L}$, which we refer to as another location but may be the same as the current location. The function $V_t^{\ell R,\ell'}$ denotes the value of a renter moving from location ℓ to location ℓ'. Within location ℓ', the household further decides to purchase or rent a home:

$$V_t^{\ell R,\ell'}(S) = \max\{V_t^{\ell R,\ell' O}(S), V_t^{\ell R,\ell' R}(S)\}.$$

When $\ell = \ell'$, the renter considers remaining a renter in the same location or becoming a homeowner in the same location.

Homeownership. The renter in location ℓ considers purchasing a new home in ℓ'. Moving from renting in ℓ to owning a home in ℓ' incurs a utility cost of $\Psi(\ell R, \ell' O)$ and a financial cost of $\psi(\ell R, \ell' O)$. We can then use the generic purchase value function in ℓ' to write the renter's problem as:

$$V_t^{\ell R,\ell' O}(X, z) = V^{\cdot,\ell' O}(X - \psi(\ell R, \ell' O), z) - \Psi(\ell R, \ell' O).$$

Renting. When the renter in location ℓ considers renting in ℓ', moving entails a utility cost of $\Psi(\ell R, \ell' R)$ and a financial cost of $\psi(\ell R, \ell' R)$. Using the value function of a renter living in location ℓ', the value from a renter in ℓ renting in ℓ' is given by:

$$V_t^{\ell R,\ell' R}(X, z) = V_t^{\ell' \tilde{R}}(X - \psi(\ell R, \ell' R), z) - \Psi(\ell R, \ell' R).$$

2.5 Housing Supply

In each region, the aggregate stock of owner-occupied housing in effective square feet is $H_{S,t}^{\ell} = \int_{\Omega_t^{\ell O}} \omega_{i,t} \, h_\ell \, di$. Each unit's quality evolves as $\omega_i' = (1 - L_{\ell,i})\,\omega_i$, where $L_{\ell,i}$ is the household-specific uninsured loss rate from Section 2.1. New construction is supplied by exogenous, perfectly competitive developers,

$$I_{S,t}^{\ell} = \overline{I}_S^{\ell} \times p_{h,\ell,t}^{\rho_\ell}, \tag{1}$$

where $\overline{I}^{\ell}_{S}$ is a vertical supply curve shifter and ρ_ℓ is the price elasticity of housing supply, which differ across locations. The aggregate stock in ℓ next period is the sum of the surviving stock and new construction:

$$H^{\ell}_{S,t+1} = H^{\ell}_{S,t} - h_\ell \int_{\Omega^{\ell O}_t} L_{\ell,i}\, \omega_{i,t}\, di + I^{\ell}_{S,t}. \tag{2}$$

The aggregate loss term $h_\ell \int L_{\ell,i}\, \omega_{i,t}\, di$ is endogenous and stochastic: it depends on the cross-sectional distribution of coverage ϕ'_i, the rejection probabilities of each household's chosen insurer ($\theta_{b,\ell}, \theta_{d,\ell}$ on the private menu, $\underline{\theta}_{b,\ell}, \underline{\theta}_{d,\ell}$ on the public contract), the realization of δ_b for each household, and the realization of the climate-disaster indicator. In steady state, expected aggregate uninsured losses equal new construction, $h_\ell\, \mathbb{E}\big[\int L_{\ell,i}\, \omega_i\, di\big] = I^{\ell}_{S}$, which we use to calibrate the supply shifter $\overline{I}^{\ell}_{S}$.

2.6 Equilibrium

2.6.1 Definition

A *dynamic spatial recursive competitive equilibrium* describes how the economy in steady state responds to unanticipated local shocks. Given exogenous time paths for local climate shocks $\{\chi^{\ell}_{\tau}\}$, an equilibrium consists of the following sequences for all locations $\ell \in \mathcal{L}$:

(i) prices for owner-occupied and rental housing $\{p_{h,\ell,\tau}, p_{r,\ell,\tau}\}$;

(ii) value functions for homeowners and renters $\{V^{\ell O}_{\tau}, V^{\ell R}_{\tau}\}$;

(iii) policy functions describing non-durable consumption, rental housing services, and homeowner insurance $\{c^{h,h'}_{\tau}, h^{h,h'}_{\tau}, \theta^{h,h'}_{LTV,\tau}, \phi'^{h,h'}_{\tau}\}$ for each possible household transition $h, h' \in \{O, R\} \times L$ between owner-occupied or rental housing, O or R, in location ℓ.

(iv) a law of motion for the cross-sectional distribution of households λ_τ across locations, housing statuses, and individual states,

such that households optimize given prices, the law of motion for the distribution of households is consistent with their individual choices market and prices, and house prices are such that housing markets clear.

2.6.2 Market Clearing

Let $\Omega_t^{\ell h}$ denote the set of households with combination of housing status $h \in \{O, R\}$ and location $\ell \in \mathcal{L}$ at date t, and let $\mathcal{M}_t^{\ell h} = \int_{\Omega_t^{\ell h}} di$ denote the mass of such households. In spatial equilibrium, this set depends on the entire vector of house prices and rents in all possible housing combinations because of endogenous sorting.

Insurance markets. The private insurer's price schedule $p_\ell(\phi)$ is pinned by the zero-expected-profit condition $\mathbb{E}[\Pi] = \sum_{\ell \in \mathcal{L}} \mathbb{E}[\pi_\ell] = 0$ (Section 2.2). The public insurer's lump-sum tax T_ℓ is set by its expected budget constraint in each location.

Housing markets. Market-clearing for owner-occupied housing in each of the N_ℓ housing markets is given is given by:

$$\int_{\Omega_t^{\ell O}} \omega_i h_\ell di = H_{S,t}^\ell, \tag{3}$$

where housing demand depends on the effective stock of housing and $H_{S,t}^\ell$ is the supply of housing in region ℓ. Rental units are perfectly elastically supplied at the rental price defined above as a function of house prices.

3 Calibration

3.1 Parameters

We organize the model parameters into three parts in Table 1. The first set of parameters are common to macroeconomic and asset pricing models with housing (Panel A). The last two sets of parameters are specific to our housing market model with climate risk and insurance. They are related to climate risk and insurance (Panel B), and geographic heterogeneity (Panel C). A subset of the parameters are calibrated externally, while the remaining parameters are chosen to match empirical targets in the data, as indicated in the last column of the table. One model period corresponds to one year and targets are in annual terms.

Preferences, income, mortgages and housing. The utility function is Epstein-Zin with a subjective discount factor of 0.95, a coefficient of risk aversion γ = 5 and an elasticity of intertemporal substitution of 0.5. These are standard values in asset pricing, which imply that households have a preference for the early resolution of uncertainty. We set the preference for housing coefficient to 0.4 as in Favilukis *et al.* (2023). The income parameters are from Kaplan & Violante (2022). We set the maximum LTV and PTI limits at mortgage origination to those in Greenwald (2018). We set rental premiums to match average price-to-rent ratios in the two regions. We give more details when we describe Table 2.

Property damage, climate risk and insurance. We model two layers of property damage against which households can purchase insurance. Baseline property damage is drawn each period from a scaled Beta distribution on $[0, \bar{d}]$, with parameters estimated from the 2021 American Housing Survey (AHS) microdata to match the cross-sectional distribution of routine maintenance expenditures relative to self-reported home values (see Appendix Appendix 1 for details). The estimated parameters imply an expected baseline damage of approximately 0.38% of home value per year. In addition, climate disaster risk is characterized by the annual probability of a climate shock and the conditional loss given a shock. Climate risk can take many forms, including severe storms, heatwaves, floods, or wildfires. We calibrate the probability of a climate disaster in the high-risk region to be 8%, following Bilal & Rossi-Hansberg (2025) estimates of probability of a 1-in-50 year storm following a 1 degree increase in temperature relative to 1920. We calibrate the conditional loss following a climate disaster to be 17% of the house value, following Bilal & Rossi-Hansberg (2025) estimate of capital depreciation following a large storm. In the baseline calibration, the rest of the U.S. has zero climate disaster probability ($p_\ell = 0$), but properties in this region still face baseline property damage risk.

We set insurance coverage choices to range from $\underline{\phi} = 30\%$ (severely underinsured) to $\bar{\phi} = 100\%$ (full coverage). We calibrate the insurance supply parameters to jointly to match the average U.S. insurance premium paid by homeowners and the empirical distribution of coverage demand. These two objects naturally depend on one another since average premiums are determined by the product of coverage demanded times the insurance cost of given coverage. We calibrate a convex price schedule with rising marginal costs, consistent with regulatory requirements around holding concentrated geographic risk in a given region. We assume that renters' landlords fully pass on insurance costs to the rental price of housing.

Claim rejection rates. To maintain our focus on insurance related to climate disasters, we set the rejection rate for baseline damages to zero for both insurers in both regions. In the high-risk region, we set the public insurer's rejection rate for climate-disaster claims based on the Citizens Property Insurance Corporation's December 2024 statement reporting a 13.2% "true denial rate" (i.e., excluding below-deductible, withdrawn, duplicate, and administrative closures) across Hurricanes Debby, Helene, and Milton. For the private insurer, we use the NAIC Market Conduct Annual Statement (MCAS) data and calculate the homeowners closed-without-payment (CWP) rate in calm years is approximately 30% in Florida. However, the bulk of these closures are mechanical (claims below deductible, withdrawn claims, duplicate filings) rather than discretionary denials of valid claims. Assuming a 20% true-denial share, we set the private insurer's rejection rate for climate-disaster claims to 6%.

Regional heterogeneity. We split the U.S. housing market between Florida, as a coastal state with high climate risk exposure, and the rest of the country as a second lower-risk region. As described in Table 2 , the model's endogenous choices are disciplined by several sets of parameters to generate rich geographic heterogeneity between low- and high- climate risk exposure areas. We calibrate age-dependent amenity shifters to target population share in Florida and the rest of the U.S., and the utility cost of moving to match the average migration rate between these two regions. We set homeowner-specific amenities to target average homeownership rates over the lifecycle. Finally, housing elasticities are calculated in Florida and the rest of the U.S. using estimates from Saiz (2010) and house prices are calibrated to match average home prices in each region.

3.2 Baseline Results

Similar to the parameters, we report the model results into three parts in Table 2. The first part is common to other models and describes key housing moments (Panel A). The last two parts are specific to our housing market model with climate risk and insurance. They center on climate risk and insurance (Panel B), and geographic heterogeneity (Panel C).

The data moments for income, population shares, and homeownership rates are drawn from the American Community Survey (ACS). We construct a panel of U.S. metropolitan statistical areas (MSAs) at the MSA–year level and use the most recent year available, 2024. We then aggregate these measures for Florida and for the rest of the United States (excluding Florida) by grouping all Florida MSAs and all non-Florida MSAs, respectively, and weighting each variable by population. Average house prices and rents are from Zillow Home Value Index and Zillow Rent Index respectively. Zillow reports these statistics at the MSA level, that we merge with our ACS panel.

Migration data are also drawn from the American Community Survey and are directly available at the state level. To construct gross migration rates between the two regions, we compute a population-weighted average of migration flows from Florida to the rest of the United States and from the rest of the United States to Florida. Specifically, flows are weighted by the population of the destination region, so that migration into larger areas receives greater weight. This measure captures the relative attractiveness of each region and can be interpreted as an average in-migration rate weighted by destination population.

Table 2 reports a detailed comparison between data moments and their model counterparts across the three groups of targets (aggregate, climate risk and insurance and geographic heterogeneity). Average income in the data is \$82.7 thousand, similar to the model value of \$87.2 thousand. The model matches housing affordability reasonably well: the average house price–to–income ratio is 6.06 in the data versus 5.76 in the model, and the rent–to–income ratio is 0.25 in the data compared with 0.24 in the model.

The model implies substantial heterogeneity in climate-shock losses across regions. Conditional losses from a climate shock are modest in low-exposure areas (-3.9%) but much larger in high-exposure areas (-24.3%). Average insurance coverage in the data is 70% (Sastry *et al.*, 2025a), while the model generates a slightly lower average coverage rate of 59%.

The average annual moving rate between areas is 2.2% in the data and 2.0% in the model. Population shares are concentrated in low-exposure areas ("rest of the U.S.", with 93% in the data and 90% percent in the model, leaving 7% percent and 10% percent, respectively, in high-exposure areas. The model closely matches housing prices by exposure: average house prices are $512 thousand in low-exposure areas and $407 thousand in high-exposure areas in both the data and the model. Rents are also similar, with low-exposure monthly rents of $1,740 per month in the data versus $1,742 in the model, and high-exposure rents of $1,917 in the data compared with $2,055 in the model.

Finally, Figure 1 plots income (Panel A) and wealth (Panel B) over the lifecycle. Wealth is total household net worth, meaning that it include home equity. More importantly, Panel C plots average homeownership rate over the lifecycle both in the model and in the data.

4 Demand for Property Insurance

We begin by examining the determinants of insurance demand in our model. Figure 2 plots the unconditional distribution of coverage endogenously chosen by homeowners. The vast majority of households do not hold full insurance, implying that a natural disaster would not be fully covered by their insurer. Insurance demand peaks around 70% coverage and there is a significant mass of households severely underinsured. To understand why some households hold nearly-full coverage while others are several uninsured, figures 3 and 4 illustrate how liquidity, age, and climate risk shape insurance demand.

Panels A and B of Figure 3 plot insurance coverage as a function of liquid wealth, where households in each region are sorted into twenty bins. Two patterns emerge. First, coverage is increasing in liquid wealth, but in a non-linear fashion: liquidity-constrained households exhibit steeper demand responses than their wealthier counterparts, while unconstrained households continue to increase coverage but at a diminishing rate. Second, coverage is uniformly lower in high-risk regions across the liquid wealth distribution, consistent with higher premiums reducing the value of insurance. A second-order compositional effect reinforces this pattern: wealthier households, who can self-insure, sort into high-risk regions, mechanically depressing average coverage. The figure also reveals endogenous precautionary savings behavior: households in high climate risk regions hold substantially higher liquid wealth on average than those in low-risk regions. These aggregate patterns, however, mask important heterogeneity at the tails of the cash-on-hand distribution, which we examine in the next figure.

The bottom panels plot insurance coverage against age. In both regions, coverage follows a hump-shaped profile over the life cycle, rising from young to middle age before declining. This pattern mirrors the lifecycle trajectory of wealth accumulation: as net worth rises, households demand more insurance, but as they age further, demand declines. Intuitively, insurance serves partly as a savings vehicle, and older households with no bequest motive have limited incentive to insure. Notably, the peak of insurance demand occurs at a later age in high-risk regions than in low-risk regions. This reflects the fact that the marginal value of insurance declines once a household has sufficient liquid wealth to self-insure against a loss, and this threshold is reached later in the life cycle in high-risk regions due to the higher cost of insurance there.

Figure 4 examines the tails of the liquid wealth distribution. The top panels restrict to homeowners in the bottom quintile of cash-on-hand, while the bottom panels restrict to the top quintile. Among liquidity-constrained households, coverage is low, reflecting the fact that purchasing insurance constitutes a transfer of resources from the present to the future. Within this group, however, an important distinction emerges across regions: in the low-risk region, coverage rises steeply with liquid wealth even among the poorest households, whereas in the high-risk region demand is nearly flat, reflecting the substantially higher cost of insurance.

The bottom panels reveal a different pattern at the top of the wealth distribution. Coverage is largely flat across the liquid wealth distribution for wealthy households, with a notable exception at the very top: the wealthiest households demand significantly less insurance than average because these households have sufficient resources to self-insure. As a result, the marginal value of insurance falls sharply once liquid wealth crosses this self-insurance threshold. This pattern is especially pronounced in high-risk regions, where the incentive to substitute away from costly formal insurance and toward self-insurance is strongest.

5 Applications

We use the calibrated model to study three counterfactual experiments, each focusing on a different part of the economy: insurance pricing, climate risk, and cross-subsidization under rate regulation. In each experiment, we modify the relevant parameters and hold all other parameters fixed at their calibrated values. We report two responses. The partial-equilibrium (PE) response applies the counterfactual parameters while holding house prices at their baseline values. The general-equilibrium (GE) response solves for the new equilibrium after house prices, location choices, tenure decisions, and insurance choices adjust. The table reports the full GE effects, while the figures use the PE effects to interpret the mechanism behind the GE outcome.

5.1 Insurance Pricing

Our first counterfactual studies how housing markets respond to an increase in the cost of supplying property insurance. We increase the insurer cost-of-capital coefficient c by 10 percent, holding climate risk and all other primitives fixed. This shock raises the price of private insurance coverage, with larger dollar effects in the high-risk region because insured losses are higher there. The experiment separates a deterioration in insurance-market conditions from an increase in the underlying physical probability of disaster.

Table 3 and Figure 5 report the results. The partial-equilibrium response shows the direct effect of the insurance-cost shock at baseline house prices. At fixed house prices, the high-risk region becomes less attractive: Florida's population share falls by 1.59 percentage points. This response reflects the higher cost of insuring housing in a region where baseline climate exposure is already high. Before prices and sorting adjust, households respond to the increase in insurance costs by reallocating away from the high-risk region.

The general-equilibrium response is much smaller. Once house prices, tenure choices, and sorting adjust, Florida's population share falls by only 0.19 percentage points, while the aggregate migration rate rises by 0.17 percentage points. The attenuation does not occur because Florida house prices fall. In fact, house prices rise slightly in both regions, by 0.22 percent in the rest of the United States and 0.09 percent in Florida.

Instead, the adjustment operates through relative housing costs and tenure choice. The movement away from Florida increases demand for housing in the low-risk region, bidding up low-risk house prices. At the same time, higher insurance costs are passed through to rental costs because landlords insure rental units at full coverage. This makes renting less attractive relative to owning and raises demand for owner-occupied housing.

These tenure effects are visible in the model outcomes. Florida's homeownership rate rises by 1.42 percentage points in GE even though its population share falls slightly. Thus, the households who remain in the high-risk region are more selected toward ownership, which supports owner-occupied housing demand and prevents Florida house prices from falling.

Homeowners also adjust on the insurance margin. Average coverage falls from 63.1 percent to 61.8 percent in the low-risk region and from 59.7 percent to 58.5 percent in the high-risk region. This endogenous coverage adjustment limits the increase in insurance payments faced by owners, while renters are more exposed to pass-through from full-coverage landlord insurance.

The welfare-relevant effects are modest but uneven across regions. In the rest of the United States, average net worth and consumption are essentially unchanged, rising by 0.25 percent and 0.03 percent, respectively. In Florida, average net worth rises by 0.90 percent and consumption by 0.85 percent. These increases should not be interpreted as the insurance-cost shock being beneficial for all Florida households. They partly reflect equilibrium selection: after the shock, the composition of households remaining in Florida shifts toward homeowners and households better positioned to absorb or avoid higher insurance costs.

Overall, the experiment shows that the incidence of insurance-market shocks depends critically on equilibrium adjustment. In partial equilibrium, higher insurance costs push households away from the high-risk region. In general equilibrium, that direct force is muted by higher low-risk housing costs, pass-through to rents, endogenous coverage reductions, and selection into ownership. The result is a small decline in Florida's population share, a rise in homeownership, and only small changes in equilibrium house prices.

5.2 Climate Risk

Our second counterfactual studies the effect of a direct increase in physical climate risk. We increase the probability of a climate disaster shock in the high-risk region by 10 percent, from 8.0 percent to 8.8 percent, holding all other primitives fixed. This experiment differs from the insurance-pricing counterfactual because it changes the underlying probability of damage, not only the cost of supplying insurance. The shock raises actuarially fair insurance prices in Florida and increases expected uninsured losses for households that do not fully insure. Renters are also affected indirectly because landlords insure rental units and pass insurance costs through to rents.

Table 3 and Figure 6 report the results. The partial-equilibrium response isolates the direct effect of the higher disaster probability at baseline house prices. In PE, Florida becomes substantially less attractive: its population share falls by 6.79 percentage points, and its homeownership rate falls by 16.89 percentage points. At fixed prices, households face higher expected losses and higher insurance premiums, but the purchase price of risky housing does not adjust downward. The result is a sharp decline in the value of owning in the high-risk region.

The general-equilibrium response is quite different because house prices and sorting adjust. Florida house prices fall by 2.27 percent, while house prices in the rest of the United States rise by 0.42 percent. This relative price movement capitalizes part of the higher climate risk into local asset values. Lower Florida house prices partly compensate marginal households for higher disaster exposure, while higher low-risk house prices make relocation to safer areas more expensive. As a result, the large PE population decline is reversed in GE: Florida's population share rises slightly, by 0.30 percentage points.

This population response does not mean that the high-risk region is unharmed. The key adjustment is tenure composition. In GE, Florida's homeownership rate falls by 3.23 percentage points, and owner-occupied housing demand in Florida falls by about 3.16 percent. At the same time, rental housing demand in Florida rises sharply. Thus, the climate-risk shock shifts the composition of Florida residents away from homeowners and toward renters. This explains why Florida house prices fall even though its population share rises slightly: house prices clear the owner-occupied housing market, and demand for owning risky housing declines.

Insurance choices also adjust. In Florida, average insurance coverage among homeowners falls from 59.7 percent to 57.1 percent. Although higher risk increases the value of insurance, premiums also rise, household resources fall, and the composition of remaining homeowners changes. In equilibrium, these price, resource, and selection effects dominate, leading to lower average coverage in the high-risk region. Coverage in the low-risk region is essentially unchanged because the physical-risk shock is local to Florida.

The welfare-relevant effects are concentrated in the high-risk region. Average net worth in Florida falls by 12.41 percent and average consumption falls by 10.21 percent. In the rest of the United States, house prices rise, and average net worth and consumption increase by 1.95 percent and 1.53 percent, respectively. These gains reflect both higher low-risk asset values and equilibrium sorting away from climate risk. The aggregate migration rate rises by 0.52 percentage points, showing that households use mobility as an adaptation margin, but not enough to undo the local balance-sheet effects of higher climate risk.

Overall, the experiment shows that climate risk is capitalized through both prices and quantities. At fixed house prices, higher disaster risk generates a large movement away from Florida and a collapse in homeownership. In general equilibrium, lower Florida house prices and higher low-risk house prices moderate the population response, but the shock still reduces demand for owning in the high-risk region, lowers Florida house prices, and substantially reduces household net worth and consumption there.

5.3 Cross-Subsidization under Rate Regulation

Our third counterfactual studies insurance rate regulation that subsidizes coverage in the high-risk region. We suppose that a regulator caps the insurer's price schedule in the high-risk region at a fraction $\lambda \in (0, 1]$ of the baseline schedule:

$$p_r(\phi) = \lambda \cdot p_r^b(\phi).$$

The national insurer compensates by raising a markup $\mu_u > 0$ in the unregulated region to maintain revenue neutrality:

$$p_u(\phi) = \frac{1 + c \cdot \phi^{\eta}}{1 - \mu_u} \cdot p_{A,u}.$$

This experiment captures the cumulative effect of binding rate-increase caps. When actuarially fair prices in high-risk areas rise faster than regulators allow, the regulated price schedule falls below the unregulated schedule. The policy therefore lowers the private cost of insurance in the high-risk region while shifting part of the financing burden to the low-risk region.

We set $\lambda = 0.98$, so that Florida insurance prices are 2 percent below their unregulated baseline. Table 3 and Figure 7 report the results. The partial-equilibrium response shows the direct effect of subsidized high-risk insurance at baseline house prices. In PE, Florida's population share rises by 6.38 percentage points, its homeownership rate rises by 4.82 percentage points, and average consumption rises by 6.08 percent. At fixed house prices, the lower Florida insurance schedule reduces the cost of living in the high-risk region for both homeowners and renters, because landlord insurance costs are also passed through to rents. The subsidy therefore makes Florida more attractive before local housing prices adjust.

The general-equilibrium response is much smaller because the subsidy is capitalized into housing markets. As households move toward Florida, demand for Florida housing rises and Florida house prices increase by 0.46 percent. This price increase offsets much of the direct benefit of cheaper insurance for marginal movers. In the rest of the United States, house prices are essentially unchanged, falling by only 0.02 percent, because the compensating markup is small under the 2 percent cap. As a result, Florida's population share rises by only 0.18 percentage points in GE, and the aggregate migration rate falls slightly, by 0.07 percentage points.

The tenure and housing-demand responses show the same moderation. In PE, the lower Florida insurance schedule strongly increases high-risk homeownership. In GE, however, Florida's homeownership rate is essentially unchanged, rising by only 0.02 percentage points. Owner-occupied housing demand in Florida rises modestly, while rental demand also increases. Thus, the policy attracts households to Florida, but the equilibrium increase in Florida house prices absorbs most of the direct incentive to switch into ownership in the high-risk region.

Insurance choices move in the expected direction. In Florida, the regulated price reduction shifts the coverage distribution to the right, raising average coverage among homeowners from 59.7 percent to 60.9 percent. In the rest of the United States, the compensating markup produces only a very small decline in average coverage. Average insurance payments in Florida rise slightly despite the lower price schedule because households choose more coverage, Florida house prices rise, and the composition of homeowners changes.

The distributional effects mirror the direction of the subsidy. In Florida, average net worth rises by 2.54 percent and average consumption rises by 1.87 percent. In the rest of the United States, average net worth and consumption fall slightly, by 0.34 percent and 0.17 percent, respectively. These effects are modest because the cap is small, but the signs are informative: rate regulation transfers resources toward households living in the high-risk region and away from households in the low-risk region that finance the cross-subsidy.

Overall, the experiment shows how insurance regulation can distort spatial allocation even when the policy change is small. At fixed house prices, subsidized Florida insurance generates a large movement toward the high-risk region. In general equilibrium, higher Florida house prices and household sorting absorb most of that direct effect, leaving only modest changes in population shares and homeownership. The main economic force is capitalization: part of the insurance subsidy is passed through into Florida housing values rather than remaining entirely with households as lower effective housing costs.

6 Conclusion

This paper studies how climate risk affects housing markets through the joint interaction of property insurance, tenure choice, and spatial mobility. We develop a dynamic spatial equilibrium model in which households choose where to live, whether to own or rent, and how much property insurance to purchase in the presence of heterogeneous local disaster risk. By embedding insurance and migration decisions into a housing market equilibrium, the framework shows how local climate risk is transmitted not only through expected property losses, but also through insurance premiums, endogenous sorting, and changes in the composition of marginal buyers across regions.

Our calibration delivers realistic patterns of household insurance demand and regional housing outcomes. In particular, the model generates substantial heterogeneity in coverage choices, including widespread underinsurance, and matches key moments on house prices, rents, migration, and homeownership across high- and low-risk areas. These features are important for understanding how climate risk is capitalized into house prices. When climate risk rises, higher expected losses increase insurance costs, reduce the attractiveness of homeownership in exposed regions, and lower house prices as some households switch tenure or migrate away. At the same time, the model shows that equilibrium responses are shaped by selection: changes in insurance costs and disaster exposure alter the composition of households who remain in or enter risky locations.

Our counterfactual exercises highlight that the housing-market effects of climate risk depend critically on the insurance environment. Increases in insurer costs or local disaster probabilities generate lower welfare and lower house prices in exposed regions, with relatively modest but non-negligible spatial reallocation. By contrast, insurance rate regulation that compresses premiums in risky areas can induce large cross-regional redistribution and substantial distortions in location choices, house prices, and homeownership patterns. These results underscore that insurance markets are not a passive backdrop to climate adaptation; they are a central mechanism through which climate risk is priced, shared, and propagated across space.

Taken together, our findings imply that evaluating the consequences of climate change for household balance sheets and housing markets requires a framework that jointly models climate risk, insurance, and spatial equilibrium. Approaches that abstract from either endogenous insurance demand or household mobility risk missing important general-equilibrium feedback effects and may mismeasure both the incidence and capitalization of climate risk.

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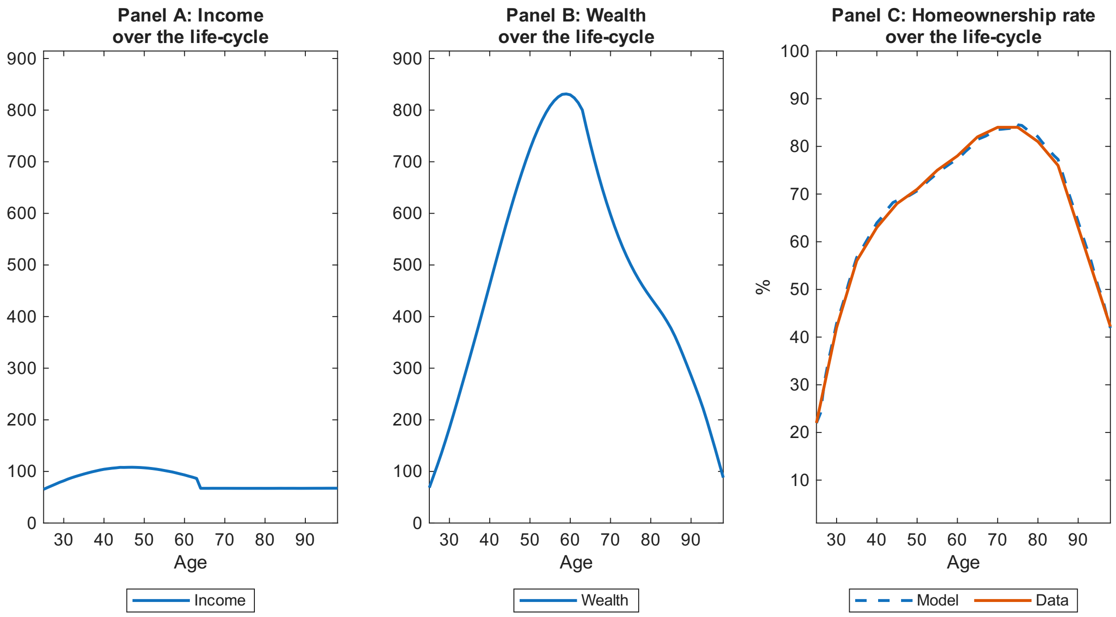
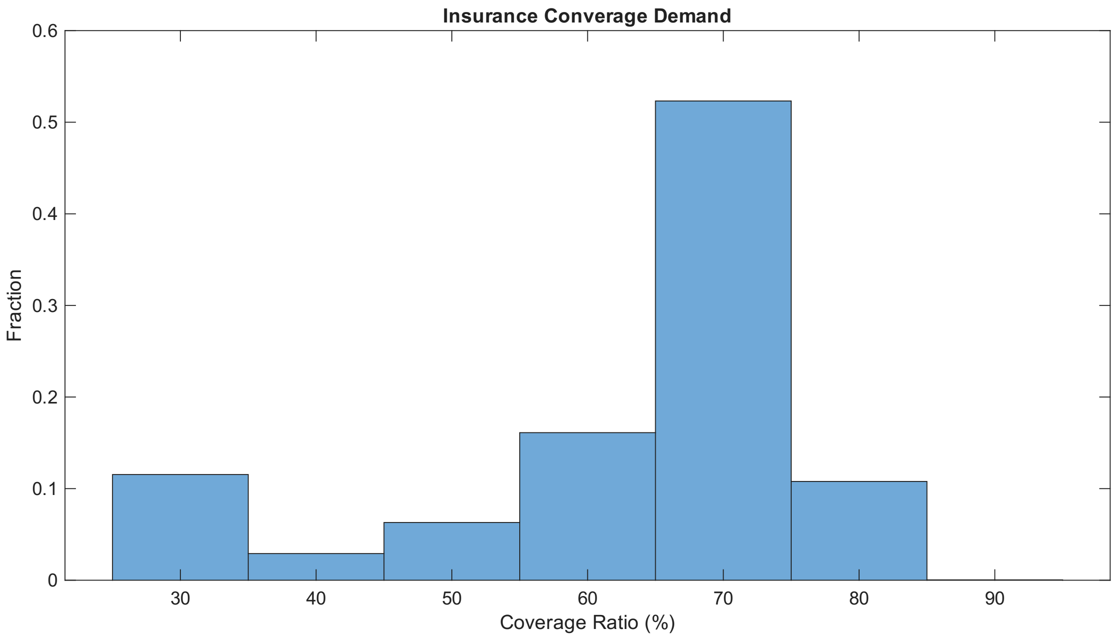
Figure 1: lifecycle profiles of income, wealth, and homeownership



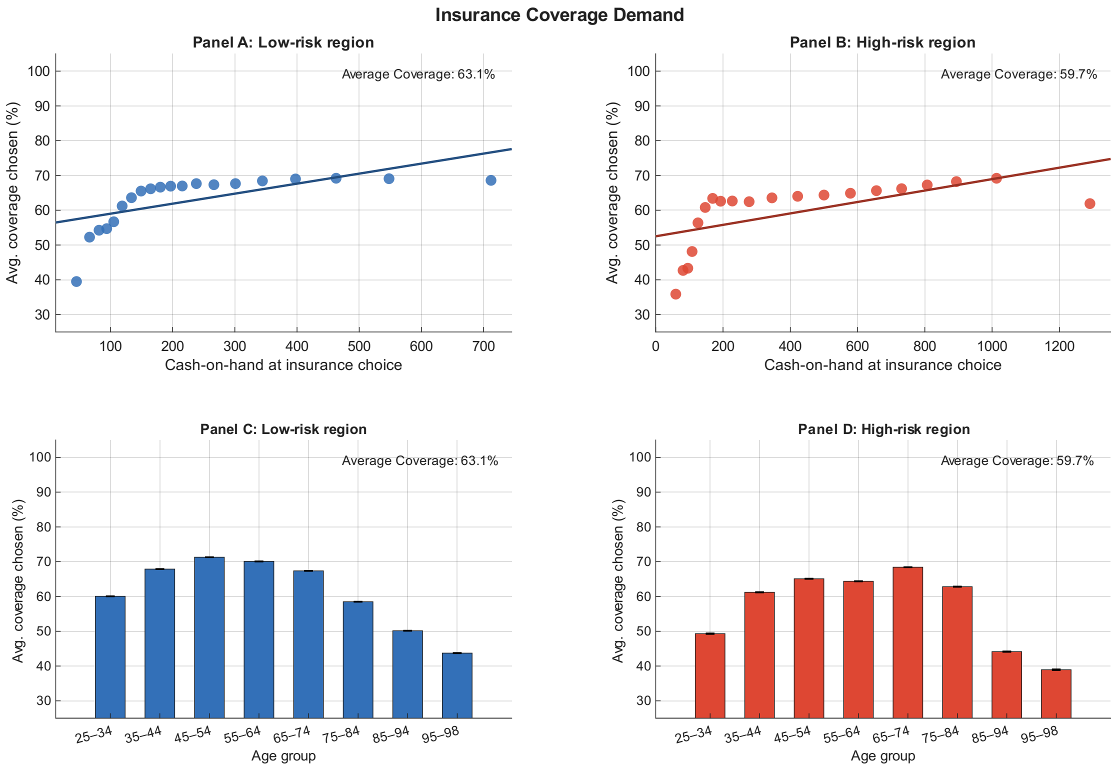
Notes: This figures plots average income over the lifecycle (Panel A), average wealth over the lifecycle (Panel B) and homeownership rate over the lifecycle (Panel C).

Figure 2: Insurance coverage demand



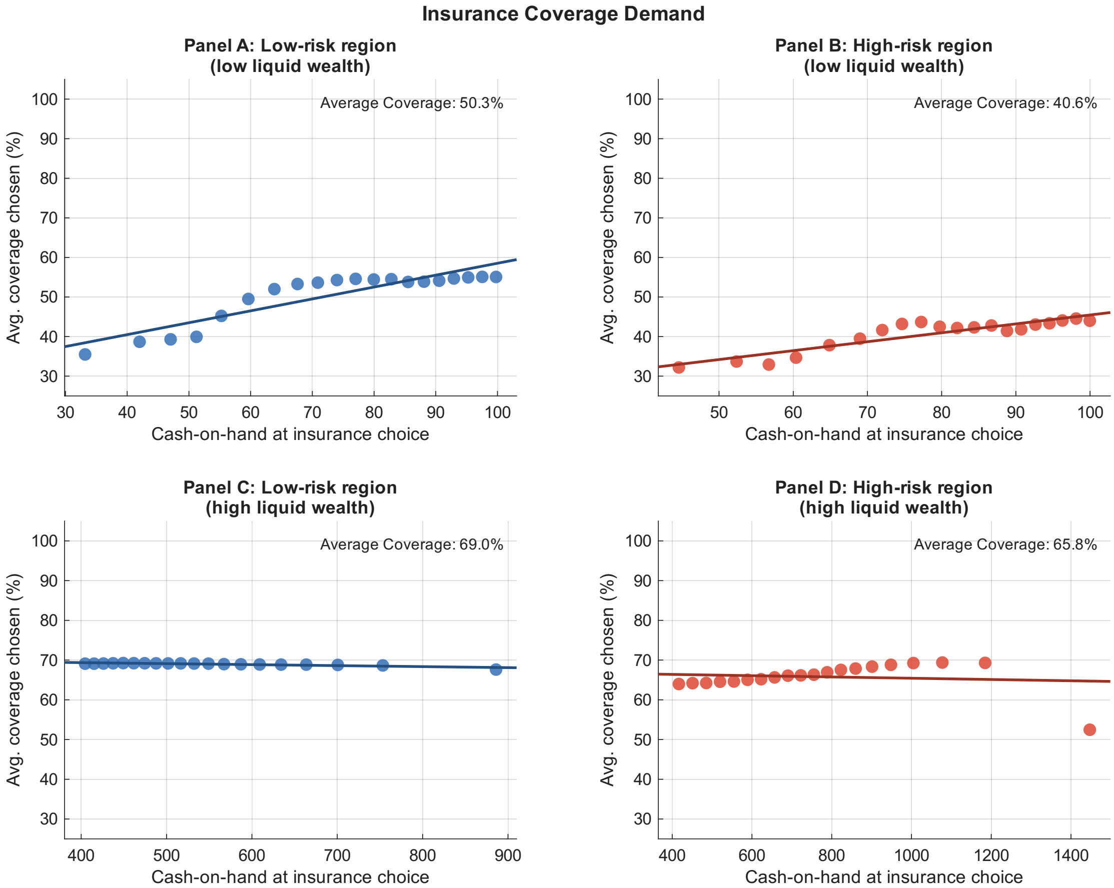
Notes: The figure shows the distribution of endogenous insurance coverage demand in the model.

Figure 3: Insurance demand by liquid wealth and age



Notes: This figure plots binscatter relationships between insurance coverage and cash-on-hand (top panels) and age (bottom panels) for homeowners, separately for the low climate risk and high climate risk regions. Each point represents the mean of insurance coverage within bins of the x-axis variable.

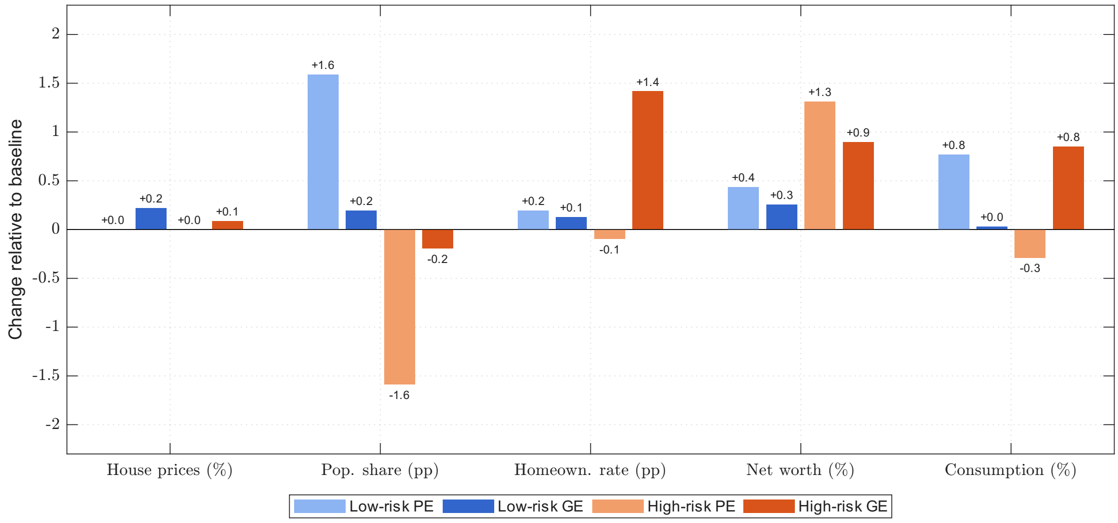
Figure 4: Insurance demand: extremes of liquid wealth distribution



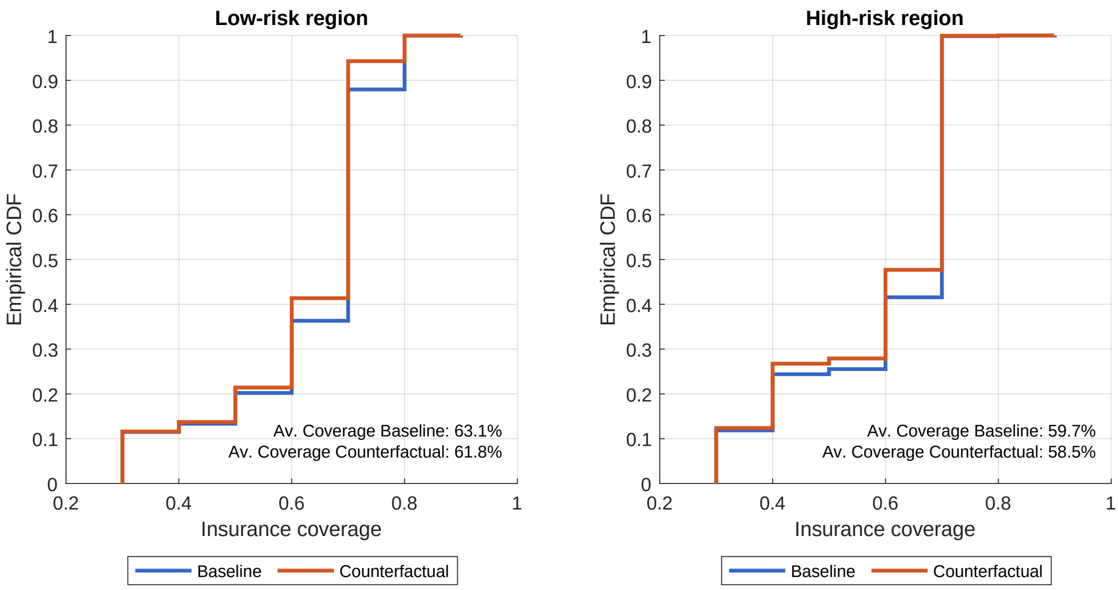
Notes: This figure plots binscatter relationships between insurance coverage and cash-on-hand for homeowners in the bottom and top liquid-wealth deciles, separately by climate risk region.

Figure 5: Insurance pricing counterfactual: PE versus GE effects and insurance coverage

(a) Partial- and general-equilibrium changes relative to baseline



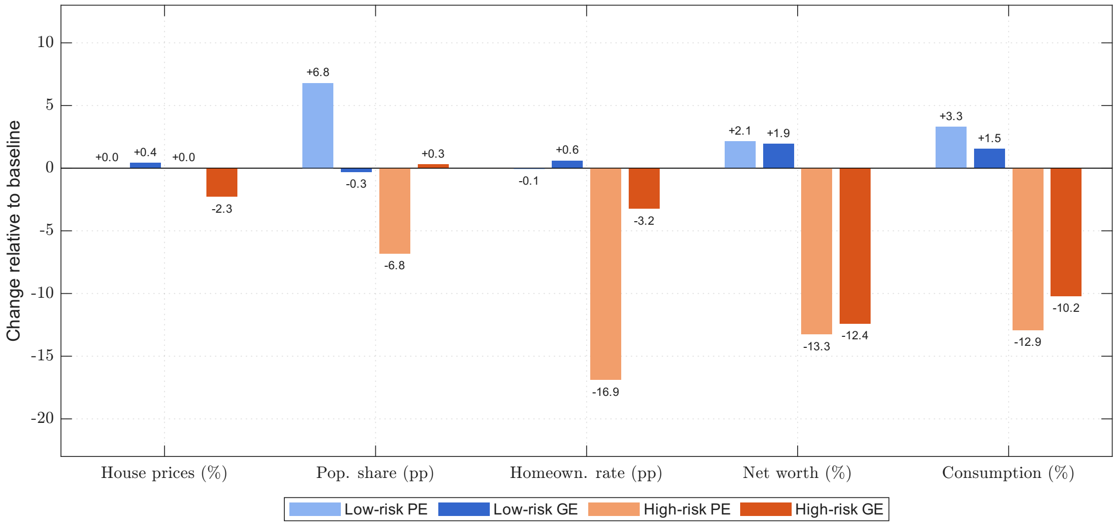
(b) Insurance coverage CDFs



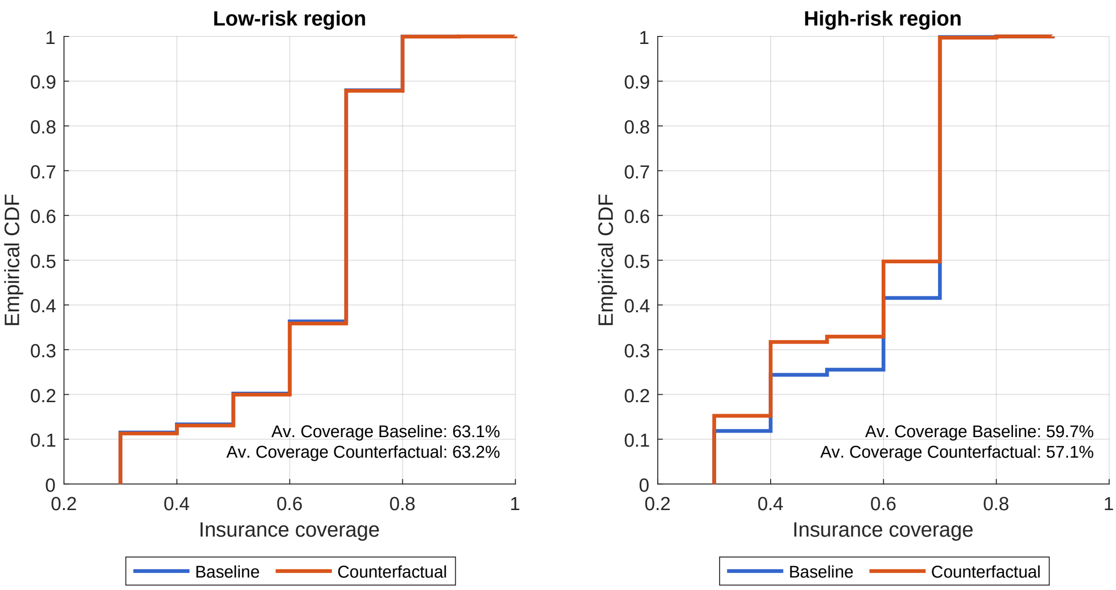
Notes: Panel (a) compares the partial-equilibrium response, computed with counterfactual insurance costs at baseline house prices, with the full general-equilibrium response after house prices and sorting adjust. Panel (b) plots empirical CDFs of insurance coverage for homeowners by region. The solid blue line shows the baseline and the solid orange line shows the counterfactual.

Figure 6: Climate risk counterfactual: PE versus GE effects and insurance coverage

(a) Partial- and general-equilibrium changes relative to baseline



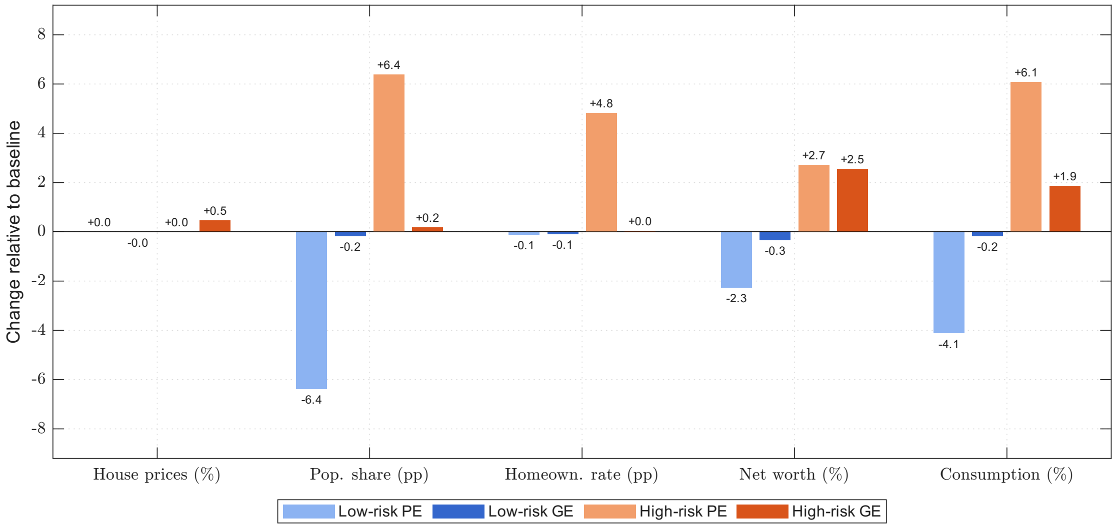
(b) Insurance coverage CDFs



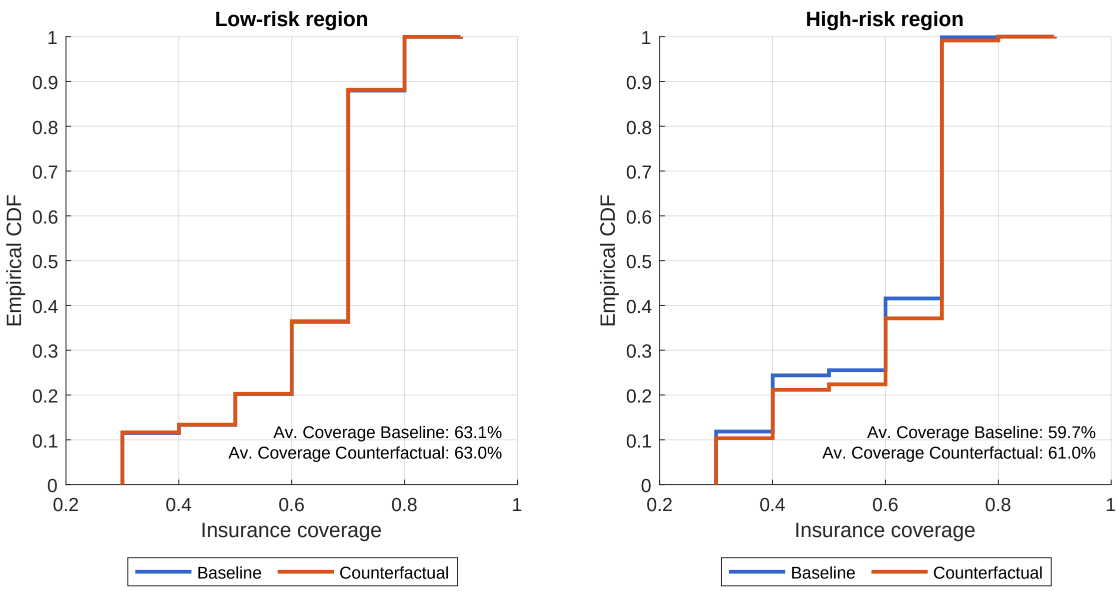
Notes: Panel (a) compares the partial-equilibrium response, computed with higher Florida disaster risk at baseline house prices, with the full general-equilibrium response after house prices and sorting adjust. Panel (b) plots empirical CDFs of insurance coverage for homeowners by region. The solid blue line shows the baseline and the solid orange line shows the counterfactual.

Figure 7: Cross-subsidization counterfactual: PE versus GE effects and insurance coverage

(a) Partial- and general-equilibrium changes relative to baseline



(b) Insurance coverage CDFs



Notes: Panel (a) compares the partial-equilibrium response, computed with the regulated insurance schedule at baseline house prices, with the full general-equilibrium response after house prices and sorting adjust. Panel (b) plots empirical CDFs of insurance coverage for homeowners by region. The solid blue line shows the baseline and the solid orange line shows the counterfactual.

Table 1: External parameters

Parameter	Description	Value	Source/Target
A. Preferences, Income, Mortgages, Housing			
β	Discount factor	0.95	standard
γ	Risk aversion	5	standard
ψ	Elasticity of intertemporal substitution	0.5	standard
α	Preference for housing	0.4	Favilukis *et al.* (2023)
ϵ	Elasticity of substitution consumption/housing	-0.5	Elasticity of substitution consumption/housing of 2/3
	Autocorelation permanent income	0.953	Kaplan & Violante (2022)
	Std. dev. permanent income	0.20543	Kaplan & Violante (2022)
	Std. idiosyncratic income	0.22226	Kaplan & Violante (2022)
r	Risk-free interest rate	0.02	Average t-bill rate (FRED)
r_M	Mortgage rate	0.05	Average mortgage rate (FRED)
$\overline{\theta}_{LTV}$	LTV limit	0.85	Greenwald (2018)
$\overline{\theta}_{PTI}$	PTI limit	0.36	Greenwald (2018)
ϕ^R	Rental premium (low / high region)	0.015 / 0.009	Avg price-to-rent ratio
f_b	Proportional transaction cost buying	0.01	
F_b	Fixed transaction cost buying	1.5	
f_s	Proportional transaction cost selling	0.05	
F_S	Fixed transaction cost of selling	3	
B. Climate risk and insurance			
p_χ	Climate shock probability (low / high region)	[0; 0.08]	Bilal & Rossi-Hansberg (2025)
χ	Conditional loss from climate shock (low / high region)	[0; 0.17]	Bilal & Rossi-Hansberg (2025)
$\bar{d}$	Upper bound of baseline damage distribution	0.05	AHS 2021
α_{base}	Beta shape parameter (baseline damage)	0.297	AHS 2021
β_{base}	Beta shape parameter (baseline damage)	3.851	AHS 2021
c	Capital charge cost	0.5	See text
η	Capital charge curvature	4	See text
μ	Constant markup	0.005	See text
ω_r	Insurance pass-through to rental units	1	
ϕ	Insurance coverage menu	{30%, 40%, . . . , 90%, 100%}	
$\theta_{b,\ell}$	Private rejection rate, baseline (low / high region)	[0; 0]	No rejection of routine claims
$\underline{\theta}_{b,\ell}$	Public rejection rate, baseline (low / high region)	[0; 0]	No rejection of routine claims
$\theta_{d,\ell}$	Private rejection rate, climate disaster (low / high region)	[—; 0.060]	MCAS
$\underline{\theta}_{d,\ell}$	Public rejection rate, climate disaster (low / high region)	[—; 0.132]	Citizens CEO statement (Dec. 2024)
C. Geographic heterogeneity			
	Amenity shifter low/high-exposure area	see text	Pop share of each location
	Homeownership value shifter low/high-exposure area	see text	Homeownership rate
	Moving costs between areas (in utils)	0.007	Avg migration Fl and U.S.
ρ	Housing supply elasticity (low / high region)	1.81341 / 0.995683	Saiz (2010)

Notes: One model period corresponds to one year. Targets are in annual terms.

Table 2: Targeted moments

Variable	Data	Model
A. Aggregate		
Avg income	82.7	82.21
Avg wealth/avg income	6.33	7.39
Avg house price/avg income	6.06	6.1
Avg rent/avg income	0.25	0.25
P90 LTV	0.90	0.85
P90 PTI	0.48	0.43
B. Climate risk and insurance		
Avg property insurance premium	1.123	1.61
Avg property insurance coverage	0.70	0.63
C. Geographic heterogeneity		
Avg moving rate between areas (%)	2.20	1.93
Population share in low-exposure area (%)	93	89.83
Population share in high-exposure area (%)	7	10.17
Avg house price low-exposure area ($ thousands)	512	512
Avg house monthly rent low-exposure area ($)	1,740	1,711
Avg house price high-exposure area ($ thousands)	407	407
Avg house monthly rent high-exposure area ($)	1,917	1,852

Notes: Moments are in annual terms. The sources are

Table 3: Counterfactual experiments: baseline levels and GE effects

	Baseline		Insurance		Climate		Cross-Subsidy	
	US	FL	US	FL	US	FL	US	FL
House prices ($K; GE %)	512	407	+0.22%	+0.09%	+0.42%	-2.27%	-0.02%	+0.46%
Population share (%; GE pp)	89.8	10.2	+0.19 pp	-0.19 pp	-0.30 pp	+0.30 pp	-0.18 pp	+0.18 pp
Homeownership rate (%; GE pp)	67.1	67.0	+0.13 pp	+1.42 pp	+0.60 pp	-3.23 pp	-0.08 pp	+0.02 pp
Net worth ($K; GE %)	467.3	535.6	+0.25%	+0.90%	+1.95%	-12.41%	-0.34%	+2.54%
Consumption ($K; GE %)	72.4	94.6	+0.03%	+0.85%	+1.53%	-10.21%	-0.17%	+1.87%
Migration rate (%; GE pp)	1.95		+0.17 pp		+0.52 pp		-0.07 pp	

Notes: The baseline columns report steady-state levels. The counterfactual columns report full general-equilibrium changes relative to baseline. "Insurance" increases the cost-of-capital coefficient c by 10%. "Climate" increases the disaster probability in Florida by 10%. "Cross-Subsidy" caps Florida insurance prices at 98% of baseline ($\lambda = 0.98$) with a revenue-neutral compensating markup in the rest of the US. House prices, net worth, and consumption baseline levels are in thousands of dollars.

Appendix 1 Baseline Damage Calibration

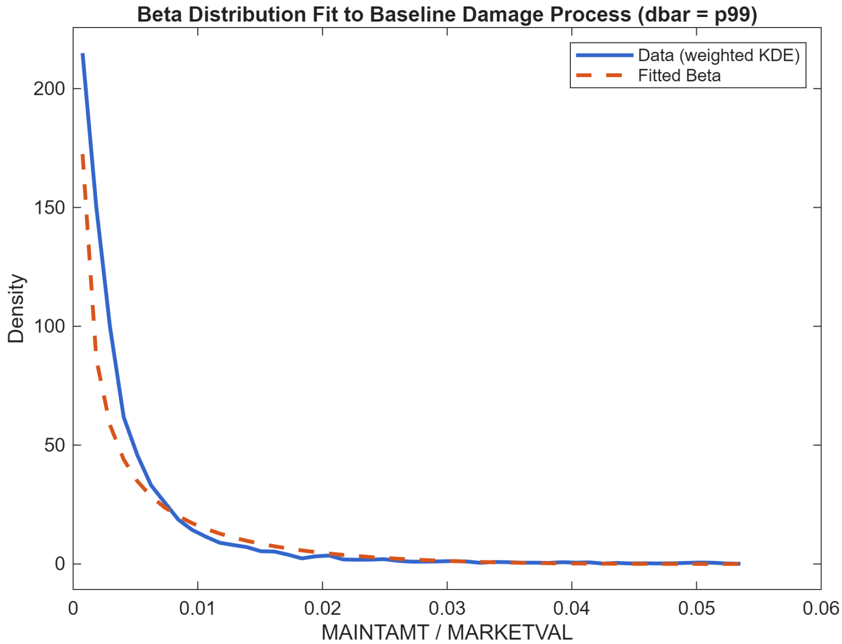
We calibrate the parameters of the baseline damage distribution using household-level microdata from the 2021 American Housing Survey (AHS), restricted to owner-occupied units. As a proxy for the annual flow of physical deterioration, we compute for each household i the ratio of self-reported annual routine maintenance expenditures (`MAINTAMT`) to self-reported market value of the housing unit (`MARKETVAL`), excluding land:

$$d_i = \frac{\texttt{MAINTAMT}_i}{\texttt{MARKETVAL}_i}.$$

The `MAINTAMT` variable covers spending on items such as painting, plumbing, roofing, and minor repairs. While this measure captures routine upkeep spending rather than physical depreciation per se, it provides a natural reduced-form proxy for baseline housing deterioration and should be interpreted as a lower bound on true annual damage rates.

We fit a scaled Beta distribution on $[0, \bar{d}]$ to the cross-sectional distribution of $\{d_i\}$ by maximum likelihood, trimming the sample at the 99th percentile to limit the influence of extreme outliers driven by major renovation projects misclassified as routine maintenance. Specifically, we maximize the log-likelihood of the observed d_i over the three parameters $(\bar{d}, \alpha_b, \beta_b)$, treating each observation as an independent draw from a Beta(α_b, β_b) rescaled to $[0, \bar{d}]$. The estimated parameters are $\bar{d} = 0.053$, $\alpha_b = 0.297$, and $\beta_b = 3.851$, implying an expected baseline damage of $\mathbb{E}[d_b] \approx 0.38\%$ of home value per year. Figure A1 plots the fitted distribution against the empirical CDF of d_i and shows that the scaled Beta provides a good fit to the data.

Figure A1: Fitted scaled-Beta distribution for baseline damage



Notes: Empirical CDF of the damage proxy $d_i = \texttt{MAINTAMT}_i/\texttt{MARKETVAL}_i$ computed from the 2021 AHS (owner-occupied units), trimmed at the 99th percentile, together with the fitted scaled-Beta distribution estimated by maximum likelihood.